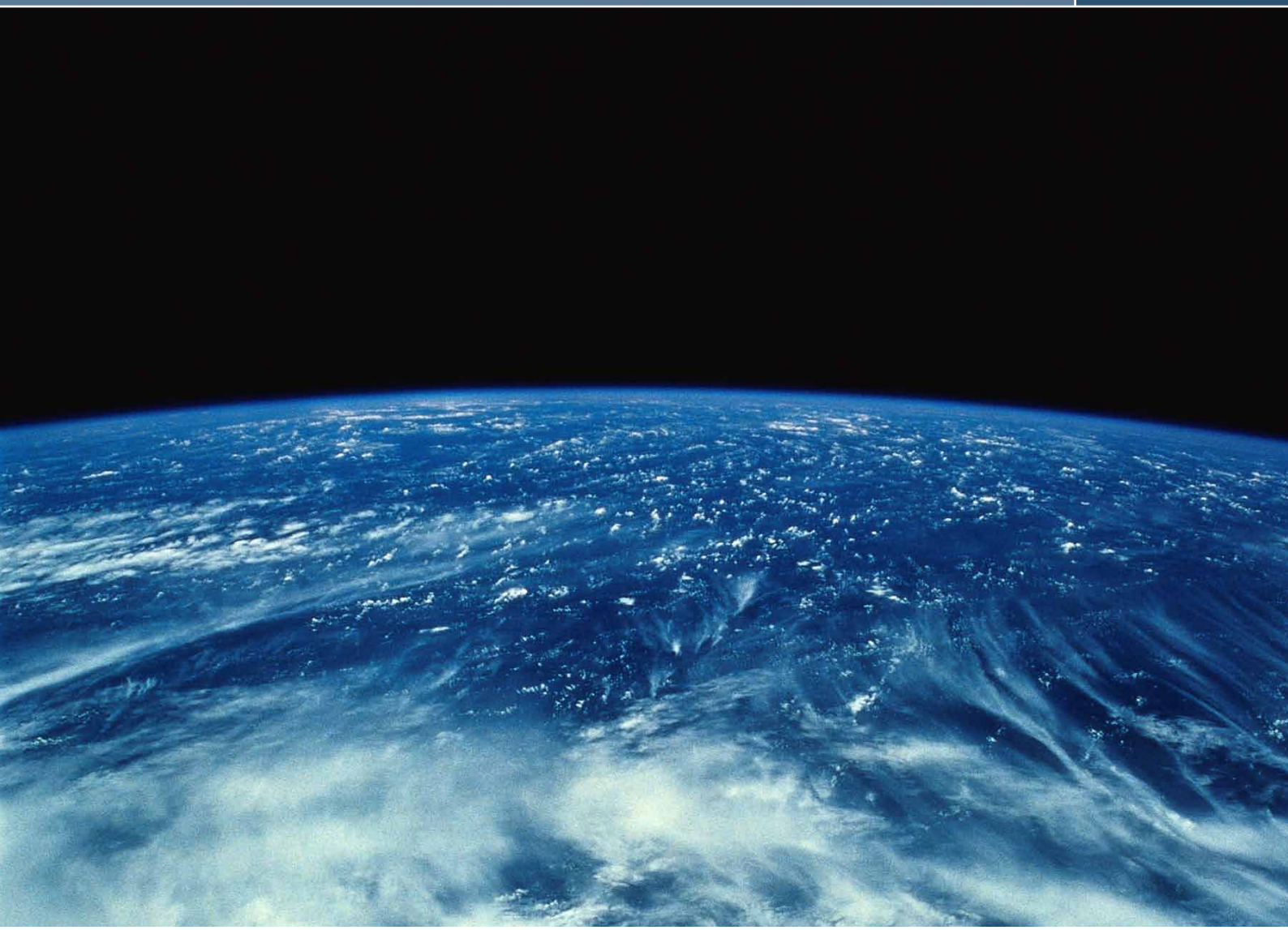
UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS

Highlights in Space 2010

Prepared in cooperation with the International Astronautical Federation, the Committee on Space Research and the International Institute of Space Law



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OFFICE FOR OUTER SPACE AFFAIRS
UNITED NATIONS OFFICE AT VIENNA

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Prepared in cooperation with the International Astronautical Federation, the Committee on Space Research and the International Institute of Space Law

Progress in space science, technology and applications, international cooperation and space law

UNITED NATIONS
New York, 2011

UNITED NATIONS PUBLICATION
Sales No. E.11.I.3
ISBN 978-92-1-101236-1

ST/SPACE/57

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Publishing production: English, Publishing and Library Section, United Nations Office at Vienna.

This document has not been formally edited.

INTRODUCTION

This publication has been compiled from reports prepared for the United Nations Committee on the Peaceful Uses of Outer Space It was first published in 1992 as part of the United Nations activities undertaken for the International Space Year, with the objective of making all countries aware of the benefits of sound space activities.

The first part of the report on space technology and space applications was prepared by the International Astronautical Federation (IAF), including input from technical committees of the IAF; the International Institute of Space Law (IISL) provided information for the section on international cooperation and space law. Both parts cover period from 1 November 2009 to 31 December 2010; covering a fourteen month to bring publication in line with the calendar year, this is a longer report than usual. The second part, focusing on space science and recent progress made regarding space research, was prepared by the Committee on Space Research (COSPAR) of the International Council for Science (ICSU) and covers the period from 1 November 2009 to 31 October 2010. Many international experts from various specialized fields have contributed to the drafting of this comprehensive report. The information contained therein indicates a wide variety of ongoing space activities in national as well as international space programmes.

A list of coordinators and contributors can also be found at the end of the report. Information within this publication has been partly prepared with information from outside sources. Where this is the case, a citation is provided which can be accessed by clicking on the link marked >>. This publication is available in English only.

This 2010 review of latest developments in space science, technology, space applications, international collaboration and space law has the aim to inform a broad worldwide audience of recent advancements in the manifold field of outer space.

We hope that “Highlights in Space 2010” can significantly contribute to all the efforts undertaken by the United Nations family, in particular the Office for Outer Space Affairs, in attempting to disseminate information on space activities and on the benefits involved to all nations of the world.

CONTENTS

PART ONE

HIGHLIGHTS IN SPACE SCIENCE AND TECHNOLOGY FOR 2010

I. OVERVIEW

It was a busy year for space transportation during the reporting period of 1 November 2009 to 31 December 2010. Overall, in the calendar year 2010 almost half of all launches (31 launches out of 74) were done by the Russian Federation, followed by China and the United States with 15 launches each. The European Space Agency (ESA) conducted 6 launches, India 3, Japan 2, Israel 1 and Republic of Korea 1. The Russian Proton set a record, making 29 launches within 29 months. Four launches in 2010 were unsuccessful.

Transfer of crew to and from the International Space Station (ISS) was accomplished through the successful execution of Soyuz/TMA missions from the Baikonur Cosmodrome in Kazakhstan. These missions accomplished the launch and safe return of three people to and from the space-station, facilitating crew rotation and human access to ISS. Soyuz TMA-17/ISS 21S was launched on 20 December 2009, Soyuz TMA-18/ISS 22S launched on 2 April 2010, and Soyuz TMA-19/ISS 23S launched 15 June 2010. Soyuz TMA-01M launched with three crew members on 7 October 2010. Finally, three more cosmonauts launched with Soyuz TMA-20 on 15 December 2010.

Between 1 November 2009 and 31 December 2010, the United States and international partners successfully launched four Space Shuttle missions from the Kennedy Space Center in Florida to ISS. These were designated STS-129 (16 Nov 2009 - 27 Nov 2009), STS-130 (8 Feb 2010 - 21 Feb 2010), STS-131 (5 April 2010 - 20 April 2010), and STS-132 (14 May 2010 - 26 May 2010). STS-129 delivered key infrastructure to the ISS, using the orbiter Atlantis, including two important external hardware storage platforms. STS-130 was a night launch of the orbiter Endeavour, delivering the Tranquillity node and observation cupola to the ISS. STS-131, a pre-dawn launch of the orbiter Discovery, delivered supplies and equipment to the ISS using the Italian-built 'Leonardo' multi-purpose logistics module. STS-132 marked the final scheduled mission for the orbiter Atlantis, delivering a Russian-built module and important spare-parts to the ISS.

Four Cargo missions to supply ISS were launched from Baikonur, using the Soyuz U/ Progress vehicle equipment set.

Many launches of commercial communications satellites are reported during this time period, the first three coming within a period of almost exactly one week in November 2009 - Intelsat 14 (Atlas V), Intelsat 15 (Proton) and Eutelsat W7 (Zenit). DirecTV 12 (Proton) followed in December 2009.

Subsequent Baikonur launches with the Proton M vehicle included Intelsat 16, Echostar 14, Echostar 15, SES 1, Arabsat 5B, Kosmos 2464-2466, XM 5 and SkyTerra 1.

ESA's Ariane 5ECA vehicle contributed more commercial satellite launches from Kourou: ComSat BW-2, ArabSat 5A, COMS 1, Nilesat 2, Rascom-QAF-1R, Eutelsat W3B, BSAT-3b, Intelsat 17, HYLAS, Hispasat 1E & KOREASAT 6.

The most recent Soyuz-U mission launched Progress M-08M to the ISS on 27 October 2010. Its most recent non-Progress launch was on 16 April 2010, when a Soyuz-U was used to carry the Kosmos 2462 spacecraft to orbit.

During the fourteen month period covered by this report, there was a series of 18 Chinese orbital missions (15 in the calendar year 2010) using the Long March family of vehicles, from the Jiuquan Launch Centre, and the Xichang Launch Centre.

ISRO successfully tested a new generation high performance sounding rocket marking a major step towards low-cost access to space by India. The ISRO Polar Satellite Launch Vehicle PSLV-C-15 carrying the remote sensing Cartosat-2B along with four other satellites, launched in July.

China, the Russian Federation and the United States all augmented their global navigation systems – Compass, Glonass and GPS – with a series of launches during the year.

Important scientific launches were achieved in this time period beginning on 2 November 2009, with the launch of the SMOS-2 Earth observation and soil moisture satellite. NASA launched the Wide-Field Infrared Survey Explorer (WISE) mission, designed to survey the cosmos in the mid-infrared region of the electromagnetic spectrum. 11 February 2010 marked the launch of the Solar Dynamics Observatory. The European Cryosat-2 was launched and the Japanese launched the Venus Planet Orbiter (Akatsuki).

A Dnepr-1 rocket lofted the climate research satellite Picard. Six days later, on 21 June, the DLR spacecraft TanDEM-X, a synthetic aperture radar imaging satellite, was launched.

Showing progress in the growing importance of commercial spaceflight, Space Exploration Technologies (SpaceX) successfully completed the first flight of its Falcon 9 launch vehicle in June 2010. This test launch carried the qualification unit for the Dragon spacecraft, and was the first flight of the Falcon-9 launch vehicle. The second Falcon 9 launch, and the first launch of the Dragon spacecraft, occurred on 8 December from Cape Canaveral. The launch was successful, with the Dragon spacecraft completing two orbits before splashing down in the Pacific Ocean.

2010 also saw failures in launches and deployment. In April, the US Department of Defense lost contact with a hypersonic glider test vehicle shortly after launch. In October, a communications satellite Eutelsat W3B launched, but in orbit, the satellite's fuel tank developed a leak, and engineers declared the craft a total loss. India saw two failures of its Geosynchronous Satellite Launch Vehicle, in April and December. Science and Technology Satellite 2B was a South Korean satellite which was lost in the failure of the second flight of the Naro-1 carrier rocket on 10 June. NASA's prototype solar-sail satellite, NanoSail-D, apparently failed to eject from its mothership satellite as planned in early December. Also that month, a Russian Proton rocket failed to place three Glonass-M navigation satellites into orbit. The failure destroyed the three spacecraft that would have ensured full Glonass operating capability which is now expected in 2011.

A major event in this reporting period was the return of the Japanese Hayabusa spacecraft to Earth and the successful recovery of the sample-return capsule in Australia on 14 June 2010. The capsule appears to contain some grains of material from the surface of the target near-Earth asteroid (25143) Itokawa. Hayabusa was launched in May 2003 and landed on Itokawa in September 2005. The probe

transmitted a wealth of scientifically valuable data, providing important information on the physical characteristics of a NEO, which is directly relevant to the question of NEO impact mitigation.

In a year of development activities in the space industry, work continued on the development of Soyuz launch capability from the Guiana Space Centre in Kourou, French Guiana, with a scheduled first-launch currently being targeted for early 2011.

ESA also continued development work on the smaller Vega launch vehicle, which, like the Soyuz, will be launched from French Guiana. The first qualification flight of the Vega is planned for 2011.

Roscosmos signed a decree to reserve a site in Amur Province for the construction of the Vostochny spaceport. In 2015 the first unmanned launch will take place, and the launch of a manned flight was planned for 2018. Russia intends to carry out up to 45 percent of its carrier rocket launches from the new centre by 2020. Russia also announced it would return to its programme of building the space shuttles and super-heavy carrier rockets after 2018. Test launches of Russia's new booster rocket, the Angara, are to start in 2013.

ISRO said that a third launch pad is proposed to be built at Sriharikota. India is also developing semi-cryogenic propulsion technology using kerosene that is expected to give the country the capability to launch six-tonne class satellite.

ESA and NASA invited scientists from across the world to propose instruments for their joint Mars mission, the ExoMars Trace Gas Orbiter. Scheduled for launch in 2016, the spacecraft will focus on understanding the rarest constituents of the martian atmosphere, including the methane that could signal life on Mars.

ESA also announced a plan to launch a Lunar Lander mission which will explore the yet-to-be-visited south polar region of the Moon. The space agency targets to send the Lunar Lander by the end of the decade.

Two South American countries announced developments during the period. Brazil’s AEB Space Agency announced plans to develop its own carrier rocket for conveying small satellites into orbit by 2014. Argentina announced that it was in the process of developing a satellite launcher which could become operational in three years time, making it the sixth country in the world with that capacity.

JAXA has unveiled three basic plans for the design of its unmanned cargo spacecraft that would be capable of bringing back supplies from ISS.

The China Academy of Space Technology put forward a plan to send a probe to Mars by 2013. China also said it would launch a space lab to be manned for long stretches within about 10 years. The country is additionally setting up the second generation of the Compass (Bei Dou) satellite navigation system to cover the Asia-Pacific region in 2012 and to establish a satellite navigation and positioning system with global coverage by 2020.

At the beginning of the reporting period, in November 2009, preliminary data from NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) indicated the mission successfully uncovered water in a permanently shadowed lunar crater. Scientists suggested that comets delivered much of the water at the impact site.

In an advance in propulsion, JAXA deployed the solar sail of the Small Solar Power Sail Demonstrator “IKAROS”. It successfully expanded and was generating

power through its thin film solar cells at about 770 km above Earth.

DLR's radar satellite TanDEM-X moved into close formation with its 'twin', TerraSAR-X. The objective of the mission is to create a high-precision, three-dimensional digital elevation model of Earth´s land surface. The project needs the satellites to operate in parallel for a period of three years. The transition to close formation flight marks the beginning of the final preparatory stage of the TanDEM-X mission. The routine operations phase is due to start in January 2011.

Preliminary results from The Tauri Group (USA) annual report on the state of the commercial spaceflight industry signal revenue increases, modest maturation, and a blurring of lines with the greater aerospace community. Total investment in the commercial human spaceflight sector has risen by 20% since January 2008, reaching a cumulative total of $1.46 billion, according to the Tauri report.

On 11 October 2010, US President Obama signed the National Aeronautics and Space Administration Authorization Act, that provides for changes in NASA policy, moving away from its moon-oriented Constellation focus and instead paving the way for manned missions to an asteroid by 2025 and to Mars during the 2030s. Because of the planned termination of the shuttle programme, the plan relies on non-US spacecraft to ferry crew and supplies to ISS. The longer-term goal is to encourage the development of American commercial space capabilities.

Estonia, Lithuania and Slovakia signed cooperation agreements with ESA during the period. Slovenia embarked on the next stages of coordination with ESA signing both a European Cooperating State Agreement and a PECS charter.

As 2010 drew to a close, ESA was unable to win its member states' approval of NASA's proposed five-year extension of operations of the ISS because of an unrelated dispute over financial support for Europe's Arianespace commercial launch services consortium.

In other international developments, both Mexico and South Africa announced national space agencies. The United Kingdom established an agency to take forward UK space policy within ESA and beyond.

II. SPACE TRANSPORTATION

II.1 Launches

Summary of ISS missions

Between 1 November 2009 and 31 December 2010, the United States and international partners successfully launched four Space Shuttle missions from the Kennedy Space Center in Florida to ISS. These were designated STS-129 (16 Nov 2009 - 27 Nov 2009), STS-130 (8 Feb 2010 - 21 Feb 2010), STS-131 (5 April 2010 - 20 April 2010), and STS-132 (14 May 2010 - 26 May 2010).

The Russian Federation launched Soyuz TMA-17 on 20 December 2009 (docked for 162 days). Then Soyuz TMA-18 launched on 2 April 2010, spending 174 days docked to the ISS. Soyuz TMA-19 launched on 15 June, spending 162 days docked to the ISS. At the close of the reporting period, on 31 December 2010, Soyuz TMA-01M, launched on 7 October and TMA-20 launched on 15 December 2010 are docked to the Space Station.

Cargo missions to supply the ISS were launched from Baikonur, using the Soyuz U/ Progress vehicle equipment set, as part of Progress M-04M/ISS 36P on 3 February 2010, Progress M-05M/ISS37P on 28 April 2010, and Progress M-06M/ISS 38P on 30 June 2010. The most recent Soyuz-U mission launched Progress M-08M to the ISS on 27 October 2010.

Summary of other launches

During the period of this report, a series of Chinese orbital missions using the Long March family of vehicles, from the Jiuquan Launch Centre and the Xichang Launch Centre took place. These missions, their launch dates, and vehicles were: 12 November 2009 - Shijan 11-01, Long March 2C; 9 December 2009 - Yaogan 7, Long March 2D; 15 December 2009 - Yaogan 8, Hope 1, Long March 4C; 16 January 2010 - BeiDou-3, Long March 3C; 5 March 2010 - Yaogan 9, Long March 4C; 2 June 2010 - BeiDou-2, Long March 3C; 15 June 2010 - Shijian 12, Long March 2C; 31 July 2010 - BeiDou-2 IG1, Long March 3A; 9 August 2010 - Yaogan 10, Long March 4C; 24 August 2010 - TianHui 1, Long March 2C; 9 September 2010 - Sinosat 6, Long March 3B; 22 September 2010– Yaogan 11 and two Pixing, Long March 2D; 1 October 2010– Chang'e 2, Long March 3C; 6 October 2010– Shijian 6-04A/B, Long March 4B; 31 October 2010– Compass G4, Long March 3C; 4 November 2010– FengYun FY 3B, Long March 4C; 24 November 2010– Chinasat 20A, Long March 3A and 17 December 2010 – Compass IGSO2, Long March 3A. This series meant that a new country - China - matched the United States in the number of its rocket launches during a calendar year (15 in 2010) for the first time. 31 launches were made by the Russian Federation in 2010.

On 2 November 2009, ESA's **SMOS** (Soil Moisture and Ocean Salinity) satellite was launched from the Plesetsk Cosmodrome by Rotok /Briz KM, 800 kilometres north of Moscow. The SMOS satellite begins a unique mission: the large-area mapping of soil moisture and ocean salinity. The mission is a particularly important one for Spain - Spanish engineers have spent 15 years developing the spacecraft's novel instrument MIRAS. The French space agency CNES, which is responsible for operating the satellite, confirmed that the instrument's three antenna arms deployed as planned the following day, and that the instrument was in good health. >>

By 19 November, the MIRAS instrument had been switched on and was operating normally. MIRAS will map soil moisture and ocean salinity to improve our understanding of the role these two key variables play in regulating Earth's water cycle. >> On 20 November, ESA announced an image, the first data sent to Earth by the MIRAS instrument. >> On 24 February 2010, the first calibrated images were delivered by SMOS. >>

Launched on the same rocket as SMOS, **Proba-2** was taken aloft - a follow-on to the highly successful Proba-1 satellite launched in 2001. It will demonstrate 17 advanced satellite technologies, such as miniaturised sensors for ESA's future space probes, validating hardware and software technology for Attitude and Orbit Control Systems and a highly sophisticated CCD camera with a wide angle view of about 120°, while carrying a set of four science instruments to observe the Sun and study the plasma environment in orbit. >> By late January 2010, Proba-2 had returned its first images of the Sun. >>

On 13 November 2009, China sent a **Shijian** research satellite into orbit. The Shijian 11-01 spacecraft lifted off on a Long March 2C rocket and originated from the Jiuquan launching base near the border of northern China´s Inner Mongolia and Gansu provinces. >>

On 22 November 2009, Russia's Space Forces launched a Soyuz-U carrier rocket with a **Cosmos**-series military satellite. >>

A series of commercial communications satellites followed. On 23 November 2009, United Launch Alliance deployed its fourth commercial mission of 2009 as an Atlas V rocket successfully launched the **Intelsat 14** (IS-14) commercial telecommunications satellite. Blasting off from Space Launch Complex-41, the launch was provided on behalf of Lockheed Martin Commercial Launch Services, which procured the Atlas V for this mission. Previous ULA commercial launches in 2009 included the Delta IV GOES-O launch for NASA/NOAA on 27 June, the Atlas V PAN mission on 8 September and the Delta II WorldView-2 mission on 8 October. >>

Also on 23 November, a Proton booster was used to launch the **Eutelsat W7** spacecraft, built by Thales Alenia Space, to a geosynchronous orbital position at 36 deg East. Co-positioned with Eutelsat W4, it enhances TV broadcasting to Russia, Central Asia and Africa currently provided by SESAT 1. It also offers the potential for data and voice services to small ground terminals.

Intelsat 15 followed on November 30, launched aboard a Zenit 3SLB, from Baikonur. Intelsat 15 was built by Orbital Sciences Corporation, on a Star-2 Bus. Intelsat planned to locate Intelsat 15 at 85º E longitude, offering capacity for the Middle East, Indian Ocean region and Russia. >>

In 2010, the Proton M vehicle launched a further series of commercial communications flights from Baikonur: **Intelsat 16** on 12 February 2010, **Echostar 14** on 21 March 2010, **SES 1** on 24 April 2010, **Badr 5B** (Arabsat 5B) on 3 June 2010, and **Echostar 15** on 10 July 2010. On 2 September, Proton-M / DM-2 launched **Kosmos 2464-2466** (GLONASS satellites). On 14 October, Proton Breeze M launched **XM 5** and on 14 November Proton-M/DM-3 launched **SkyTerra 1**. On 5 December 2010, the Proton-M/DM-3 launch of GLONASS satellites proved a failure. A Block DM upper stage fuelling error caused it to crash into the Pacific Ocean. >> >>

On 26 December 2010 a Proton rocket successfully launched a European communications satellite **KA-SAT**, three weeks after the previous Proton launch failed.

Intelsat 16 was built by Orbital Sciences Corporation, on a Star-2 Bus and was deployed at 58º W longitude. EchoStar 14, built by Space Systems/Loral, was positioned in geostationary orbit at a longitude of 119° West, from where it is used to provide high-definition television direct broadcasting services to the continental United States for Dish Network. EchoStar 15, is similar to Echostar 14 but located at a longitude of 61.5° West, from where it is intended to provide direct broadcasting of high-definition television services to the continental United States and Puerto Rico for Dish Network. SES-1 was the 42nd satellite in SES World Skies' constellation. Built by Orbital Sciences, it is a hybrid C- and Ku-band spacecraft that replaces AMC-2 and AMC-4 at 101 deg west longitude. >> >> The first of the fifth-generation Arabsat satellite, named BADR-5 (technically: Arabsat-5B), was launched to 26° East, Arabsat's Direct-to-Home television "Hot Spot". >> XM-5 will serve as an in-

orbit spare for Sirius XM, and will be tested in a temporary location before shifting to its permanent geostationary home. >> LightSquared's SkyTerra 1 marked the tenth Proton M launch of 2010. >> Two days after launch, Boeing received the first on-orbit signals from SkyTerra. >> The KA-SAT satellite, a Eurostar E3000 model built by EADS Astrium, carries a Ka-band payload that will be used by satellite operator Eutelsat to provide high-speed Internet access across Europe and the Mediterranean Basin. This final Proton launch of the year came just over three weeks after another Proton failed to place three Glonass navigation satellites into orbit. That problem was traced to the upper stage, a different model than the Breeze M, clearing the way for this launch.

Outside commercial communications, late November 2009 was a busy period. Further launches included Japan's of a next-generation spy satellite as part of efforts to enhance its surveillance of the threat of North Korean missiles. >>. Then, on 29 November, the launch of the German Aerospace Center (DLR) **TEXUS 47** rocket from Esrange in Kiruna, northern Sweden, and the successful recovery of its payload was the conclusion of 2009 TEXUS research campaign. During the parabolic flight, weightlessness was experienced for nearly seven minutes and scientists conducted biological and materials science experiments. >>

On 1 December 2009 a New Zealand company, Rocket Lab, launched a rocket in what it claimed was the inaugural private missile launch in the Southern Hemisphere. The next day, on 2 December, a fisherman found the first stage booster from **Atea-1**, which had been launched from Great Mercury Island off the Coromandel Peninsula. On 3 December, the battery powering the rocket's connection to its tracking satellite failed. >> >>

On 5 December, a Delta IV launched the US Air Force's **Wideband Global Satcom-3** spacecraft into geosynchronous orbit. The ultimate six-spacecraft constellation was to replace and greatly enhance the wideband service provided by the Defense Satellite Communications System. The sixth spacecraft is being funded by Australia in exchange for participation in the programme. >>

After a series of delays, NASA's **Wide-field Infrared Survey Explorer** (WISE) began its mission on 14 December 2009. WISE launch from Vandenberg Air Force Base in California was initially delayed because of a scheduling conflict with a satellite launch on the East Coast, then twice pushed back due to an anomaly in a steering engine on its booster rocket. It was launched into a 525 km sun- synchronous orbit. WISE was a 6-month mission that surveyed the whole sky (hundreds of millions of object) at infra-red wavelengths. Over its mission, the satellite was expected to take 1.5 millions of pictures covering the entire sky. >>

Also on 14 December, flying for the 350th time, a Proton rocket launched three new satellites for Russia's **GLONASS** space navigation network to ensure the system continues providing coverage of its home territory. The spacecraft launched from the Baikonur Cosmodrome. The Proton's three core stages placed the Block DM upper stage and three Glonass satellites in a temporary parking orbit less than 10 minutes after liftoff. >>

The next day, China successfully launched two of its satellites from the Tai-yuan Satellite Launch Centre in Shanxi Province. The **Yaogan VIII** remote-sensing satellite and science researching mini-satellite, **Hope One** were put into the orbit by a Long March 4C carrier rocket. >> >> Yaogan VIII will be mainly used for

scientific experiment, land resources survey, crop yield estimates and disaster prevention and reduction. The satellite was developed by the China Academy of Space Technology under the China Aerospace Science and Technology Corp. The rocket was designed by the Shanghai Academy of Spaceflight Technology, also under the corporation. The flight was the 120th of the Long March series of carrier rockets. >>

The commercial television broadcast satellite **DirecTV 12** was launched from Baikonur on 29 December 2009, using a Proton M/Briz M launch vehicle. Built by Boeing, it was the seventh ILS Proton mission on 2009. DIRECTV 12 is intended to boost high definition television service to America by 50%, to more than 200 HD channels. >> >> >>

Black Brant IX, a Canadian sounding rocket was the first launch of the new year, on 10 January 2010 followed the next day by the Chinese launch of **Dong Feng 21** from Urumqi. 16 January saw the launch of the Chinese **BeiDou-3** atop a Long March 3C and 29 January, a Proton M launch vehicle, carrying a Russian military satellite, blasting off from the Baikonur Cosmodrome. >>

On 3 February 2010, the government of Iran launched the **Kavoshgar 3** research sounding- rocket carrying an announced payload of turtles, worms, and a mouse. The same day, Iran unveiled a satellite launch vehicle named 'Simorgh', designed to carry a 100 kg satellite to an orbit of 500 km, according to Iranian State Television. >>

On 11 February 2010, NASA launched the **Solar Dynamics Observatory** (SDO) into a geosynchronous orbit which is not a usual trajectory for an astronomy or solar observation mission which more often go either into a lower earth orbit or to one of the Lagrange points L1 or L2. SDO will observe the Sun for over five years. The observatory is part of the "Living With a Star" programme, the goal of which is to develop the scientific understanding necessary to effectively address those aspects of the connected Sun–Earth system that directly affect life and society. SDO's goal is to understand the Sun's influence on Earth and near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously. SDO will investigate how the Sun's magnetic field is generated and structured, how this stored magnetic energy is converted and released into the heliosphere and geospace in the form of solar wind, energetic particles, and variations in the solar irradiance. The three SDO instruments provide unprecedented precise measurements and images of solar coronas and solar magnetic fields. >> By April, scientists were seeing the violent and dynamic processes of the Sun. The "first light" data from SDO was providing extreme close-ups of the Sun´s surface, including never-before-seen detail of material streaming outward and away from sunspots. >>

Another major scientific mission, the $500 million NASA/NOAA **Geostationary Operational Environmental Satellite-P** (GOES-P) lifted off from Cape Canaveral on 4 March 2010 atop a United Launch Alliance Delta IV rocket which would carry the weather-watching satellite to its orbit. It will form part of the Geostationary Operational Environmental Satellite (GOES) system operated by the US National Oceanic and Atmospheric Administration. The spacecraft was constructed by Boeing, and is the last of three GOES satellites to be based on the BSS-601 bus. The other BSS-601 GOES satellites; GOES 13 and GOES 14 were launched in May 2006 and June 2009 respectively. It was the sixteenth GOES satellite to be launched. >> Twelve days after its launch, GOES-P reached its proper orbit

and was renamed GOES-15. The latest weather satellite would complete its checkout in mid August 2010 and be stored in-orbit, ready for activation should one of the operational GOES satellites degrade or exhaust their fuel. >> >>

Meanwhile, also on 4 March, ISRO successfully tested a new generation high performance sounding rocket marking a major step towards low-cost access to space by India. >>

Another sounding rocket, ESA's **Maxus-8** sounding rocket was launched in March from Kiruna in northern Sweden carrying four microgravity research modules on a hectic 12-minute space voyage. >>

On 8 April 2010 an important launch was made replacing Cryosat, which was destroyed during a launcher anomaly in September 2005, with **Cryosat-2,** launched for ESA. CryoSat-2 is an environmental research satellite that provides scientists with unprecedented data about the polar ice caps and track changes in the thickness of the ice down to around half an inch. This is seen as vital information for monitoring climate change. Cryosat 2 was an advanced replacement for Cryosat, with software upgrades and greater battery capacity powering an interferometric radar range-finder with twin antennas which measures the height difference between floating ice and open water. CryoSat-2 is operated as part of the CryoSat programme to study the Earth's polar ice caps, which is itself part of the Living Planet programme. The CryoSat-2 spacecraft was constructed by EADS Astrium, and was launched by ISC Kosmotras, using a Dnepr-1 carrier rocket, on 8 April 2010. On 22 October 2010, CryoSat-2 was declared operational following six months of on-orbit testing. >> >>

One week after the launch of Cryosat-2, India's bid to launch an advanced communications satellite into orbit for the first time by using a cryogenic engine – **GSAT-4** - failed. The rocket took off as planned but the phase powered by the new engine failed to perform and deviated from its path. >>

Soyuz-U's most recent non-Progress launch took place on 16 April, when it was used to carry the Kosmos 2462 optical imaging spacecraft to orbit. >>

An **Orbital Minotaur IV** rocket made its maiden flight on 22 April with lift off from Space Launch Complex 8 at the Vandenberg Air Force Base in California. The rocket flew a suborbital trajectory, carrying a prototype hypersonic re-entry vehicle. It lost of contact nine minutes after launch. >>

The same day, from Cape Canaveral, the maiden flight of **Atlas V 501** and **Boeing X-37B** took place.

On 20 May 2010, JAXA performed an important launch for its scientific programme. The launch vehicle, the H-IIA rocket, took off from the Tanegashima space centre in southern Japan on schedule, three days after its original launch was postponed by bad weather. The rocket released all of its six satellites within an hour. It launched the **Venus Climate Orbiter** (Planet-C, AKATSUKI) together with **IKAROS** (Interplanetary Kite-craft Accelerated by Radiation of the Sun). IKAROS is a pilot mission to demonstrate solar sailing. The attitude control of the deployed solar sail is performed by changing the reflectivity of certain parts of the solar cells that cover the sail surface. First results show the expected performance of the solar sail technology was what was expected. H-IIA 202, Waseda-SAT2, Hayato (K-Sat), Negai, SHIN-EN (UNITEC-1), DCAM-1 and DCAM-2 were the other satellites deployed in the launch. >> >>

Later in the year, on 7 December 2010, the Institute of Space and Astronautical Science of the Japan Aerospace Exploration Agency (ISAS/JAXA) performed the Venus Orbit Insertion manoeuvre (VOI-1) for the Venus Climate Orbiter. The orbiter was not injected into the planned orbit and hurtled past Venus. ISAS/JAXA said it hoped for a successful rendezvous six years from now. >> >>

The following day to the JAXA launch, 21 May, the 50th Ariane 5 (5ECA) lifted off from Europe's Spaceport at Kourou in French Guiana. **SES ASTRA 3B**, built by EADS Astrium, was launched by Ariane into geosynchronous orbit at 23.5 deg east longitude. It will deliver direct to home broadcast services at Ku- and Ka-band to the Benelux countries and Eastern Europe, as well as public and private satellite communications networks across Europe and the Middle East. The new satellite will join ASTRA 3A at that locations and will allow ASTRA 1E and ASTRA 1G to be used for other missions. >> The payload included the second communications satellite for the German armed forces, **COMSAT Bw-2**.

On 28 May 2010, the United States launched the first of a new class of GPS satellite, the **IIF series**. This launch sustains the GPS constellation at over 30 operational satellites and supports the expanded-slot constellation design that was recently adopted for improved availability robustness. In addition to providing all the legacy GPS civil and military signals such as L1 Coarse/Acquisition, L1 P(Y), L2(P(Y), the GPS IIF also provides the GPS modernized signals (L1 and L2 M code, L2C) deployed on the last eight IIR-M satellites. The Block IIF also introduces the second modernized civil signal, L5, which was specifically designed for the aviation community to provide safety of life navigation. >>

June 2010 began with the successful launch of the **SERVIS-2** satellite from Plesetsk Cosmodrome in Northern Russia using a ROCKOT launch vehicle. SERVIS-2, or Space Environment Reliability Verification Integrated System 2, is a Japanese technological research satellite. It was constructed by Mitsubishi Electric, and is be operated by the Institute for Unmanned Space Experiment Free Flyer, USEF. Nine experiments are being conducted by SERVIS-2. >>

The successful second-stage test in January 2010 of the **Falcon 9** rocket, followed by a test firing in March, cleared the way for its maiden flight. On 4 June 2010, Space Exploration Technologies (SpaceX) successfully completed the first flight of its Falcon 9 launch vehicle from the Cape Canaveral Air Force Station in Florida. This test launch carried the qualification unit for the Dragon spacecraft, and was the first flight of the Falcon-9 launch vehicle. Then, on 12 August, SpaceX completed a drop test from 14,000 feet of its Dragon spacecraft, splashing down successfully near the coast of California. The Falcon 9/Dragon combination will be used by SpaceX to deliver and return cargo to and from ISS as part of the Commercial Resupply Services contract with NASA. One day it may also transport astronauts. The second Falcon 9 launch, and the first launch of the Dragon spacecraft, occurred on 8 December from Cape Canaveral. The launch was successful, with the Dragon spacecraft completing two orbits of manoeuvres before splashing down in the Pacific Ocean. SpaceX became the first commercial company in history to re-enter a spacecraft from low-Earth orbit >> >> >> >> >>

STSAT-2B, or Science and Technology Satellite 2B, was a South Korean satellite which was lost in the failure of the second flight of the Naro-1 carrier rocket on 10 June. It was to have been operated by the Korea Aerospace Research Institute, and was intended to demonstrate technology for future spacecraft. The rocket

exploded during first stage burn.

On 15 June 2010, two satellites were launched by Dnepr from the Yasni Cosmodrome. The two **Prisma** satellites demonstrate new technologies for formation flying and rendezvous. The Swedish Space Centre is the prime contractor for Prisma and has developed the majority of the onboard technology and navigation experiments as well as the mission control software. Prisma later separated into 2 spacecraft Mango and Tango which are undergoing a series of formation flying manoeuvres. **PICARD**, from CNES, is an investigation dedicated to the simultaneous measurement of the absolute total and spectral solar irradiance, the diameter and solar shape, and to the Sun's interior probing by the helioseismology method. These measurements obtained all along the mission will allow the study of their variations as a function of the solar activity. A further instrument, **BPA-1**, intentionally remained attached to upper stage. >> The Mango and Tango spacecraft, part of the Prisma mission, then conducted a complicated manoeuvre. Over the next six months, Mango - a 150-kg craft will continue to perform a sort of dance with the smaller Tango. Mango will try to stay close to Tango, demonstrating each of the technologies that are part of the programme. The spacecraft, designed by the Swedish Space Corp., will test orbital repairs, automatic docking and scientific missions that bring together multiple satellites to form a massive telescope to study distant stars.

On 21 June 2010, Germany's second Earth observation satellite, **TanDEM-X**, was launched successfully from the Baikonur Cosmodrome in Kazakhstan. Atop a Russian Dnepr rocket, the satellite, weighing more than 1.3 tons and five metres in length, started its journey into orbit. The first signal was received via the Troll ground station in the Antarctic. TanDEM-X, the twin spacecraft of TerraSAR-X already in orbit will see both satellites' orbits closely linked to follow formation flying requirements during certain mission phases for X-SAR interferometry. TerraSAR-X and TanDEM-X together form the first bistatic SAR mission. The primary mission objective is the generation of a consistent global digital elevation model with an unprecedented accuracy. >>

On 22 June, Israel successfully launched a new satellite using an improved version of its Shavit rocket. >>

On 26 June, Arianespace successfully launched two payloads: **Arabsat-5A** and **COMS-1** satellite payloads. Arabsat-5A was deployed at 30.5° East. Chollian (COMS-1) from KARI of South Korea is a communications, oceanography and weather satellite. >> On 17 July, COMS-1 successfully sent photos to the ground after entering geostationary orbit last week. >>

On 12 July 2010, the ISRO Polar Satellite Launch Vehicle PSLV-C-15 carrying the remote sensing **Cartosat-2B** along with four other satellites blasted off from the Satish Dhawan space centre. The 694 kg Cartosat-2B satellite is orbiting in a 630 km sun-synchronous orbit. The panchromatic camera onboard is capable of imaging a swath of 9.6 km with a resolution of better than 1 metre. >> Two weeks later, Cartosat-2B started beaming high quality images of the India's landscape from low orbit. >>

Another payload of this launch saw Norway deploying a spacecraft with the intention to help monitor shipping in its territorial waters. The **AISSat-1** satellite will track ships over 300 gross tons by picking up signals from their Automatic Identification System (AIS) transponders. AIS is used principally for collision-

avoidance, and the authorities use it to keep watch on cargo, passenger and fisheries activity. >>

On 4 August 2010, **Nilesat 201** and **Rascom-QAF 1R** were launched by an Ariane 5 rocket. Built by Thales Alenia Space, Nilesat 201 was placed at 7 deg W longitude and carries 24 Ku-band and 4 Ka-band transponders to provide direct-to-home, radio and broadband Internet services to Africa and the Middle East. Rascom-QAF 1R was launched to replace a satellite launched in 2007 whose operational life was reduced by a helium leak. It was placed at 2.85 deg E longitude to provide television, telephone and Internet services to Africa. >>

On 14 August, the US Air Force launched an advanced military satellite. A sophisticated satellite was launched into space to improve the pre-eminent path of communications between the president, military commanders and troops on the battlefield. The maiden flight of **Atlas V 531** alas failed as its liquid apogee motor failed to operate during the orbital insertion process. >>

The Japanese H-2A Launch Vehicle launched the Quasi-Zenith Satellite (**MICHIBIKI**) from Tanegashima Space Centre on 11 September 2010. The **Quasi-Zenith Satellite System** (QZSS), is a proposed three-satellite regional time transfer system and enhancement for the Global Positioning System, that would be receivable within Japan. Full operational status is expected by 2013. QZSS is targeted at mobile applications, to provide communications-based services (video, audio, and data) and positioning information. The first satellite of the Quasi-Zenith Satellite System performs technological demonstration. >>

On 25 September 2010, a satellite that will monitor the clutter in Earth orbit launched, nearly three months later than originally planned. The **Space-Based Space Surveillance** satellite was scheduled to launch on July 8, but it was grounded by concerns about software in the Minotaur IV rocket and a problem in the rocket's electronics. >> Two days later, The Boeing Company acquired initial on-orbit signals from the satellite following its launch from Vandenberg Air Force Base in California. >>

On 1 October 2010, a Chinese rocket carrying a probe destined for the Moon launched. A Long March 3C rocket with the Chang'e-2 probe took off from Xichang launch centre. China's second lunar mission, **Chang'e 2**, will perform several tasks during its flight. Some of these are purely scientific, aimed at helping the understanding of the Moon and the space around it. China is using the spacecraft to scout landing sites for future Chinese Moon missions. >> >> Five days after leaving Earth, China´s second lunar mission slipped into a preliminary orbit around the moon early Wednesday, setting the stage for at least six months of scientific observations. >> Then, in November, China released photos that its lunar probe took of the spot chosen for China's first landing on the moon. Chang'e-2 will conduct various tests over a six-month period in preparation for the expected launch in 2013 of Chang'e-3. >>

The same day, 1 October, the Aeronautics and Cosmonautics Romanian Association (ARCA) launched **Helen 2**, the first Romanian rocket from the Black Sea. >>

On 19 October, a Soyuz 2.1a/Fregat launched from Baikonur with six US **Globalstar** spacecraft. Facilitated by the Starsem venture, Arianespace said that the launch opened a new page in development of Russian-French cooperation. >> An

Ariane 5 from Arianespace lifted off on 28 October from Europe's Spaceport in French Guiana on a journey to place two telecommunications satellites, **W3B** and **BSAT-3b**, into orbit. Flight V197 was Ariane 5's fourth dual-payload mission of the year. >> On 30 October, the Eutelsat W3B communications satellite fell victim to a significant propellant leak shortly after separating from its Ariane 5 rocket, prompting the company to declare the five-ton spacecraft a total loss. >>

On 5 November, a new Italian satellite, **COSMO-4**, lifted into orbit atop the 350th Delta 2 rocket launched. It was the final flight of Delta II 7420. The COSMO-SkyMed (COnstellation of small Satellites for the Mediterranean basin Observation) series is an Earth observation satellite system funded by the Italian Ministry of Research and Ministry of Defence and conducted by the Italian Space Agency (ASI), intended for both military and civilian use. Observations of an area of interest are repeated several times a day in all-weather conditions. The imagery is applied to defence and security assurance in Italy and other countries, seismic hazard analysis, environmental disaster monitoring, and agricultural mapping. >>

On 20 November, NASA's Fast, Affordable, Science and Technology Satellite, or **FASTSAT**, was launched aboard a Minotaur IV rocket from Kodiak Launch Complex on Kodiak Island, Alaska. It was launched as part of a series of nanosats launched in the same payload. FASTSAT is a unique platform that can carry multiple small payloads to low-Earth orbit creating opportunities for researchers to conduct low-cost scientific and technology research on an autonomous satellite in space. FASTSAT was to have deployed another satellite, NanoSail-D2, sixteen days later - designed to demonstrate solar sail concepts. The Minotaur 4 is a rocket that uses recycled Peacekeeper IBCM motors for its lower stages and this was the second orbital launch for the rocket. The launch was also the first orbital mission from Kodiak since 2001. >>

Another of the nanosatellites of the mission, known as Organism/Organic Exposure to Orbital Stresses, or **O/OREOS**, could help answer astrobiology´s fundamental questions about the origin, evolution, and distribution of life in the universe. >>

NanoSail-D2 was expected to separate from FASTSAT on 9 December, but it is unclear if full ejection had occurred. >>

The following day to the Kodiak launch, a United Launch Alliance Delta IV Heavy rocket carrying a payload for the National Reconnaissance Office lifted off from Cape Canaveral. Designated **NROL-32**, the mission was in support of US national defence. The launch had been planned for two days previously but was postponed because of anomalous temperature readings during fuelling; the problem was later traced to faulty sensors. The nature of the heavy payload atop the rocket was not disclosed, but observers speculate it is an electronic eavesdropping satellite with a large antenna to intercept signals. >>

On 26 November 2010, a flawless launch delivered **HYLAS-1** (Highly Adaptable Satellite) - ESA's first public-private partnership in a full satellite system - into space. The satellite was released into its transfer orbit after a textbook launch by Ariane 5 V198 vehicle from Europe's Spaceport in French Guiana. It will be positioned at 33.5ºW and will provide new and innovative services including High Definition Television and interactive satellite delivered broadband services. The satellite will help address the issue of poor broadband coverage in many parts of

Europe which have less developed ground infrastructure. HYLAS was constructed by EADS Astrium for the UK telecommunications company Avanti Communications Plc. Development of the satellite is being supported by a £23m investment from the British National Space Centre. HYLAS is based on the Indian Space Research Organisation's I-2K small satellite platform under a cooperative arrangement between EADS Astrium and ISRO/Antrix. Ariane 5's fifth mission of 2010 also orbited Intelsat 17. >> >>

On 12 December 2010, Brazil successfully launched a midsized unmanned rocket into space, with hundreds of kilograms in cargo and experiments in tow. Scientists from the Agencia Espacial Brasilena (AEB) said the **VSB-3** rocket took off from the Alcantara Launch Centre in northeast Brazil, reaching an altitude of some 242 kilometres. Officials said the rocket, designed by Brazilian and German scientists, carried some 400kg in cargo, as well as various micro-gravity experiments for several academic institutions. >>

On 20 December, China successfully launched its final spacecraft of the year from the Xichang Satellite Launch Centre. It was the seventh orbiter that China has launched for its independent satellite navigation and positioning network, also known as **Beidou**, or Compass system. It was the 136th flight for the country's Long March series of rocket >>

A failed launch of ISRO's **GSAT-5P** occurred on 25 December 2010. The rocket, the Geosynchronous Satellite Launch Vehicle (GSLV) was to carry GSAT-5P, an advanced communications satellite meant to retire an earlier one sent up in 1999 and ensure continuity of telecom, TV and weather services. >> A week later, it was concluded that GSLV failed because of a snapped data cable. It had lifted off normally but started losing attitude control 47.8 seconds later; the rocket broke up at T+53.8 seconds and was destroyed by range safety at T+64 seconds. An initial investigation, chaired by former ISRO chair G. Madhavan Nair, concluded that the primary cause of the failure is the "untimely and inadvertent" snapping of a group of 10 connectors at the base of the upper stage linking the rocket's avionics, located in the upper stage, with the rocket's lower stages. The snapped cables prevented commands from reaching the first stage's electronics, causing the rocket to lose control.

On 29 December 2010, the Ariane 5 V-199 launched **Hispasat 1E** and **KOREASAT 6**. Hispasat is a group of Spanish communication satellites, developed by the *Instituto Nacional de Técnica Aeroespacial* (National Institute for Aeronautical Technology) and ESA. It now belongs to Eutelsat (27.69%) and other private shareholders from Spain. KoreaSat 6, a South Korean telecommunications satellite has 30 active Ku-band transponders.

II.2 Development Activities

Work continued on the development of Soyuz launch capability from the Guiana Space Centre in Kourou, French Guiana. Workers have completed the construction of the mobile gantry system, and the first two flight vehicles are being integrated at the launch site. Installation of launch pad systems continues, with a scheduled first-launch currently being targeted for early 2011.

ESA also continued development work on the smaller Vega launch vehicle, designed to loft a payload of approximately 1500 kg to a 700 km orbit of 90-degree inclination. This vehicle, like the Soyuz, will be launched from the European Spaceport in French Guiana, and will use facilities adapted from the Ariane-1 vehicle.

Production launcher contracts were signed between ESA, Arianespace, and the ELV company on 8 September 2010, with the first qualification flight of the Vega planned for 2011.

Gaia, ESA's next-generation star mapper, will be carried into space by a Soyuz from Kourou. David Southwood, ESA's Director of Science and Robotic Exploration, signed the contract for the launch with Jean-Yves Le Gall, Chair and CEO of Arianespace. >>

Dark energy, habitable planets around other stars, and the mysterious nature of our own Sun, have been chosen by ESA as candidates for two medium-class missions to be launched no earlier than 2017. ESA's Science Programme Committee approved three missions to enter the so-called 'definition phase'. >>

ESA also announced its plan to launch a Lunar Lander mission which will explore the yet-to-be-visited south polar region of the Moon. The space agency targets to send the Lunar Lander by the end of this decade. The spacecraft will be launched with two objectives. First to fly a precise course from lunar orbit to the surface and touch down safely and accurately. On the way down, it would image the surface and recognise 'dangerous features' by itself, using its own 'intelligence' and navigation technology. >>

As part of the procedure to realise ESA's series of Earth Explorers, two new mission proposals have been selected for further development. The missions, called FLEX and CarbonSat, now vying to be the eighth Earth Explorer both address key climate and environmental change issues. >>

ESA and Arianespace signed a contract for the launch of Sentinel-1A, the first Earth observation satellite to be built for Europe's Global Monitoring for Environment and Security programme. Sentinel-1A is scheduled for launch in December 2012 by a Soyuz rocket from Europe's Spaceport. >>

Early in 2010, ESA and NASA invited scientists from across the world to propose instruments for their joint Mars mission, the ExoMars Trace Gas Orbiter. Scheduled for launch in 2016, the spacecraft will focus on understanding the rarest constituents of the martian atmosphere, including methane that could signal life on Mars. >> Then in August 2010, ESA and NASA announced that they had selected the scientific instruments for the mission. >>

NASA began work on a new kerosene-fuelled first-stage rocket engine comparable to Russia's RD-180 >>

In November 2009, NASA's Constellation Program recommended dropping a planned follow-on to October 2009's successful Ares I-X flight-test because it didn't have the funding necessary to get an upper stage engine ready in time. >> However, in a new test of its Orion crew capsule, on 6 May 2010, NASA engineers catapulted the capsule 2km into the air to test its abort system. >>

NASA and the Italian Space Agency ASI announced that the Leonardo Multi-Purpose Logistics Module (MPLM) would be modified into a Permanent Multipurpose Module (PMM) for the ISS. The modifications, to be led by Thales Alenia Space, will ensure safe, long-term operation of the PMM as a storage, logistics and possibly research module, adding 70 cubic metres of volume. Launch of the PMM was planned for the STS 133 mission in February 2011. >>

NASA selected Orbital Sciences Corp. to launch the agency's Orbiting Carbon Observatory (OCO) replacement satellite aboard a Taurus XL rocket, giving the company a second chance after the original spacecraft was lost in a February 2009 failure involving the same vehicle. >>

NASA plans to purchase a clone of a stopgap weather satellite to be the first member of a new civilian fleet of environmental platforms, but the future of U.S. climate- monitoring spacecraft hinges on congressional approval of a White House budget proposal to pay for the new programme. Scheduled to launch in 2014, the new spacecraft will be identical to the NPOESS Preparatory Project platform under construction at Ball Aerospace and Technologies Corp. >>

One of the key proposals on NASA's internal interpretation of the Augustine Commission's 'Flexible Path' option included a 45 day manned mission to construct a giant telescope in Geostationary orbit (GEO). A huge deep space telescope is also included in the roadmap, which would focus on a major advancement for the search of Earth-like planets. >>

NASA announced that it was developing a new mission to plunge a car-sized probe directly into the Sun's atmosphere. The spacecraft, called Solar Probe Plus, is slated to launch no later than 2018. >>

The replacement for the NASA/ESA Hubble telescope, JWST, will be delayed by a year to 2015 and will cost 1.5 billion dollars more than current estimates, independent experts said. >>

NASA also started an initiative to launch small cube-shaped satellites, dubbed CubeSats, as auxiliary payloads on launch vehicles already scheduled. >>

Russia announced a series of developments. The country’s Financial Ministry finalized and signed the project of building a new space launch site in Russia’s Far East. Vostochny, located in the Amur region bordering China, will host two booster sites, a training centre and a medical research centre. The space complex will be connected to the outside world with a series of new roads and railways. >> The Vostochny spaceport project will be implemented in stages, with construction due to begin in 2011. In 2015 the first unmanned launch will take place, and the launch of a manned flight was planned for 2018. >> Roscosmos added that it intended to carry out up to 45 percent of its carrier rocket launches from Vostochny by 2020. >> Russia will fully rebuild its network of weather forecasting and monitoring satellites by 2030 under a state programme for the development of meteorology. At present, Russia has only one weather satellite, the Meteor-M type, in orbit and mostly uses meteorological data from U.S. and European weather agencies. >>

Russia’s Rocket and Space Corporation Energia announced that it would build a special orbital pod designed for sweeping-up the near-Earth space from satellite debris. The system was estimated to cost about 60 billion roubles (1.9 billion U.S. dollars). >> Test launches of Russia's new booster rocket, the Angara, are to start in 2013, the rocket designer said. Vladimir Nesterov, head of the Khrunichev State Research and Production Space Centre, said the rocket assembly would be completed in the first quarter of 2011, adding that the first-stage engine was nearly ready and the second-stage engine had already been tested three times. >> >> Russia would return to its programme of building space shuttles and super-heavy carrier rockets after 2018. According to the director of Moscow's Central Machine-building Institute new carrier rockets will have a workload over 24 tons. >>

ESA said that it was hoping to launch four satellites into orbit using Russia's new carrier rocket, Rokot, from the Plesetsk launch pad in northwestern Russia. An ESA spokesman said that three Swarm satellites and one Sentinel space probe were scheduled for launch from Plesetsk. >>

The Russian Economic Development Ministry proposed launching the Arktika (Arctic) satellite system in 2014. The system, worth around 70 billion roubles ($2.5 billion), will monitor climatic changes and survey energy resources in the Arctic region. >>

Engineers continued to test Geo-IK-2. This is a Russian satellite system, consisting of two space vehicles, aimed at performing geodetic surveys: measuring parameters of Earth's gravity field, creating a highly accurate geodetic network in geocentric coordinate system, finding out the direction continental plateaus move, collecting information about tides, Earth's rotation speed and poles' coordinates. >>

The launch of the Phobos-Grunt unmanned lander to one of the moon of Mars, Phobos, was scheduled for October 2011. The spacecraft will return to the Earth with soil samples. >>

Russia will develop a lander that will ferry a rover to explore the moon's surface as part of the Indian Chandrayaan-II mission, slated for launch in 2013, the project director of Chandrayaan said. >> >>

India's space scientists are developing semi-cryogenic propulsion technology using kerosene that is expected to give the country the capability to launch six-tonne class satellite, almost three times the weight its rockets can currently handle. >>

The Indian Minister for Environment and Forest Jairam Ramesh announced that ISRO will launch a dedicated forestry satellite in 2013. The facility will help to continuously monitor the forest cover, health and diversity. >> ISRO a plans to launch 30 satellites in the next 10 years to strengthen its lead role in data collection and dissemination and that a third launch pad is proposed to be built at Sriharikota. >>

Efforts in commercial space continued. In January 2010, Space Exploration Technologies (SpaceX) conducted a three-day long demonstration of cargo loading and unloading procedures for its Dragon spacecraft. >> Also in 2010, Virgin Galactic's SpaceShipTwo was flown to launch altitude. The milestone was achieved on the second captive-carry test flight, which took the vehicle to about 51,000 ft. >> >>
It was announced that work on Spaceport America is in full swing, with the state-of-the-art space launch facility in New Mexico expected to become fully operational in 2011. >>

The German Aerospace Center DLR reported it was midway through design studies of a telecommunications research satellite to include advanced Ka-band broadcast technologies as part of a partnership with a commercial satellite operator. The satellite, named 'Heinrich Hertz' would use the Small Geo satellite platform being developed by OHB Technology of Bremen, Germany, and a payload developed by Tesat-Spacecom of Backnang as well as other equippment from Astrium GmbH of Ottobrunn. >> Furthermore, DLR assigned OHB-System AG overall system management for the definition phase (Phase B) of the future German Orbital Servicing Mission (DEOS). >>

The Italian PRORA-USV (unmanned space vehicle) programme completed its second successful Dropped Transonic Flight Test (DTFT) on 11 April 2010. CIRA, the Italian Aerospace Research Centre, executed DTFT-2 by carrying the drop-test vehicle "Polluce" to an altitude of 24 km by means of helium balloon, where it was dropped to accelerate to a speed of Mach 1.2 under the influence of gravity. During the descent phase, the Polluce performed a series of complex operations, including attitude manoeuvres, constant speed-variable "Alpha sweep" manoeuvre, and two turns with lateral-directional manoeuvres. A final attitude manoeuvre slowed the vehicle to Mach 0.2 for deployment of a conventional parachute and water-recovery. This experiment acquired data pertaining to trans-sonic and low-supersonic flight using a vehicle with a more tapered shape than those of current re-entry systems.

CIRA, along with ESA's Technical Directorate, also developed the Sounding Hypersonic Atmospheric Re-entry Kapsule (SHARK), which was deployed on 26 March 2010 as part of the ESA MAXUS-8 sounding rocket campaign to further programmes of experimentation in weightlessness. SHARK is a fully-autonomous system aimed at assessing the feasibility of dropping a "black-box" from outside Earth's atmosphere as part of a former space object, such as a spent rocket booster. In the March 2010 experiment, SHARK was deployed shortly after the end of the motor-thrust phase of the sounding rocket, continuing to an apogee of approximately 720 km, before executing a re-entry experiment to test new hot structures concepts and materials.

The European and Japanese space agencies were considering upgrades to outfit their robotic space station servicing spacecraft to return cargo to Earth, potentially laying the groundwork for crewed capsules by the 2020s. >> In this area, JAXA unveiled three basic plans it has worked out for the design of its unmanned cargo spacecraft. >> >>

Japan is developing a low-cost surveillance satellite to aid disaster relief and other purposes as it looks to expand its reach into emerging markets. >> Furthermore, Japan will send another satellite on a mission to capture material from an asteroid and bring it back to Earth for study, scientists say. JAXA plans a successor to Hayabusa, which managed to return a capsule to Earth this year, that could launch as early as 2014. >>

China announced that it would launch its first high resolution, stereoscopic mapping satellite for civilian use in the second half of 2011. >> China will launch 14 meteorological satellites in 10 years, according to Yang Jun, director of the National Meteorological Satellite Centre. >> The China Academy of Space Technology put forward a plan at the Third China Space Technology Forum in Beijing to send a probe to Mars in November 2013. >> China said it would launch a space lab to be manned for long stretches within about 10 years following the launches of Tiangong-1 and Shenzhou without crew in 2011 and Shenzhou 9 and 10 with crew in 2012. >> >>

After the successful launch of six navigation satellites, China is setting up the second generation of the Compass (Bei Dou) satellite navigation system to cover the Asia- Pacific region in 2012 and to establish a satellite navigation and positioning system with global coverage by 2020. >>

China announced that it would launch a French-made communications satellite for the Hong Kong- based APT Satellite Holding Limited in the first half of 2012. The satellite, dubbed APTSTAR-7 and made by the Thales Alenia Space, will

be sent into space by China's Long March 3B/E carrier rocket at the Xichang Satellite Launch Centre in southwestern China, according to a statement issued by the China Great Wall Industry Corporation (CGWIC), the contractor of the launch. >>

In developments from South America, Brazil's AEB Space Agency said that it had plans to develop its own carrier rocket for conveying small satellites into orbit by 2014. The agency said the rocket is being built by its main satellite launch vehicle project, VLS. >> Also, Argentina said that it was in the process of developing a satellite launcher which could become operational in three years time, making it the sixth country in the world with that capacity. >>

Israel plans to invest $77.5 million over five years to jump-start a space programme that officials say could become a $10 billion civilian space industry. >>

The European meteorological satellite organization EUMETSAT has selected Arianespace to launch its Metop-C spacecraft. The 4,250-kg. satellite will be placed into polar orbit by a Soyuz launch vehicle operated from the Spaceport in French Guiana. Metop-C will be fitted with a dozen instruments designed to take atmospheric measurements at different altitudes, and to map temperatures and wind fields on the ocean surface. >>

A consortium led by Thales Alenia Space of France will enter into negotiations for a 1.3bn-euro contract to build Europe's next weather satellites. The TAS group was selected after a competitive process run by ESA. The Meteosat Third Generation (MTG) system will comprise six satellites, with the first spacecraft likely to be ready for launch in 2016. >>

In February 2010, Eutelsat switched a planned launch of its W3B telecommunications satellite from a Chinese Long March vehicle to a European Ariane 5 rocket amid concerns about an insufficient supply of the non-U.S. components that would permit the satellite's export to China, Eutelsat and W3B prime contractor. >>

Eutelsat announced that it had selected Thales Alenia Space to build a 40-transponder Ku-band satellite enabling a 50% increase in capacity operated at its 21.5º East location in geostationary orbit. Scheduled for launch in third quarter 2012, the satellite will replace Eutelsat's W6 craft at a core neighbourhood anchored for data, professional video and government services across Europe, North Africa, the Middle East and Central Asia. >>

On 4 February in Turin, Italy, Thales Alenia Space Italy and its main industrial partners presented to ESA the new Intermediate eXperimental Vehicle (IXV) design baseline, a key milestone in the start of the full development phase of the IXV, due to make its first flight three years from now. >> Thales Alenia Space announced it had signed the contract with French Space Agency (CNES) to build the Jason-3 satellite. >>

MacDonald Dettwiler and Associates Ltd. was authorized by the Canadian Space Agency to spend $11.8-million on more design work on the Radarsat Constellation satellite mission. MDA built Radarsats 1 and 2 and has led work on the $40-million spent so far on Constellation. >>

Small satellite pioneer Surrey Satellite Technology Ltd (SSTL) was awarded a grant to commence the design phase of a UK national technology demonstration satellite called TechDemoSat-1. SSTL, UK industry and UK academia will fund the

novel payload technologies and the grant will enable the final payload selection process to be completed. >>

SSTL announced that it would launch the NigeriaSat-2 and NigeriaSat-X satellites on behalf of the National Space Research and Development Agency (NASRDA). NigeriaSat-2 is the most advanced small satellite ever to be launched, defining new standards in Earth observation and avionics. The spacecraft, which is based upon the SSTL-300i platform, will be used primarily for resource management and mapping of the Nigerian territory. >>

The next-generation of Europe´s polar orbiting weather satellites will fly in a two- spacecraft configuration. Eumetsat, the organisation that operates Europe´s weather observatories, took the decision at a council meeting. It will allow additional instruments to be flown, producing even more data for numerical weather prediction models. >>

III. ROBOTIC EARTH ORBITAL ACTIVITIES

III.1 Telecommunications

The European Geostationary Overlay System (EGNOS) ground system is nearly operational, while the space segment has several satellite payloads already in orbit (on INMARSAT and ESA's ARTEMIS satellites). These will be augmented via contracts awarded by the European Commission for two payloads, the first on the SES ASTRA Sirius 5 satellite to be launched in 2011 , and the second on the SES ASTRA 5B satellite to be launched in 2013.

Sirius XM Radio placed its Sirius FM-5 geostationary satellite, launched in June 2009, into operation in autumn 2009, forming a hybrid constellation with the three Sirius 1/2/3 non- geostationary satellites launched in 2000. Measurements showed that availability of its satellite radio service was improved using this constellation configuration. Sirius XM-5 was launched into a geostationary orbit at 85 degrees West Longitude. The satellite was made by Space Systems/Loral and will be used as an in-orbit spare.

During this period, there were also several launches of satellites to improve existing communications services. Intelsat launched three satellites. In November 2009, Intelsat 14 was launched on an Atlas V rocket to replace Intelsat 1R at 45 deg W longitude. The satellite, which was built by Space Systems Loral, provides C- and Ku-band services to customers in Latin America, Europe and Africa. It also carries an Internet router in space for Cisco and a hosted U.S. Defense Dept. payload - the Internet Router In Space (IRIS), designed to test how well ground forces can communicate through the space link using Internet protocol and their existing equipment. >> Intelsat 15, which was built by Orbital Sciences Corporation, was launched on 30 November 2009 on a Zenit launcher and provides upgraded Ku-band video and data services, replacing Intelsat 709 at 85 deg E longitude. Finally, Intelsat 16 was launched on a Proton Breeze M launcher on 11 February 2010. It was also built by Orbital Sciences and provides expanded capability for SKY Mexico's direct-to-home services and will also serve as a back-up for SKY Brazil.

An International Launch Services' Proton booster launched two EchoStar spacecraft for DISH network, one on 20 March 2010, and another on 10 July 2010. EchoStar 14 was placed at 119 deg west longitude, replacing EchoStar 7, to expand HD services to the U.S., including Alaska, Hawaii and Puerto Rice. EchoStar 15 was

placed at 61.5 deg west longitude, to upgrade services to the eastern U.S. previously provided by EchoStar 3 and 12. Both new satellites were built by Space Systems Loral.

Arabsat added two new satellites. Badr 5 was launched on 3 June 2010 to provide redundancy for two older satellites at 26 deg east longitude, as well as upgrade Arabsat's direct to home TV broadcasting, route Internet connections, and enable interactive TV. The spacecraft was built jointly by Astrium and Thales Alenia Space, has a 15 year design life, and carries Ka-band capabilities and steerable antennae. ARABSAT-5A was launched 26 June 2010 to a geosynchronous position at 30.5 deg east longitude. Also built by Astrium and Thales Alenia Space, it carries 26 C- and 24 Ku-band transponders to provide communications services, primarily for Africa and the Middle East.

During this period, Thales Alenia Space announced new contracts to build several spacecraft, to be launched in the next three years: Apstar 7B for APT Satellite Holdings of Hong Kong, W5A and W6A for Eutelsat, Yamal 401 and 402 for Gazprom Space Systems, and 72 satellites for Iridium NEXT. Orbital Sciences announced contracts to build Star One C3 for Star One S.A. and Azerspace/Africasat-1a. Space Systems Loral announced contracts to build Satmex 8 for Satmex of Mexico and DirecTV 14. China Great Wall Industry Corporation announced a contract to build Laos at-1 for the government of Laos. Astrium announced plans to build SES-6 for SES World Skies. Lockheed Martin announced a contract to build Vinaigrette 2 for Vietnam Posts and Telecommunications Group.

Satlynx teamed up with Arabsat to deliver a fully redundant satellite network that will provide the foundations of a new extensive communications platform for the Central Bank of Iraq. >>

SES announced that it was investing in satellite broadband startup O3b, a Google-backed global high-speed Internet access project. O3b intends to employ satellites to bring broadband backbone and backhaul capacity to Internet service providers serving the hundreds of millions of people around the world who are unserved and underserved by terrestrial networks - hence its name, which stands for “the other 3 billion.” >>

SES-1, launched by a Proton Breeze M booster from Baikonur in April 2010, is a hybrid C- and Ku-band spacecraft that replaces AMC-2 and AMC-4 at 101 deg west longitude. Six of the 24 transponders in each band can be cross-strapped to the other band, enabling new communications services. >>

SES ASTRA 3B, launched by Ariane in May will join ASTRA 3A at 23.5ºE and will allow ASTRA 1E and ASTRA 1G to be used for other missions. >>

A Delta IV launched the US Air Force's Wideband Global Satcom-3 spacecraft into geosynchronous orbit. The ultimate six-spacecraft constellation will replace and greatly enhance the wideband service provided by the Defense Satellite Communications System. The sixth spacecraft is being funded by Australia in exchange for participation in the programme. >>

Surrey Satellite Technology Limited delivered eighteen SGR-10 GPS receivers to Sierra Nevada Corporation (SNC) of the USA to provide on-board orbit determination for the ORBCOMM Generation 2 (OG2) satellites. >>

Telesat placed an order for a new direct broadcast satellite Nimiq 6. The satellite will be manufactured by Space Systems/Loral and launched by an International Launch Services Proton rocket in mid-2012. Nimiq 6 will carry 32 high powered Ku-band transponders and will have a service life of 15 years. Bell TV has leased all of the satellite's capacity for the expected lifetime, replacing Nimiq 1 and Nimiq 2 at 91 deg west longitude.

Telesat also announced the procurement of Anik G1, to be built by SS/L using their 1300 platform and to be launched by an International Launch Services Proton rocket in the second half of 2012. Anik G1 is be co-located at 107.3 deg west longitude with Anik F1R. It will carry 16 Extended Ku-band transponders allowing Shaw Direct to increase significantly the video content and programming services it offers throughout Canada. Anik G1 will also have capacity operating at X-band with geographical coverage of the Americas and part of the Pacific Ocean. In addition, Anik G1 will provide expansion and follow-on capacity at Ku-band with 12 transponders for Anik F1 also located at 107.3 deg west longitude and doubling the number of C-band transponders, with 24 providing South- America coverage.

Nilesat 201 and Rascom-QAF 1R were launched by an Ariane 5 rocket. Built by Thales Alenia Space, Nilesat 201 will be placed at 7 deg W longitude and carries 24 Ku-band and 4 Ka-band transponders to provide direct-to-home, radio and broadband Internet services to Africa and the Middle East. Rascom-QAF 1R was launched to replace a satellite launched in 2007 whose operational life was reduced by a helium leak. It will be placed at 2.85 deg E longitude to provide television, telephone and Internet services to Africa. >>

In November, China launched the second Shen Tong-1 military communications satellite via a CZ-3A Chang Zheng-3A (Y19) launch vehicle, providing secured voice/data communications services for PLA ground users in Ku-band. Receiving the designation ZX-20A ZhongZhing-20A, the satellite was launched from the Xi Chang Satellite Launch Centre, in Sichuan Province. >> China also announced that it would launch a French-made communications satellite for the Hong Kong- based APT Satellite Holding Limited in the first half of 2012. >>

Overcoming an unspecified glitch, the SkyTerra 1 wireless communications satellite deployed a broad L-band antenna to relay mobile phone calls across North America. >>

III.2 Remote Sensing

South Africa's Sumbandila microsatellite, launched earlier that autumn, was commissioned in November 2009. It is in a low Earth orbit at an altitude of 500 km. Its orbit is circular and Sun-synchronous, which means that it overflies South Africa at the same time each morning, around 0900. >>

NASA mission managers were assessing options for future operations of the QuikScat satellite following the age-related failure of a mechanism that spins the scatterometer antenna. >>

The nearly 26-year-old Landsat 5 remote sensing satellite has cheated death once again, but Earth scientists will have to wait three more years for a fresh spacecraft to meet all their research needs. While one radio transmitter failed in December, another that had been declared failed almost 23 years ago unexpectedly revived. The USGS stated that science operations could begin again in January, even

though the spacecraft is suffering from other issues as well. However, the spacecraft is providing scientists with better data than its younger sibling because Landsat 7's imaging instrument no longer works. A new satellite, Landsat 8, is scheduled to launch at the end of 2012. So far there is no serious threat to this launch other than a new thermal instrument that was recently added to the programme.

ESA's GOCE gravity mission achieved another major milestone in November 2009 as control of the satellite was transferred to the operations teams, marking the end of its commissioning and calibration phase. >>

In April, the Geostationary Operational Environmental Satellite known as GOES-13 became the official GOES-EAST satellite. GOES-13 was moved from on-orbit storage and into active duty. >>

In December 2009, Boeing announced that GOES-14 (formerly GOES-O), the second satellite in a series of Geostationary Operational Environmental Satellites built by Boeing for NASA and the National Oceanic and Atmospheric Administration (NOAA), had completed on-orbit testing and been accepted into service. NOAA will use GOES-14 to accurately predict storms and monitor weather conditions across approximately 60 percent of the planet, including the United States. >>

In March 2010, Boeing received the first on-orbit signals from the third Geostationary Operational Environmental Satellite (GOES) built by Boeing for NASA and the National Oceanic and Atmospheric Administration (NOAA). The satellite, GOES-15 (formerly GOES-P), was thus healthy and ready to begin thruster firings to move to its on-orbit test location. GOES-15 is a Boeing 601 satellite that will provide enhanced Earth-observation and weather-monitoring services. >>

Astronomers at the Goddard Space Flight Centre produced the most detailed pictures of Earth, called 'Blue Marble', using the Terra satellite more than 700km above the Earth's surface. >>

During April 2010, the Meteosat-9 satellite, amongst many others, observed the ash cloud from the volcanic eruption under Eyjafjallajokull Glacier in Iceland. >>

ESA Envisat images captured oil that was spilling into the Gulf of Mexico after a drilling rig exploded and sank off the coasts of Louisiana and Mississippi, USA, on 22 April. >> In a further environmental disaster, northwest Pakistan in July 2010 was seriously affected by floods and mudslides caused by heavy rain. Amongst other remote sensing satellites, JAXA's Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) onboard the Advanced Land Observing Satellite (ALOS, "Daichi") provided data for relief efforts. >>

Taking advantage of NASA's 'Operation Ice Bridge' campaign, measurements of Arctic sea ice were made from an aircraft flying directly under CryoSat-2's orbital path. These measurements offered an early opportunity to check the quality of the newly launched CryoSat-2 satellite data over sea ice. >>

ESA's SMOS satellite completed its six-month commissioning and formally began operational life. This milestone meant that the mission was now set to provide much-needed global images of soil moisture and ocean salinity to improve our understanding of the water cycle. >>

NASA Deputy Administrator Lori Garver and DLR Executive Board Chair Johann-Dietrich Woerner signed an agreement during a bilateral meeting at the Berlin Air Show, ILA 2010, to extend the Gravity Recovery and Climate Experiment

(GRACE) mission through the end of its on-orbit life, expected in 2015. >>

On 27 August 2010, Metop-A, Europe's first polar-orbiting satellite dedicated to operational meteorology, completed its 20,000th orbit of the Earth. >>

In October 2010, the TanDEM-X and TerraSAR-X satellite pair acquired their first image of Earth´s surface, synchronised to the microsecond, while flying over Mount Etna in Italy. Scientists at DLR used the data to create a three-dimensional digital elevation model with an unprecedented elevation accuracy down to two metres. The image, taken while the satellites were flying just 350 metres apart, was the first in the world to be made by satellites flying in such a close formation. >>

On 27 October 2010, Egypt reported its EgyptSat 1 as lost in space. Since its launch, the satellite had transmitted data, images and maps worth some 100 million Egyptian pounds. >>

ESA's Earth-observing satellite Envisat moved to a lower orbit in order to conserve fuel and extend its life by three years. >> Then, in November 2010, ERS-2 and Envisat were paired up again for the last time. Data from this final duet are generating 3D models of glaciers and low-lying coastal areas. >>

Eutelsat announced that it would not attempt to deorbit its failed W3B satellite >>

III.3 Global Navigation Systems

During this period, there were a number of developments in the area of satellite-based navigation and timing systems. Glonass satellites, with expected lives of 7 years, were placed in orbit by two launches from Baikonur on 14 December 2009, 1 March and 2 September 2010. >> >> When complete, the constellation will include a full 24 satellites in 8 orbital planes, each transmitting coded signals in two frequency bands. >>

In December 2010, the three satellites meant to complete the system were destroyed upon touchdown in the Pacific Ocean in an aborted launch following a blastoff from Baikonur space centre in Kazakhstan. The crash cost up to $500 million, and Russian President Dmitry Medvedev ordered a full audit of the entire $2 billion programme and an investigation into the failure.

Significant progress was made in Europe, towards the implementation of the operational Galileo system. The two test satellites, Giove A and Giove B, already in orbit, will be followed by the launch of four pre-operational satellites in early 2011. These satellites will be built by EADS Astrium and Thales Alenia Space. The site of a ground station for Galileo, inside the Guiana Space Centre (CSG), near Kourou in French Guiana, was inaugurated. >>

On behalf of the European Commission, ESA signed a contract for the manufacture of 14 Galileo satellites, the first to be delivered in July 2012. The prime contractor OHB (Bremen, Germany) will lead system activities and build the satellite platforms, while the payload will be built by Surrey Technology Limited. The launches will be provided by Arianespace using Soyuz launchers with an upgraded Fregat upper stage from the European spaceport in French Guiana. Later in the year, the United States and the European Union announced a bilateral cooperation between the U.S. Global Positioning System and Galileo. >>

In January 2010, Jean-Yves Le Gall, CEO of Arianespace, and Rene Oosterlinck, Director of the Galileo Programme and Navigation-related Activities at ESA, signed the launch contract for the first ten FOC (Full Operational Capability) satellites. >>

China launched five Beidou (or Compass) satellites, on 16 January 2010, 2 June, 1 August, 1 November and 16 December 2010, as the beginnings of its own operational space-based navigation and timing system. These, along with one launched previously, were place in geosynchronous orbits. There is also one satellite in an orbit at an altitude of about 13000 miles. China reported that it would eventually have 35 satellites to provide global coverage, with an accuracy of 10 metres for civilian users. >> >> >>

In December 2009, Twitter, the micro-blogging service announced that it had purchased Mixer Labs, a California-based startup that builds location-tracking tools via satellite. >>

India reported it was on target to launch a constellation of seven navigation satellites in 2011 that will help give accurate directions for civil aero planes and aircraft and be a homegrown version of GPS system. >>

The United States launched the first of a new class of GPS satellite, the IIF series. This launch sustains the GPS constellation at over 30 operational satellites and supports the expanded-slot constellation design that was recently adopted for improved availability robustness. In addition to providing all the legacy GPS civil and military signals such as L1 Coarse/Acquisition, L1 P(Y), L2(P(Y), the GPS IIF also provides the GPS modernized signals (L1 and L2 M code, L2C) deployed on the last eight IIR-M satellites. The Block IIF also introduces the second modernized civil signal, L5, which was specifically designed for the aviation community to provide safety of life navigation. >> >> >> >>

In September 2010, JAXA launched its GPS technology MICHIBIKI satellite. Michibiki, which means "guiding" or "showing the way" in Japanese, then underwent three months of technology tests. >>

At the end of 2010, India and Russia signed an agreement to share high-precision signals from GLONASS for defence as well as civilian use. >>

III.4 Nanosatellites

Japan launched the world's first tweeting satellite, the CubeSat XI-V. Developed by the Nakasuka Lab at the University of Tokyo, the pico satellite is currently orbiting Earth and keeps posting various data to its followers on Twitter. >>

The UK Space Agency has announced a one year pilot programme to design and launch a CubeSat that will allow the UK to test new space technologies and carry out new space research cheaply and quickly. >>

The Organism/Organic Exposure to Orbital Stresses, or O/OREOS, nanosatellite managed by NASA's Ames Research Center, launched on 19 November from Alaska Aerospace Corporation's Kodiak Launch Complex on Kodiak Island, Alaska. Also aboard were the Air Force Research Laboratory's Space Test ProgramSat-2 (STPSat-2), NASA's Fast, Affordable, Science and Technology Satellite, or FASTSAT, payload bus which carried the NanoSail-Demonstration, NASA's first solar sail, as well as other satellites developed by universities and

industry. >>

Other nanosatellite launches are mentioned in the 'Launches' section of this report.

III.5 Space Debris

In November 2009, the U.S. military announced that it was tracking 800 manoeuvrable satellites on a daily basis for possible collisions, and it expected to add 500 more non-manoeuvring satellites by year's end. >>

A study called "Catcher's Mitt" will look for technically and economically feasible ways to remove space debris. The Pentagon's research and development division is studying concepts to remove dangerous space debris from orbit, an endeavour long dismissed as too costly but potentially feasible with technology advancements. The DARPA programme was the focus of a conference sponsored by NASA and DARPA in Washington, DC. Presenters discussed exotic concepts including lasers, tethers, solar sails and methods of capturing debris to move objects out of often-used orbits. Some of these techniques, if practical, promise to be less costly than older concepts. DARPA is collecting information for the study from a conference held in December, independent utility analyses by the military and NASA, and a formal request for information released to industry in September 2009.

On 2 December 2009, a tiny piece of a defunct Russian satellite zipped by the International Space Station but was far enough away that the crew did not have to move into a spacecraft to wait out the close shave. >>

The already untidy mass of orbital debris that litters low Earth orbit nearly got nastier in January, with the near collision between a spent Chinese rocket and the ESA's Envisat Earth satellite. While significant progress has been made by the U.S. and the international aerospace communities in recognizing the hazards of orbital debris, and measures are being made to reduce new debris, it will get worse without additional corrective measures. Even with an immediate halt of launch activities, space-faring nations will be dealing reported with an unstable low-Earth orbit environment in some altitude and inclination bands, according to Nicholas Johnson, chief scientist for orbital debris at the NASA Johnson Space Center.

In July 2010, it was reported that debris from a satellite destroyed in 2007 by a Chinese missile was in the vicinity of the International Space Station and astronauts were ready to take cover if required. >> According to NASA, the debris had been monitored, its distance from the station was substantial, and no debris avoidance manoeuvre was required.

Then on 27 October, Russia's space command ordered the ISS to change its orbit slightly to avoid collision with a piece of floating debris that could have caused serious damage, officials said. Officials ordered that rockets be fired for 180 seconds to shift the orbit by 700 metres. The new orbit would allow the unidentified object to pass 1.5 kilometres away from the station. >>

NASA expects to put into action the new US Orbital Debris Policy, but it may be too early to tell exactly how the new policy will be transformed into programmes and budgets. The ESA's 8000-kilogram Envisat Earth observation satellite is likely to pose even greater threats when its useful life in space ends in 2013. The question will be whether to de-orbit it over the Pacific Ocean, or place it in an unused orbit.

During the meeting of the COPUOS Legal Subcommittee, held from 22 March to 1 April 2010, national mechanisms on space debris mitigation was one of the agenda items. Several delegations presented information on national measures that have been, or are being adopted to mitigate this problem. Some European delegations emphasized the need to adhere to the Code of Conduct that was drafted in January 2009. The Japanese delegation proposed that satellites that are in lower orbits be de-orbited, the same as satellites in geostationary orbit are placed in an orbit where they are unlikely to collide with other non-operational satellites. For more information see documents and report of the 49th session of the Legal Subcommittee at www.unoosa.org.

The US Strategic Command (StratCom) will oversee a military mission that tracks satellites and debris and tries to prevent space collisions. StratCom officials have long planned for this move, which allegedly has nothing to do with the last year's satellite collision or any problems in the pilot programme, according to StratCom. Rather, this adds a layer of oversight to satellite monitoring. If a collision seems imminent, or if an object can be moved or destroyed to prevent a collision, StratCom leaders will pass the information along to the rest of the US military, foreign governments and companies that own and operate satellites.

Future satellites could deploy solar sails to help take down pieces of space junk floating around Earth and a tiny new spacecraft hopes to make it possible. The CubeSail satellite developed by the University of Surrey (U.K.) will test this idea in the near future. If successful, the one-year mission could help lead to bigger, better solar sail spacecraft capable of trawling the space around Earth for dangerous space junk. The mission could also lead to future CubeSail designs that can attach to existing pieces of space junk and take them down, so that space-faring nations can finally begin cleaning up some of the orbital mess.

The CubeSail 30-kilogram nanosatellite, intended to clear more than 5,500 tons of debris in low-Earth orbit, has been developed by UK scientists, and funded by Astrium. It is fitted with a solar sail, designed to attach to other satellites or launch vehicle upper stages and independently deploy itself to passively de-orbit equipment that has reached the end of its mission. Following successful in orbit demonstration, the proposed de-orbit system will be offered as a standard de-orbit system for low-Earth orbit missions for satellites with a mass of less than 500 kilograms at a very low cost, according to the lead project researcher at the Surrey Space Centre. CubeSail is scheduled for launch with new satellites in 2011 and is expected to be available for shifting existing debris in 2013. The deployable sail will be used in a demonstration mission to be launched in late 2011.

Another alternative to decreasing space debris: at the Astrodynamics Specialist conference held in Toronto, Canada in early August, the Global Aerospace Corporation proposed that balloons could be used to drag satellites into an orbit where they would burn up in the atmosphere and not add to space debris. A balloon 37 metres across would take just one year to drag a 1200-kilogram satellite from an initial orbit of 830 kilometres to an altitude low enough to burn up in the atmosphere, the Global Aerospace team calculates. Without the balloon, this would take centuries. The balloon would be stowed in the satellite and inflated when the satellite's mission was over. Global Aerospace admits that the balloon concept would only work below 1500 km or so but notes that this includes a particularly congested region between 750 and 900 km.

Norman Augustine, head of the Augustine Commission, stated that a treaty on space debris is a good idea and that the US has a window in which to put one together. Augustine made the statement at a Center for a New American Security panel that discussed the global commons.

In April, Intelsat's Galaxy 15 stopped communications with the ground operators and the satellite began drifting in an uncontrolled fashion posing a threat to neighbouring GEO satellites. Constant coordination among satellite operators was needed to avoid on-orbit collision. >> >> >> Later in 2010, Galaxy 15 operation was recovered.

A US Air Force satellite that will provide the first continuous tracking of thousands of pieces of space debris and hundreds of satellites launched in July. The new Space-Based Space Surveillance (SBSS) satellite will give scientists a full-time view of the increasingly congested traffic in Earth's orbit. >>

IV. HUMAN SPACEFLIGHT

IV.1 International Space Station Deployment and Operations

STS-129 delivered key infrastructure to the International Space Station (ISS), using the orbiter Atlantis, including two important external hardware storage platforms. STS-130 was a night launch of the orbiter Endeavour, delivering the Tranquillity node and observation cupola to the ISS. STS-131, a pre-dawn launch of the orbiter Discovery, delivered supplies and equipment to the ISS using the Italian-built 'Leonardo' multi-purpose logistics module. STS-132 marked the final scheduled mission for the orbiter Atlantis, delivering a Russian-built module and important spare-parts to the ISS.

In an expedition which overlapped the reporting period, Expedition 21 was the 21st long-crew-flight of the ISS. The expedition began on 30 September 2009. Frank de Winne is the first ESA astronaut to command a space mission. The handover between Expedition 20 and Expedition 21 required three Soyuz vehicles being docked to the station at the same time, the first time this has occurred.

Soyuz TMA-16 brought the final members of Expedition 21 to the ISS along with space tourist Guy Laliberté. Laliberté returned on Soyuz TMA-14 with two members of Expedition 20.

Nicole P. Stott was the last expedition crew member to fly on the Space Shuttle. She returned to Earth aboard STS-129 in November 2009.

On 1 November 2009, the Japanese H-II Transfer Vehicle (HTV-1) vehicle was deorbited after spending 52 days in space, 43 days docked to ISS. This marked the successful completion of the first flight of HTV, which brought approximately 4.5 tonnes of cargo to ISS and removed 1.6 tonnes of discarded equipment and trash from ISS. HTV-1 had been launched from Tanegashima on 10 September 2009. >>

Expedition 22 began in November 2009 when the Expedition 21 crew departed.

On 10 November 2009, the Russian Poisk module, also known as Mini-Research Module-2 (MRM-2) was launched from the Baikonur Cosmodrome, and docked to the Zvezda module's zenith port on the ISS on 12 November. Poisk will serve as an additional docking port for Soyuz and Progress vehicles as well as an

airlock for ExtraVehicular Activities (EVA). On 14 January 2010, Expedition 22 cosmonauts Maxim Surayev and Oleg Kotov conducted a 5-hour 44-minute EVA to complete outfitting Poisk as a docking port. It was first used in that capacity on 21 January when the Soyuz TMA16 spacecraft was relocated there. >> >>

Space Shuttle Atlantis launched from the Kennedy Space Center on 16 November 2009, to begin the ULF3 mission to the ISS. Atlantis docked with the ISS on 18 November, beginning 8 days of joint operations. Shuttle crewmembers Mike Foreman, Robert Satcher and Randy Bresnik conducted three EVAs totalling 18 hours and 27 minutes to perform maintenance on the station and to install experiments on the station's exterior. During the mission, the first two EXPRESS Logistics Carriers (ELC-1 and -2), designed to hold science experiments as well as station spares, were attached to the ISS truss.

The first spacewalk on 22 November was delayed more than an hour by false decompression alarms that rang through the orbiting complex, for the second night in a row. The high-pitched beeps - emanating from Poisk - triggered a series of smoke alarms. Atlantis hauled up nearly 15 tons of equipment to keep the outpost running long after the shuttles' retirement next year. >> >> Atlantis landed at Kennedy Space Center on 27 November 2009. >> >>

On 1 December 2009, the Soyuz TMA-15 reentry module landed safely in Kazakhstan bringing ESA astronaut Frank De Winne, Russian cosmonaut Roman Romanenko and Canadian Space Agency astronaut Robert Thirsk back to Earth. The ISS, which was crowded the previous week with 12 astronauts onboard, reduced to a crew of two. >> For a period of 3 weeks, there were only 2 crew members; it was the first time that had happened since STS-114 had delivered a third person to restore the ISS crew to 3. Commander Jeff Williams and flight engineer Maksim Surayev were joined by the rest of their crew on 22 December 2009, making the Expedition 22 a crew of five.

The international crew of Oleg Kotov, Timothy Creamer and Soichi Noguchi launched from Baikonur on 20 December aboard the Soyuz TMA17 spacecraft. They docked with ISS two days later and joined Jeff Williams and Maxim Surayev as the ISS Expedition 22 crew. During their stay, they were visited by the STS 130, 131 and 132 crews and resupplied by two Progress vehicles. >>

On 15 January 2010, it was reported that ISS's $250 million water recycling system was facing a problem as the astronauts' urine clogged the system that turns it into drinkable clean water. >>

On 21 January, the Soyuz TMA-16 spacecraft was moved from the aft port of the Zvezda service module to the Poisk module. >>

On 22 January, astronauts aboard the ISS received a special software upgrade - personal access to the Internet and the World Wide Web. >>

On 27 January, Roscosmos raised the orbit of the ISS by about 5 kilometres ahead of the launch of its Progress M-04M space freighter in February. >> The Progress M-04M (36P) left the Baikonur Cosmodrome on 3 February 2010, and docked with the ISS two days later, bringing 2,686 kg of cargo, fuel and water. On 7 May 2010, 36P undocked from ISS after being loaded with trash and discarded equipment, and stayed in an autonomous orbit until 1 July, when it was safely commanded to a destructive reentry over the Pacific Ocean. >>

On 8 February, Space Shuttle mission STS 130 began with the launch of Endeavour from KSC. The 20A mission's main purpose was to deliver the Tranquillity Node 3 and the Cupola to the ISS. Endeavour docked with ISS on 10 February, and during the next 10 days of joint operations, Shuttle crewmembers Bob Behnken and Nick Patrick completed three EVAs totalling 18 hours and 14 minutes. During those excursions, they completed power and thermal connections to the newly arrived modules. The Shuttle mission ended on 22 February after a 14-day flight. >> >> >> >> >>

On 8 March 2010, Boeing officially turned over the U.S. on-orbit segment of the ISS to NASA with the signing of government form DD-250 at the conclusion of an Acceptance Review Board meeting. >>

ISS Expedition 22 ended when Soyuz TMA-16 undocked on 17 March 2010, and was immediately followed by the start of Expedition 23.

Three Russian cosmonauts, two American and one Japanese astronauts made up the Expedition 23 crew. It was the first ISS crew to include three Russians at once. The Expedition 23 crew continued outfitting the newest modules of the nearly completed space station. The crew welcomed the shuttle flight STS 131 in April 2010. The Expedition 23 crew also saw the arrival of the Rasvet Russian docking module (MRM1) aboard Space Shuttle Atlantis on STS 132, which launched on 14 May 2010.

Expedition 23 began with the Soyuz TMA-16 undocking on 18 March 2010. Crewmembers Williams and Surayev returned to Earth on 18 March aboard TMA-16, after having spent 169 days in space (They were launched on 30 September 2009). >> >> Shortly thereafter cosmonauts Aleksandr Skvortsov and Mikhail Korniyenko and astronaut Tracy Caldwell-Dyson arrived at the Space Station on Soyuz TMA-18 on 4 April 2010. The Soyuz spacecraft lifted off from the Baikonur Cosmodrome on 2 April 2010. >> >>

Space Shuttle Discovery began the STS 131 mission with a launch from KSC on 5 April. ISS Mission 19A carried the Leonardo MPLM, which included four new research racks in its complement: the European-built MARES (Muscle Atrophy Research Exercise System), installed in the Columbus module; the Window Observation Research Facility (WORF); the third Minus-eighty degree Laboratory Freezer for ISS (MELFI-3); and the seventh Expedite the Processing of Research for Space Station (EXPRESS-7) rack. Discovery astronauts Rick Mastracchio and Clay Anderson conducted three EVAs during the 10 days of docked operations. During the 20 hours and 17 minutes the crew spent outside, they removed a used ammonia tank from ISS and installed a new one delivered by Discovery, and performed other maintenance on the station's exterior. The Shuttle landed on 20 April after 15 days in space. >> >>

A resupply mission to ISS got underway on 28 April with the launch of Progress M-05M (37P) from Baikonur. The spacecraft docked with ISS on 1 May, carrying 1,497 kg of cargo, fuel and water. >> >>

The STS 132 mission got underway with the launch of Space Shuttle Atlantis on 14 May 2010. The main cargo item on the ULF4 flight was the Russian Rassvet module, also known as the Mini-Research Module-1 (MRM-1). This module is used for science research and cargo storage. It also provides an additional docking port for Progress and Soyuz vehicles. Atlantis also carried new batteries for the ISS. After docking with the ISS on 16 May, Atlantis astronauts Garrett Reisman, Steve Bowen

and Mike Good performed three EVAs totalling 21 hours and 20 minutes to assist in the transfer and berthing of Rassvet, replace six old batteries with new ones and conduct other station maintenance activities. Atlantis landed back on Earth on 26 May after a 12-day flight. >> >> >> >>

Finishing the expedition, on 1 June 2010, Expedition 23 Commander Oleg Kotov and Flight Engineers T.J. Creamer and Soichi Noguchi landed their Soyuz-17 spacecraft in Kazakhstan, wrapping up a five-and-a-half-month stay. >>

Expedition 24, starting on 1 June, was the twenty-fourth long-duration mission to the ISS. Expedition 24 initially had 2 planned spacewalks, one Russian and one American Extra-vehicular Activity (EVA). The U.S. EVA was re-planned and a second U.S. EVA was added.

On 5 June, the ISS was moved to a higher orbit prior to the docking of Russia's Soyuz TMA-19 spacecraft. The Station was moved 7.5 kilometre higher by the thrusters on the Russian Zvezda module. The orbit would twice more readjusted on 7 June to receive the Soyuz spacecraft, which was scheduled to blast off from Baikonur on 16 June. >>

Soyuz TMA19 blasted off from Baikonur on 16 June, carrying Fyodor Yurchikhin, Shannon Walker and Doug Wheelock. They docked with ISS two days later and became part of the Expedition 24 crew, joining Skvortsov, Korniyenko and Caldwell Dyson. The latter were to return to Earth aboard their Soyuz TMA17 in September 2010. >>

On 28 June, the crew moved a docked Russian spacecraft to a different research module. The Soyuz TMA-19 undocked from the Zvezda module and docked with the Rassvet research module in a 28-minute manoeuvre. >>

On 30 June, Progress M-06M (38P) blasted off from Baikonur on 30 June, with docking expected on 2 July. However, during the final rendezvous, the spacecraft aborted the docking due to an unauthorized command in the backup control loop, and Progress missed the ISS. A second docking attempt on 4 July was successful, and 38P's cargo was safely delivered to ISS. The craft is undocked from ISS on 31 August with a destructive reentry over the Pacific Ocean on 6 September. >>

Expedition 24 cosmonauts Fyodor Yurchikhin and Mikhail Korniyenko conducted a Russian segment EVA on 17 July. The main purpose of the 6-hour 42-minute EVA was to prepare the recently delivered Rassvet module for future automated dockings by Progress and Soyuz vehicles.

On 31 July 2010, the Expedition 24 crew was awoken by an alarm on the station. The alarm was caused by a cooling pump that had failed and caused a Remote Power Controller to trip and cut power to some of the ISS. Astronauts Tracy Caldwell-Dyson and Doug Wheelock performed some steps to assist ground controllers in re-powering some of the station components such as two main power buses and one Control Moment Gyroscope. After the steps had been completed Capcomm James Kelly told the crew they could go back to bed as all the work required by the crew on the ISS was complete. A short time later, another alarm sounded and awoke the crew, when the ground attempted to restart the pump module. >> >>

A failure in the docking ring on the Mini-Research Module 2 (MRM2) Poisk, caused a delay in the planned landing of the Soyuz TMA-18 spacecraft. Soyuz TMA-

18 was originally planned to undock and land on 24 September 2010, but instead undocked less than 24 hours later on 25 September 2010. The failure is believed to be due to a faulty indication from a micro-switch on the hatch between the Soyuz and MRM2. A drive gear, which is related to the docking mechanism was also found to have two broken teeth, and is believed to be related to the problem as well.

Three spacewalks, one in Orlan space suits and two in U.S. Extravehicular Mobility Units (EMUs) were originally planned for Expedition 24. However, additional spacewalking tasks were added to remove and replace the failed ammonia pump module.

EVA1 took place on 27 July. Astronauts Korniyrnko and Yurchikhin ran three data cables between Rassvet and the Zvezda module, routing them along the Zarya module. The pair then installed cables between Rassvet and Zarya. They next moved onto relocate a camera already on Rassvet's exterior, from the zenith or space-facing side to the nadir or Earth-facing side. As their final task, Yurchikhin and Kornienko replaced a camera used for docking European Automated Transfer Vehicles to the station.

EVA2 of Expedition 24 took place on 7 August. Wheelock and Caldwell-Dyson disconnected electrical and fluid connectors. The spacewalkers did not complete all of the planned tasks due to a quick disconnect that got stuck and would not release. The pair had to complete a "bake-out" in order to ensure there was no ammonia on their suits before re-entering the Space Station. >>

In EVA3 on 11 August, Wheelock successfully closed the quick disconnect valve for the fourth and final fluid connector for the failed pump, and detached the final fluid line from the failed pump. Caldwell-Dyson demated five electrical and data cables while Wheelock broke torque and removed four bolts from the old pump. The pump was extracted from the truss through the use of a grapple bar and installed on a payload bracket on the Mobile Base System on the station's truss. Caldwell-Dyson then prepared the spare pump for future installation, disconnecting three of five electrical cables and reconfiguring insulation. >>

Finally, during EVA4 on 16 August, Wheelock removed the spare pump module from an external stowage platform. The pump module was successfully installed on the S1 Truss after Wheelock attached four bolts and Caldwell Dyson mated five electrical connectors. >>

On 13 September, Progress M-07M successfully docked with the International Space Station. The vehicle attached to Zvezda and delivered about 2.5 t of cargo to the station, including propellant, food and water, personal crew parcels, scientific hardware for many Russian biotechnological experiments. >>

Expedition 25 began with the Soyuz TMA-18 undocking on 25 September 2010. Three new crewmembers (Scott Kelly, Alexander Kaleri and Oleg Skripochka) arrived aboard the ISS October 2010 on Soyuz TMA-01M to join Douglas Wheelock, Fyodor Yurchikhin, and Shannon Walker and formed the full six member crew of Expedition 25. NASA astronaut Doug Wheelock accepted command of Expedition 25 on 22 September 2010, taking over from Russia's Alexander Skvortsov. The departure of Wheelock, Walker and Yurchikhin on 25 November 2010 marked the official end of Expedition 25. >>

The 10th anniversary of human life, work and research on the ISS fell during Expedition 25. On 2 November 2000, Expedition 1 Commander William Shepherd

and Flight Engineers Sergei Krikalev and Yuri Gidzenko became the first residents of the space station. The International Space Station set a record and became the longest habitable space outpost ever built. The new record was set by the ISS on 22 October. The previous record was set by Russian orbital station Mir. The crews were permanently working in Mir from 8 September 1989 until 28 August 1999, within 3641 days, or about 10 years. However, this figure includes also the time spent for many relocations of Soyuz-TM vehicles. >>

On 28 October, NASA announced the successful activation of new hardware that will support water production services aboard the International Space Station. >>

During Expedition 25 Progress M-08M spacecraft visited the ISS. Progress M-08M docked with the space station on 30 October 2010 bringing 2.5 tons of cargo supplies. Space shuttle Discovery on STS-133 mission was scheduled to arrive at the ISS on 3 November 2010 but was re-scheduled for launch on 3 February 2011.

The Progress M-05M autonomous mission was completed on 15 November. >>

Germany's first experiment in space robotics came to an end. On the evening of 15 November 2010, Russian cosmonauts Fyodor Yurichikhin and Oleg Skripochka performed a space walk during which they removed the Rokviss robotic arm developed by DLR from the experimental platform on the Russian service module Svezda and took it inside the ISS. >>

On 25 November, in accordance with the International Space Station mission ballistics support programme, an ISS reboost took place. The manoeuvre was assisted by 8 attitude thrusters of the Progress M-07M cargo vehicle attached to the Zvezda instrumentation compartment. As a result of the manoeuvre which lasted 351.6 sec, the station obtained the burn of 1 mps. The altitude of the station became 1.7 km higher, and achieved 351.6 km. The operation was aimed at providing favourable conditions for further docking to the station of Russian Soyuz TMA-20 to be launched on December 15. >>

Expedition 25 ended on November 26th when a Russian cosmonaut and two NASA astronauts came safely back to Earth in a Soyuz capsule. >>

Expedition 26 is the current mission to the International Space Station. The mission got underway with one US astronaut and two Russian cosmonauts on 26 November 2010 with half of the crew of Expedition 25 coming back to Earth on board Soyuz TMA-19. The rest of Expedition 26 crew - one US astronaut, one Russian cosmonaut and one ESA astronaut joined the onboard trio when their Soyuz TMA-20 spacecraft docked with the station. Expedition 25 commander Douglas Wheelock handed over the station to Expedition 26 commander Scott Kelly on 24 November 2010.

Aboard Soyuz TMA-20, Soyuz commander Dmitry Kondratiev, NASA's Catherine Coleman and ESA's Paolo Nespoli joined their colleagues Alexander Kaleri, Oleg Skripochka and Scott Kelly on the ISS. >>

On 22 December, Russia´s Mission Control adjusted the orbit of the International Space Station (ISS) by raising it 4.2 kilometres. >>

Other ISS developments

In an announcement, the U.S. ambassador to Moscow confirmed that the

United States will continue to use Russian Soyuz spacecraft after space shuttles retire from service. >>

On 27 November 2009, a top Russian space official said that there was no more room for space tourists hoping to fly to the International Space Station. Sergei Krikalyov, the chief of the Cosmonaut Training Centre, said since the space station's crew doubled to six people, there was no longer room for tourists who pay tens of millions of dollars for a trip on a Russian spacecraft from Earth. >> However, on 26 September 2010, Roscosmos said it planned to send Soyuz spacecraft with two space tourists to the International Space station (ISS) after 2013, according to the head of Roscosmos's manned flights department, Alexei Krasnov. >>

On 14 January 2010, Director General Jean-Jacques Dordain said that ESA was hoping to use the International Space Station as a platform to conduct research into global climate change. >>

On 30 March, Space Exploration Technologies (SpaceX) announced the successful activation of its new Dragon spacecraft communication hardware aboard the ISS. >>

On 3 July, European and Canadian space officials were in talks with Russia to purchase dedicated Soyuz capsules to ferry their astronauts to the International Space Station. The discussions focus on continuing crew transportation services after 2015, and possibly expanding European and Canadian astronaut access to the orbiting lab before then. >>

On 30 September, the United States Congress approved a blueprint for NASA's future that extended the life of the space shuttle programme while backing President Barack Obama's intent to use commercial carriers to lift humans into near-Earth space. >>

On 27 October, the ISS partners set docking interface standards. The standards give engineers the information they need to build docking systems for the space station and other missions. >>

By 12 December 2010, ESA's experimental ship detector on the International Space Station had pinpointed more than 60 000 ocean-going vessels. It has been able to follow the routes of individual ships for months at a time. >>

IV.2 Other Human Flight Operations

On 9 November 2009, Russia's space corporation Energia said it was doubling production of manned spacecraft. Energia's president Vitaly Lopota said production of space freighters would increase by 50%. >>

Space Exploration Technologies (SpaceX) reported in late 2009 that it had recently conducted its first Dragon spacecraft operations training for a group of NASA astronauts and personnel at its corporate headquarters in Hawthorne, California. >>

Chinese officials announced that they planned to launch their Tiangong-1 space station within a year. Tiangong-1 will be an 8 tonne orbital module. Crews of the Shenzhou 8, Shenzhou 9 and Shenzhou 10 spacecraft will conduct experiments aboard it during a 2-year period. >>

The Indian Space Agency ISRO said that is was whittling down a list of pilots to find four "vyomanauts" to fly on its first manned space mission in 2015. >>

NASA selected four astronauts for a mission the agency never wants to launch: a rescue operation in case something goes wrong during the last flights of the space shuttle era. >>

Yang Liwei, the Deputy Director of the Chinese Manned Space Flight Project, as well as the nation's first person to travel into space, said a second crew of astronauts are now undergoing training. He adds that the country will send its first female astronauts into space by 2012. >>

IV.3 Medical Issues

On 3 June 2010, six 'astronauts' commenced a virtual trip to Mars. Sealed into a cramped container at the Moscow Institute of Biomedical Problems for 520 days, they will experience the rigours and isolation of long-duration spaceflight. This marks the start of the main part of the Mars 500 experiment, and on completion will constitute the longest ever space simulation experiment. >> >> >>

According to a report in "The Journal of Leukocyte Biology", it was reported that long-term space travel appears to weaken astronaut's immune systems; and it increases the virulence and growth of microbes. This combination of factors makes it vital for scientists to find tools that can help space travellers cope with these microscopic hitchhikers before they lead to disease, especially because astronauts won't have the ability to return home to a hospital. >> >>

It was announced that NASA's Human Research Programme and the National Space Biomedical Research Institute in Houston will fund 11 proposals to help investigate questions about astronaut health and performance on future space exploration missions. >>

Pratt & Whitney Rocketdyne received a $1.8 million contract from United Launch Alliance to help design and develop an Emergency Detection System for human spaceflights to be proposed for Atlas V and Delta. >>

Long-term space flight so weakens fitness that an astronaut heading to the Red Planet may lose up to half the power in key muscles in the course of the mission, scientists have found. >>

Researchers at MIT unveiled a new, skin-tight spacesuit that mimics the effects of Earth's gravity and could help prevent the loss of bone mass in astronauts. >>

V. SPACE STUDIES AND EXPLORATION

V.1. Astronomy and Astrophysics

V.1.1 Astronomy and Astrophysics Missions

Cassini

Along with discoveries involving Saturn and its rings, NASA's Cassini spacecraft successfully glided near nine Saturnian moons, sending back a stream of raw images as mementos of its expedition. The spacecraft sent back particularly intriguing images of the moons Dione and Rhea. >> In particular, a very tenuous atmosphere known as an exosphere that is infused with oxygen and carbon-dioxide

was discovered at Rhea by Cassini. This is the first time a spacecraft has captured direct evidence of an oxygen atmosphere - albeit a very thin one - at a world other than Earth. >> On 2 November 2009, Cassini spacecraft made its deepest plunge yet into the plumes of Saturn's moon Enceladus, sending images and data of the encounter back to Earth. >> In the first video showing the auroras above the northern latitudes of Saturn, Cassini spotted the tallest known "northern lights" in the solar system, flickering in shape and brightness high above the ringed planet. >>

Chandra X-ray Observatory

Evidence for a thin veil of carbon has been found on the neutron star in the Cassiopeia A supernova remnant. This discovery, made with NASA's Chandra X-ray Observatory, resolves a 10-year mystery surrounding this object. >> NASA extended a contract with the Smithsonian Astrophysical Observatory to provide science and operational support for Chandra, a powerful tool used to better understand the structure and evolution of the universe. >> Findings from Chandra have provided a major advance in understanding a type of supernova critical for studying the dark energy that astronomers think pervades the universe. >>

Euclid

It was announced that ESA's proposed Euclid space telescope would use a microlensing technique to detect the bending of light as it travels through clumps of dense matter. That would allow scientists to map out the locations of galaxies scattered across the universe, which in turn may reveal more about the role of dark energy as a theorized unseen force behind the universal expansion. >>

Fermi Gamma-ray Space Telescope

Nearby galaxies undergoing a furious pace of star formation also emit lots of gamma rays, said astronomers using NASA's Fermi Gamma-ray Space Telescope. Two so-called "starburst" galaxies, plus a satellite of our own Milky Way galaxy, represent a new category of gamma-ray-emitting objects detected both by Fermi and ground-based observatories. >> Fermi made the first unambiguous detection of high-energy gamma-rays from an enigmatic binary system known as Cygnus X-3. >> A galaxy located billions of light-years away commanded the attention of Fermi and astronomers around the globe. Thanks to a series of flares that began on 15 September 2009, the galaxy was the brightest source in the gamma-ray sky - more than ten times brighter than it had been in summer 2009. >> Using the Large Area Telescope (LAT) on board Fermi, astronomers have detected gamma rays from a nova for the first time, a finding that surprises both observers and theorists. The discovery dispels the long-held idea that nova explosions are not powerful enough to produce such high-energy radiation. >> Fermi unveiled a previously unseen structure centred in the Milky Way. >>

Hayabusa

A major event in this reporting period was the return of the Japanese Hayabusa spacecraft to Earth and the successful recovery of the sample-return capsule in Australia on 14 June 2010. The capsule appears to contain some grains of material from the surface of the target near-Earth asteroid (25143) Itokawa. Itokawa has a diameter of about 300 m and appears to be a gravitationally accumulated body, or so-called rubble pile, from a catastrophic collision between two bodies. Hayabusa was launched in May 2003 and reached Itokawa in September 2005. The probe transmitted a wealth of scientifically valuable data and made contact with the surface of Itokawa

in November 2004. It is not clear whether the sample-collection mechanism actually worked correctly, but it was hoped that at least some grains of material from the surface had been stirred up as the probe touched down and caught in the sample-return capsule. Examination of any captured grains may provide insight into the composition of the solar nebula from which the planets formed. In any case, Hayabusa has provided important information on the physical characteristics of a NEO, which is directly relevant to the question of NEO impact mitigation. >> In November 2010, it was confirmed that Hayabusa became the first ever to collect asteroid dust. >> Overall the Hayabusa mission has been a great success and represents an outstanding achievement for the Japanese space programme and the mission scientists and engineers involved.

Herschel Space Observatory

Early in the reporting period, the European Space Agency released a preview of the first science results from the Herschel Space Observatory. >> In January 2010, the Herschel telescope's highest resolution instrument began observing the infrared universe after operations were suspended in August 2009, due to faulty electronics. >> Herschel revealed the chemical fingerprints of potentially life-enabling organic molecules in the Orion nebula, a nearby stellar nursery in our Milky Way galaxy. >> Images from Herschel show thousands of distant galaxies furiously building stars and beautiful star-forming clouds draped across the Milky Way. One picture even catches an 'impossible' star in the act of formation. >> In May 2010, Herschel made an unexpected discovery: a hole in space. The hole has provided astronomers with a surprising glimpse into the end of the star-forming process. >>

Hubble Space Telescope

The new camera installed on the ESA/NASA's Hubble Space Telescope during Servicing Mission 4 in May 2009 delivered the most detailed view of star birth in the nearby spiral galaxy M83. >> Hubble discovered the smallest object ever seen in visible light in the Kuiper Belt, a vast ring of icy debris that is encircling the outer rim of the solar system just beyond Neptune. >> The Hubble Space Telescope broke the distance limit for galaxies and uncovered a primordial population of compact and ultra-blue galaxies that have never been seen before. The data from the Hubble's new infrared camera, the Wide Field Camera 3 (WFC3), on the Ultra Deep Field (taken in August 2009) were analysed by five international teams of astronomers. >> Astronomers using Hubble confirmed the existence of a baked object that could be called a "cometary planet." The gas giant planet, named HD 209458b, is orbiting so close to its star that its heated atmosphere is escaping into space. >>

James Webb Space Telescope

In April 2010, NASA's James Webb Space Telescope passed its most significant mission milestone to date, the Mission Critical Design Review. >>

Keppler

The list of known exoplanets in the galaxy got bigger, thanks to the first observations of NASA's Kepler space telescope, which found five new lightweight worlds orbiting distant stars. >> At a 7 January 2010 meeting of the American Astronomical Society, mission scientists unveiled five hot, massive planets discovered by Kepler , a space telescope that should in the coming years be able to turn up potentially habitable, Earth-like worlds. >> Kepler discovered the first confirmed planetary system with more than one planet crossing in front of, or transiting, the

same star. >> An international cadre of scientists that used data from Kepler announced the detection of stellar oscillations, or "starquakes," that yield new insights about the size, age and evolution of stars. >>

MESSENGER

NASA's MESSENGER mission team and cartographic experts from the U.S. released the first global map of Mercury. The MESSENGER mission will perform its Mercury Orbit Insertion on 18 March 2011. The latest release of science data collected during the 3rd flyby (29 September 2009) is already providing scientists with new understanding of Mercury. >>

Planck

The Planck space observatory - ESA's mission to study the early Universe - has delivered its first image of the entire sky. By looking at microwave radiation, it not only provides new insight into the way stars and galaxies form, but also tells us how the Universe itself came to life after the Big Bang. >> >>

Rosetta

Scientists announced that close-up images of asteroid (2867) Steins, obtained with the OSIRIS cameras on ESA's comet mission Rosetta, provided extensive new measurements of the physical properties of this main-belt asteroid. Steins is revealed to be a loosely-bound 'rubble pile' whose diamond shape has been honed by the YORP effect. >> In July 2010, Rosetta performed a fly by at asteroid Lutetia. In the weeks before closest approach optical navigation was used together with Delta-DOR measurements to determine the motion of the spacecraft relative to the asteroid whose orbit is known with very limited accuracy. Asteroid Lutetia was revealed as a battered world of many craters. Rosetta returned the first close-up images of the asteroid showing it is most probably a primitive survivor from the violent birth of the Solar System. >>

Spitzer Space Telescope

NASA's Spitzer Space Telescope found a young star. Young planets circling the star are thought to be disturbing smaller comet-like bodies, causing them to collide and kick up a huge halo of dust. >> Spitzer also contributed to the discovery of the youngest brown dwarf ever observed - a finding that, if confirmed, may solve an astronomical mystery about how these cosmic misfits are formed. >> Astronomers have discovered that a huge, searing-hot planet orbiting another star is loaded with an unusual amount of carbon. The planet, a gas giant named WASP-12b, is the first carbon-rich world ever observed. The discovery was made using NASA's Spitzer Space Telescope, along with previously published ground-based observations. >> >>

Stardust

It was announced in March 2010 that scientists may have identified the first specks of interstellar dust in material collected by the US space agency's Stardust spacecraft. A stream of this dust flows through space; the tiny particles are building blocks that go into making stars and planets. The NASA spacecraft was primarily sent to catch dust streaming from Comet Wild 2 and return it to Earth for analysis. >>

Suzaku

Astronomers used the Suzaku orbiting X-ray observatory, operated jointly by NASA and the Japanese space agency, to discover the largest known reservoir of rare

metals in the universe. Suzaku detected the elements chromium and manganese while observing the central region of the Perseus galaxy cluster. The metallic atoms are part of the hot gas, or "intergalactic medium," that lies between galaxies. >> In a supernova remnant known as the Jellyfish Nebula, Suzaku detected X-rays from fully ionized silicon and sulphur - an imprint of higher-temperature conditions immediately following the star's explosion. The nebula is about 65 light-years across. >>

Voyager

The veteran Voyager probes discovered that 'interstellar space fluff' is more magnetized than previously believed, a factor that seems to allow its very existence. >> In December 2010, Voyager 1, the most distant spacecraft from Earth, reached a new milestone in its quest to leave the Solar System. Now 17.4bn km from home, the veteran probe detected a distinct change in the flow of particles that surround it. These particles, which emanate from the Sun, are no longer travelling outwards but are moving sideways. It means Voyager must be very close to making the jump to interstellar space. >>

WISE (Wide-field Infrared Survey Explorer)

After launch, NASA's Wide-field Infrared Survey Explorer (WISE) captured its first look at the starry sky that it will soon begin surveying in infrared light. >> >> On 18 February 2010 NASA published these first images. >> On 26 January 2010, WISE spotted its first never-before-seen near-Earth asteroid, the first of hundreds it was expected to find during its mission to map the whole sky in infrared light. >> By October 2010, although WISE has 'warmed up,' NASA decided that the mission will still continue. WISE will now focus on our nearest neighbours - the asteroids and comets travelling together with our solar system's planets around the Sun. >>

V.1.2 NEO Mitigation

The number of near-Earth objects (NEOs) discovered by September 2010 exceeded 7000, of which around 820 have diameters of 1 km or more. The number of potentially hazardous objects (PHOs), defined as objects with absolute visual magnitudes of 22 or brighter (diameters of around 150 m or more) that come close to crossing the Earth's orbit, reached about 1140 by September. Some 150 PHOs have diameters larger than 1 km. By far the main contributors to NEO discoveries remain the search programmes funded by the US.

The NASA Wide-field Infrared Survey Explorer (WISE) was launched on December 14, 2010. By September WISE had discovered about 130 new NEOs with its 40-cm telescope and multi-wavelength infrared camera. Currently WISE is finding 20 - 30 % of the NEOs discovered in 2010. WISE detects asteroids by virtue of their thermal radiation, which provides direct information on the sizes of the objects. In contrast, optical telescopes detect sunlight reflected from an asteroid's surface, which provides only a very rough size estimate. However, the combination of observations made in the visual and thermal- infrared spectral regions enables both the size and albedo of an asteroid to be determined.

The above principle is used by the international ExploreNEOs programme, in which the Spitzer Space Telescope in its post-cryogenic phase is being used to observe the thermal emission from known NEOs, which have been observed by optical telescopes, with the aim of providing sizes and albedo for around 700

members of the NEO population.

Observations commenced in October 2009 and will continue into 2011. As of September 2010 some 300 NEOs had been observed by Warm Spitzer. The programme will help to characterize the NEO population and provide a very useful database for the selection of targets for NEO rendezvous and mitigation test missions.

V.2 Plasma and Atmospheric Physics

NASA's Solar Terrestrial Relations Observatory (STEREO) made new observations about a controversial phenomenon on the sun known as the "solar tsunami." >>

Physicists working in space plasmas made clever use of the ESA/NASA Ulysses spacecraft and the solar minimum to create a massive virtual lab bench to provide a unique test for the science underlying turbulent flows. Researchers have an ideal mathematical model of turbulence in fluids (ideal because the model is of an infinitely large flow). >>

Scientists from the University of Leicester, UK used observations from NASA's STEREO and ACE satellites to come up with more accurate predictions of when blasts of solar wind will reach Earth, Venus and Mars. >>

Russian scientists acknowledged that solar research satellite Koronas-Foton has been lost due to technical problems, barely a year after its launch. >>

In June 2010, NASA's Transition Region And Coronal Explorer, known as TRACE, conducted its final observations of the sun. >>

Cameras on NASA's Solar Dynamics Observatory captured activity on the sun as powerful, glowing magnetic loops erupted from a solar hot spot. SDO recorded the events in the extreme ultraviolet range of the light spectrum over several days beginning July 6. >>

Researchers using the four spacecraft of ESA's Cluster mission uncovered the long journey that energetic ions undergo during geomagnetic storms and how they ultimately precipitate into the Earth's atmosphere. Such precipitation affects the composition of the ionosphere, preventing GPS and communications satellites from operating correctly. >>

The CNES Picard microsatellite delivered a first image of the Sun. Teams on the ground used this image to make final adjustments before the science mission begins. >>

NASA's IBEX found that Energetic Neutral Atoms, or ENAs, are coming from a region just outside Earth's magnetopause where nearly stationary protons from the solar wind interact with the tenuous cloud of hydrogen atoms in Earth's exosphere. >>

On 7 October 2010, SDO observed its first lunar transit when the new Moon passed directly between the spacecraft (in its geosynchronous orbit) and the Sun. With SDO watching the Sun in a wavelength of extreme ultraviolet light, the dark Moon created a partial eclipse of the Sun. >>

V.3 Space Exploration

At the beginning of the reporting period, in November 2009, preliminary data from NASA's Lunar Crater Observation and Sensing Satellite, or LCROSS, indicated

the mission successfully uncovered water in a permanently shadowed lunar crater. >> _Scientists then said that the discovery of volatiles in lunar material ejected by NASA's LCROSS mission suggests comets delivered much of the water at the impact site. >>

That same month, ISRO's Chandrayaan-1 discovered and confirmed for the first time the presence of magnetic spheres on the far side of the moon - the side we cannot see from the earth. This could theoretically mean a longer and secure stay for astronauts on the Moon. >>

A radar experiment aboard Chandrayaan-1 had identified thick deposits of water ice near the Moon's north pole. Analysis of data obtained by the Miniature Synthetic Aperture Radar (Mini-SAR) onboard Chandrayaan-1 spacecraft provided evidence for the presence of ice deposits near the moon's North Pole. The Mini-SAR instrument found more than 40 small craters (2-15 km in diameter) with sub-surface water ice located at their base. The interior of these craters is in permanent sun shadow. >> >>

In November 2009, it was reported that Mercury was even more of an “iron planet” than scientists had previously supposed. Richer concentrations of iron and titanium were seen on Mercury's surface by NASA's Messenger probe. >>

Rosetta's OSIRIS instrument imaged the Moon from 4.3 million km as the satellite sped towards Earth for its final gravity-assist swingby, scheduled for 13 November 2009. >> On that date, Rosetta spacecraft swung by Earth and passed within 2500 km of Earth´s surface. The manoeuvre was the fourth and last in a series of gravity assists and will provide the spacecraft with the required orbital boost to set course for the mission´s final destination: comet 67P/Churyumov-Gerasimenko. >>

On 10 December 2009, XMM-Newton, the most powerful X-ray observatory ever built and launched into space, marked its 10th anniversary. >>

JAXA announced that SUZAKU data had helped find major hard X-ray emissions around Jupiter >>

NASA extended the Cassini spacecraft's mission until 2017, meaning it will get the first detailed look at summer in Saturn's northern hemisphere >>

In March 2010, ESA’s Mars Express encountered Phobos, smoothly skimming past at just 67 km, the closest any manmade object has ever approached Mars enigmatic moon. The data collected could help unlock the origin of not just Phobos but other “second generation” moons. >> Images of the flyby were released showing the rocky moon in detail, with a resolution of just 4.4 metres per pixel. They show the proposed landing sites for the forthcoming Phobos-Grunt mission. >>

ESA's Venus Express returned the clearest indication yet that Venus is still geologically active. Relatively young lava flows have been identified by the way they emit infrared radiation. The finding suggests the planet remains capable of volcanic eruptions. Although some uncertainty remains, the most recent infrared data from the VIRTIS spectrometer seem to confirm the suspicion. >> Venus Express completed an aerodrag campaign that used its solar wings as sails to catch faint wisps of the planet´s atmosphere. The test used the orbiter as an accurate sensor to measure atmospheric density barely 180 km above the planet. >> Also, a mysterious high-altitude layer of sulphur dioxide discovered by ESA’s Venus Express has been explained. As well as telling us more about Venus, it could be a warning against injecting our atmosphere

with sulphur droplets to mitigate climate change. >>

Engineers worked to solve a problem with science data transmissions from the Voyager 2 spacecraft near the edge of the solar system. >> In May, they shifted the spacecraft into a mode that transmits only spacecraft health and status data while they diagnosed an unexpected change in the pattern of returning data. >> Then, they revived Voyager after correcting a single incorrect computer bit in the spacecraft's memory. >>

CNES announced that the UVolution photochemistry experiment has delivered its first results. Certain organic molecules would be degraded by the Sun's UV rays in space. >>

Data from NASA's Phoenix Mars Lander suggest liquid water has interacted with the Martian surface throughout the planet's history and into modern times. The research also provides new evidence that volcanic activity has persisted on the Red Planet into geologically recent times, several million years ago. >>

NASA's Lunar Reconnaissance Orbiter, or LRO, completed the exploration phase of its mission after a number of successes that transformed understanding of Earth's nearest neighbour. LRO completed a one-year exploration mission in a polar orbit some 50km above the moon's surface. It produced a comprehensive map of the lunar surface in unprecedented detail; searched for resources and safe landing sites for potential future missions to the moon; and measured lunar temperatures and radiation levels. >>

NASA's Hubble Space Telescope captured images of the large asteroid Vesta that will help refine plans for the Dawn spacecraft's rendezvous with Vesta in July 2011. >>

A pair of NASA spacecraft, THEMIS P1 and P2, that were supposed to have finished their mission are now flying to the Moon for a breakthrough mission in lunar orbit. >> >>

V. 4 Space Operations

On 1 May 2009 (5 years after landing and over 20 times the planned mission duration), the Mars rover Spirit became stuck in soft soil. This was not the first of the mission's "embedding events" and for the following eight months NASA carefully analysed the situation, running Earth-based theoretical and practical simulations, and finally programming the rover to make extrication drives in an attempt to free itself. These efforts continued until 26 January 2010, when NASA officials announced that the rover was likely irrecoverably obstructed by its location in soft soil, though it will continue to perform scientific research from its current location. >>

However, there has been no communication with Spirit since sol 2210 (22 March 2010) and there is some concern that the rover was not able to survive the Martian winter. The rover team plans to continue to attempt to contact the lander, which may be hibernating while increasing solar levels charge its batteries, until at least summer solstice at Spirit's location in March 2011. >> >>

Effort to contact NASA's Phoenix Mars Lander had also continued during the reporting period. In November 2009, winter images of Phoenix showing the lander shrouded in dry-ice frost on Mars were captured with the High Resolution Imaging Science Experiment, or HiRISE camera, aboard NASA's Mars Reconnaissance

Orbiter. >> During January 2010, NASA's Mars Odyssey orbiter started to listen for possible radio transmissions from Phoenix. >> >>

Mars Odyssey orbiter completed some 30 overflights without hearing anything from the lander and attempts were made in February and March. >>

In May 2010, it was declared that Phoenix had ended operations after repeated attempts to contact the spacecraft were unsuccessful. >>

November 2009

NASA's Dawn spacecraft re-entered the solar system's asteroid belt, and from now on would stay there. Dawn first entered the belt (whose lower boundary may be defined as the greatest distance Mars gets from the sun (249,230,000 kilometres) in June 2008. >>

The Hayabusa asteroid probe was back on track to return to Earth after a workaround coaxed one of its ion engines back to life. The recovery was yet another reversal of fortune for the Japanese spacecraft, which had been plagued with problems since its visit to asteroid Itokawa in 2005. It landed on the asteroid twice in November of that year, but its pellet gun - designed to dislodge material for collection - failed to fire. After an episode where it spun out of control and temporarily lost contact with Earth, engineers regained control and set it on a course back home. >>

NASA's New Horizons mission passed the halfway point on its journey to Pluto >>

The Mercury-bound MESSENGER spacecraft completed its fifth and final deep-space manoeuvre of the mission, providing the expected velocity change needed to place the spacecraft on course to enter into orbit about Mercury in March 2011. >>

NASA's Mars Odyssey orbiter put itself into a safe standby mode and the team operating the spacecraft began implementing careful steps to resume Odyssey's science and relay operations. >>

December 2009

ESA's SMOS satellite completed its first phase of life in orbit - the Launch and Early Orbit Phase (LEOP), which means that all the systems are working as they should and the satellite was ready for full commissioning. >>

Boeing acquired the first on-orbit signals from the third of six Wideband Global SATCOM (WGS) satellites. >>

February 2010

Mars Express began a series of flybys of Phobos, the largest moon of Mars. The campaign would reach its crescendo on 3 March, when the spacecraft will set a new record for the closest pass to Phobos, skimming the surface at just 50 km. The data collected could help untangle the origin of this mysterious moon. >>

NASA's Stardust-NExT (New Exploration of Tempel) spacecraft fired its engines for 22 minutes 53 seconds to purposely delay its arrival at comet Tempel 1 by 8 hours 21 minutes. >>

March 2010

After eight large manoeuvres and three trim burns since rocketing to space aboard an Atlas booster in February, NASA's Solar Dynamics Observatory arrived on

station in geosynchronous orbit. >>

April 201

Since mid-March 2010, NASA/CNES reported a degradation of the on-orbit performance of the star trackers and gyro wheels on Jason-1, which has caused large off-nadir angles of the platform. >>

ESA's CryoSat-2 has delivered its first data, hours after ground controllers switched on the satellite's radar instrument for the first time. >>

May 2010

Hayabusa achieved the second and largest of four engine firings designed to guide the probe back home. >>

June 2010

The Hayabusa asteroid mission eventually returned to Earth. The reentry capsule was recovered in the Woomera area of Australia. Minute particles were confirmed in the capsule. Further tests were reported as underway in the Curation Centre of Sagamihara Campus of JAXA. >>

JAXA began to deploy the solar sail of the Small Solar Power Sail Demonstrator IKAROS on June 3. On June 10, JAXA confirmed that it was successfully expanded and was generating power through its thin film solar cells at about 770 km above Earth. >>

NASA's Deep Impact/EPOXI spacecraft flew past Earth. This helped propel the mission toward its appointment with comet Hartley 2. >>

A short but important course-correction manoeuvre kept New Horizons on track to reach the "aim point" for its 2015 encounter with Pluto. A June 30 thruster-firing lasted 35.6 seconds and sped New Horizons up by just over 1 km/hour. >>

July 2010

Astrium Satellites GmbH of Germany and the German armed forces announced July 9 that the ComsatBw-2 military telecommunications satellite had been declared operational in orbit and delivered to the German military. >>

ESA's comet mission Rosetta performed a fly by at asteroid Lutetia. In the weeks before closest approach optical navigation was used together with Delta-DOR measurements to determine the motion of the spacecraft relative to the asteroid whose orbit is known with very limited accuracy. Asteroid Lutetia was revealed as a battered world of many craters. Rosetta returned the first close-up images of the asteroid showing it is most probably a primitive survivor from the violent birth of the Solar System. >>

August 2010

Two Chinese satellites seem to have had a close encounter and may have even touched 600 kilometres above Earth. The unannounced rendezvous - a first for China - could be a test of technology needed to build a space station. >>

September 2010

Ground controllers raised the orbit of Europe's GOCE gravity-measuring

satellite in a successful attempt to recover its failed data-transmission function. >> >> >>

As tiny thrusters continue to nudge the U.S. military´s AEHF 1 satellite toward a higher orbit, investigators hope to know within the next few weeks what knocked out the craft´s main engine and whether the programme's next launch will be delayed. >>

The MESSENGER team finished a two-week flight test to ensure that the Mercury-bound spacecraft is ready for orbital operations. >> >>

NASA's Mars Reconnaissance Orbiter put itself into a precautionary standby mode after experiencing a spontaneous computer reboot. The mission's ground team restored the spacecraft. >> >>

October 2010

The results from ESA's SMOS satellite were bugged by patches of interference from radar, TV and radio transmissions in what should be a protected band. Painstaking efforts to reduce these unwanted signals are now paying off. >>

On 14 October 2010, DLR's radar satellite TanDEM-X moved into close formation with its 'twin', TerraSAR-X. The objective of the mission is to create a high-precision, three-dimensional digital elevation model of Earth´s land surface. The project needs the satellites to operate in parallel for a period of three years. The transition to close formation flight marks the beginning of the final preparatory stage of the TanDEM-X mission. The routine operations phase is due to start in January 2011. >>

Moving into the next phase of its orbital rescue, the US Air Force´s Advanced Extremely High Frequency satellite warmed up electric thrusters to begin 10 months of propulsion-with-persistence that is required to save the craft´s life. >>

JAXA conducted the scheduled initial functional verification of the satellite bus and mission devices of MICHIBIKI. >>

November 2010

Engineers at NASA's Jet Propulsion Laboratory worked to understand and fix what caused NASA's Cassini spacecraft to put itself into "safe mode," a precautionary standby mode. The malfunction prevented the probe from making its next scheduled swing by Saturn's largest moon Titan. >> >>

Surrey Satellite Technology Ltd successfully repositioned the UK-DMC-1 spacecraft, which is reaching the end of its operational life, using unspent propellant to reduce the orbital lifetime and the probability of generating space debris. >>

December 2010

The FASTSAT team continued during December to troubleshoot the inability to make contact with NanoSail-D. Then, NASA reported that the satellite carrying a folded-up solar sail may not have ejected from its mothership after all. >> The FASTSAT microsatellite and all remaining five onboard experiments continue to operate as planned. >>

Russia has switched on two reserve Glonass-M satellites to replace the ones that were lost when a rocket deviated off course. >>

The Italian COSMO-SkyMed constellation was reported as fully operational

and complete with the arrival of the system's fourth satellite in its final orbit position. The satellite was launched on 5 November from the Vandenberg base in California. >>

VI. TECHNOLOGY - IMPLEMENTATION AND ADVANCES

VI.1 Propulsion

ESA's gravity mission GOCE released its first data set. To ensure that the gravity measurements taken by GOCE are of true gravity, the satellite has to be kept stable and in 'free-fall'. Any buffeting from residual air the satellite encounters along its orbital altitude of just 250 km could potentially drown the gravity data. This posed a technological challenge - the satellite structure had to be as aerodynamic as possible and a system had to be developed that would continually and instantaneously compensate for variations in air drag. The success of GOCE´s ultra-sensitive gravity measurements depends on finely controlling the satellite´s orbit and speed. The spacecraft´s sophisticated electric propulsion system, commissioned in April 2009, had shown that it is able to keep the satellite completely free from drag as it cuts through the remnants of Earth´s atmosphere. The electric ion propulsion system is mounted at the back of the satellite, relative to its direction of flight. Unlike conventional fuel-driven engines, the system uses electrically- charged xenon to create a gentle thrust. The system continually generates tiny forces between 1 and 20 millinewtons (mN), depending on how much drag the satellite experiences as it orbits Earth. This is a very small force - a thrust of a few mN is similar to the weight of a few drops of water on Earth. Yet, by thrusting continuously during GOCE´s routine operations, it is sufficient to maintain a 'freefall' orbit. GOCE is the first-ever mission to fly drag free in low-Earth orbit using an electric propulsion system. >>

JAXA confirmed that its experimental spacecraft IKAROS started to accelerate after unfurling its kite-like solar sail, proving that the new fuel-saving propulsion technique works. >>

Aerojet, along with Russian partner SNTK, and US-based Orbital Sciences Corporation successfully completed a series of tests of the NK-33 rocket engine, originally designed for the Russian N1 lunar launch vehicle. The NK-33 is the basis for the AJ26 commercial derivative engine, that will power the first stage of Orbital Sciences' Taurus II launch vehicle. Data from these tests will be used to support the first series of AJ26 engine tests at NASA's Stennis Space Center E-1 test stand. The first AJ26 engine arrived at Stennis on 15 July 2010. >>

In July 2010, US engine manufacturer Pratt & Whitney Rocketdyne completed the fourth series of tests on the Common Extensible Cryogenic Engine (CECE), demonstrating a throttling range 35% greater than in previous tests of the liquid Oxygen / liquid Hydrogen engine.

The tests are part of NASA's Exploration Technology Development Program, and achieved successful closed-loop engine control across the full range of throttling, the ability to quickly re-start the engine over varying power levels, and a 17.6:1 deep-throttling capability. The 6,800 kg-thrust class engine is being used to develop and demonstrate capabilities needed for throttled landings of large payloads on the Moon, asteroids, or another planet.

The Planetary Society announced plans to launch its second attempt at a spacecraft that will be powered by the Sun. The first time the society attempted to

launch a solar sail five years before, it fell short of its orbital target and landed in the ocean. >>

NASA partnered with Lockheed Martin Space Systems and MT Aerospace to successfully manufacture the first full-scale friction stir welded and spun formed tank dome designed for use in large liquid propellant tanks. >>

The Russian government allocated USD 17 million for the development of a spaceship with nuclear powered engine. Under a cabinet decree, 500 million roubles are being allocated to the RosAtom State Nuclear Corporation and the Federal Space Agency Roscosmos for a project to develop nuclear engine for spacecraft. >> >>

Space Systems/Loral announced that it had been selected to provide a propulsion system to NASA Ames Research Center for the Lunar Atmosphere Dust Environment Explorer (LADEE) spacecraft. >>

ISRO successfully conducted static testing of its largest solid propellant booster, S200, which will form the strap-on stage for the GSLV-Mk III launch vehicle being developed for putting heavier satellites in space. >>

NASA awarded a set of contracts to commercial companies working on new propulsion technologies for future spacecraft. >>

NASA issued a Broad Agency Announcement (BAA) seeking proposals and industry input on heavy-lift system concepts and propulsion technology. NASA is seeking an innovative path for human space exploration that strengthens its capability to extend human and robotic presence throughout the solar system. The information also may help lay the groundwork for humans to safely reach multiple potential destinations, including asteroids, Lagrange points, the moon and Mars. >>

In May 2010, NASA and US company Aerojet completed a series of altitude-tests of a 2,500 kg thrust liquid Oxygen/liquid methane (LO2/LCH4) rocket engine at the NASA White Sands Test Facility. A part of NASA's Exploration Technology Development Program, the LO2/LCH4 engine demonstrated a specific impulse of 345.2 seconds, and provided risk reduction data for the new, non-toxic propellant combination.

NASA's Dawn spacecraft set an all-time velocity change record for a spacecraft when it accumulated a total of 15,450 km/h in velocity change. The previous record was held by NASA's Deep Space 1 mission. Dawn is on its way to the asteroid belt and will have a speed of over 38,000 km/h by the end of its 8 year mission. Dawn is expected to arrive at the asteroid Vesta and the dwarf planet in 2011 and 2015, respectively.

VI.2 Power

Dutch Space signed a contract with Orbital Sciences Corporation for the development of solar arrays for NASA´s new cargo missions to the International Space Station to be carried out under NASA's Commercial Resupply Service project. The contract of more than USD 35 million covers the design, manufacturing, assembly, integration and testing of the solar arrays for nine pressurized cargo missions to the ISS. >>

Aerojet announced that it has been awarded a NASA MSFC contract to continue the innovative multi- circuit liquid oxygen/liquid hydrogen injector development. >>

NASA's Space Shuttle Program conducted the final test firing of a reusable solid rocket motor. The flight support motor, or FSM-17, burned for approximately 123 seconds - the same time each reusable solid rocket motor burns during an actual space shuttle launch. >>

EADS Astrium was awarded a contract by the European Space Agency (ESA) to develop key technologies for new re-ignitable upper stage. >>

ATK and NASA successfully tested the second five-segment Ares DM-2. The test marks the second time that NASA and ATK has tested one of these motors intended for use in the Ares family of rockets. >>

VI.3 Spacecraft Design, Technology and Development

On 1 November 2009, the Japanese H-II Transfer Vehicle (HTV-1) vehicle was deorbited after spending 52 days in space, 43 days docked to ISS. This marked the successful completion of the first flight of HTV, which brought approximately 4.5 tonnes of cargo to ISS and removed 1.6 tonnes of discarded equipment and trash from ISS. >> Engineers at NASA's Goddard Space Flight Center teamed up with engineers at NASA's Johnson and Kennedy Space Centers to design, build, and test five new ExPRESS Logistics Carriers, or ELCs, which will be delivered to the ISS >>

Igor Khamits, chief of Russian Rocket and Space Corporation Energia's research and technological design centre, told reporters that a reusable spacecraft was under initial design while drawing on experiences from the "Soyuz" manned spacecraft. >>

Arianespace and ESA signed a contract defining Arianespace's support services for the qualification campaign and combined testing of the lightweight Vega launcher. This testing was conducted at Europe's Spaceport in French Guiana starting in April, in preparation for Vega's service entry. >>

Space Exploration Technologies (SpaceX) conducted a three-day long demonstration of cargo loading and unloading procedures for its Dragon spacecraft, which NASA has contracted to provide delivery services to the International Space Station. >>

In June 2010, two satellites were launched by Dnepr from the Yasni cosmodrome. The two Swedish Space Centre Prisma satellites demonstrate new technologies for formation flying and rendezvous. >>

ESA is studying a cargo-return capsule based on the Automated Transfer Vehicle. >>

Russia will use the leased facilities at Baikonur Cosmodrome in Kazakhstan to test the proposed Rus M launch vehicle that is expected to replace the Soyuz rocket, and although the Rus M will eventually be launched from a new facility on Russian soil, Russia has no plans to abandon Baikonur before the lease expires in 2050. >>

The International Space Station Multilateral Coordination Board (MCB) approved a docking system standard. The international standard will provide guidelines for a common interface to link future spacecraft ranging from crewed to autonomous vehicles and from low-Earth orbit to deep-space exploration missions. >>

VI.4 Materials and Structures

NASA conducted a test to validate an approach that would be used to test the parachutes for the Orion spacecraft. >>

A special kind of titanium and a manufacturing technique used to build the Ariane 5 rocket could become the next successful spin-offs from Europe's space programme, benefiting the oil and gas industry. >>

VI.5 Information Technology and Datasets

JAXA released data from the lunar explorer KAGUYA (SELENE) (L2 products) during the nominal operation phase (from 21 December 2007 to 31 October 2008) to the public via the Internet. >>

ESA, on behalf of the Committee on Earth Observation Satellites (CEOS), announced the release of the 2009 edition of the CEOS Missions, Instruments and Measurements (MIM) database. >>

Access to data from the ESA-NASA SOHO mission became easier with the launch of a new SOHO science archive with enhanced capabilities for searching and visualising the vast SOHO data archive. This is the first in a new generation of science archives under development at ESA's European Space Astronomy Centre. >>

The von Karman Institute (VKI) joined the STA project. The Space Trajectory Analysis or STA software suite is conceived as a research tool to support the analysis phase of a space mission having the ability to analyse, determine, simulate, and visualize a wide range of space trajectories. >>

RapidEye released the German version of their online shop for satellite imagery. >>

The publicly accessible Planetary Data System (PDS) released data sets from the seven instruments on board NASA's Lunar Reconnaissance Orbiter. >> PDS serves as NASA's permanent online data archive providing these measurements to the science community and the world at large. >>

One of the teams behind ESA's XMM-Newton X-ray mission unveiled the latest edition of their 2XMM catalogue. The newest incarnation boasts an additional 42 000 entries, ratcheting up the total to over a quarter of a million X-ray sources. This unprecedented cosmic X-ray library is a valuable resource allowing astronomers to explore the extreme Universe. >>

ESA's gravity mission GOCE issued its first dataset release. Over its life of about 24 months, GOCE will map global variations in the gravity field with extreme detail and accuracy. This will result in a unique model of the ´geoid´, which is the surface of equal gravitational potential defined by the gravity field - crucial for deriving accurate measurements of ocean circulation and sea-level change, both of which are affected by climate change. GOCE-derived data are also much needed to understand more about processes occurring inside the Earth and for use in practical applications such as surveying and levelling. >>

Access to data from Europe's future generation of Sentinel Earth observation satellites is likely to be free after a joint decision by the ESA and the European Parliament. The Global Monitoring for Environment and Security (GMES) project

will provide information on how the planet and its climate are changing from data captured from three Sentinel satellites, jointly owned by the nations of the European Union. >>

Scientists produced a first-of-its kind map of the height of the world's forests by combining data from three NASA satellites. The map will help scientists build an inventory of how much carbon the world's forests store and how fast that carbon cycles through ecosystems and back into the atmosphere. >>

The complete archive of data sets from ESA's 3-year SMART-1 mission to the Moon was released to the scientific community. Contained within the archive are 3D maps of the lunar poles along with detailed spectroscopic measurements of the lunar surface. Researchers can utilize this information, and cross-reference it with the wider Planetary Science Archive, to further investigate the formation and evolution of our nearest neighbour in space. >>

NATO will offer Russia access to some US military satellite data in exchange for its participation in a missile shield project for continental Europe, a Moscow newspaper reported. >>

NASA's Lunar Reconnaissance Orbiter is allowing researchers to create the most precise and complete map to date of the moon's complex, heavily cratered landscape. "This dataset is being used to make digital elevation and terrain maps that will be a fundamental reference for future scientific and human exploration missions to the moon," said Dr. Gregory Neumann of NASA's Goddard Space Flight >>

ESA's 2009 global land cover map was released and is now available to the public online from the GlobCover website. >>

VI.6 Automation and Robotics

NASA successfully completed a series of autonomous "drop" tests of a robotic lander test article - in a record 10 months - to demonstrate the ability to perform a controlled landing on the moon or other airless planetary bodies. >>

A sounding rocket was launched from Japan. The S-520-25 was designated to conduct basic experiments on the electro-dynamic tether (EDT) in the ionosphere and to control the attitude of a robot using a tether under a micro-gravity environment. >>

VI.7 Space Research Facilities and Ground Stations

The Gulf Earth Observation Centre, is under construction in Abu Dhabi. >>

China's fourth space centre, Wenchang, will be put into service between 2014 and 2015. >>

A key ESA lab gained a new home with the signing of an agreement to relocate the Agency's High-Power Radio Frequency Laboratory from ESTEC in the Netherlands to Valencia in Spain. >>

In December 2010, Galileo's terrestrial nerve centre formally entered service. With the first Galileo satellites due to be launched next August, Fucino in central Italy will oversee the running of all navigation services provided by Europe's global satellite system. >>

The continent of Antarctica now has its first satellite terminal, installed as part of the Galileo programme. >> The new Kiruna Galileo Station in the Swedish Arctic

will also play a vital role communicating with the satellites of Europe's global navigation system, which are due to start launching next year. >>

CLS of France will install and service an X-band satellite Earth station on France's Reunion Island in the Indian Ocean to receive imagery from Canadian and European radar and optical Earth observation satellites under a $9.2 million contract with the Reunion regional government. >>

The German Aerospace Center DLR inaugurated its first satellite data receiving station in Inuvik, Canada. DLR will use the new ground station particularly to receive data for the German TanDEM-X satellite mission. >>

VII. SPACE AND SOCIETY

VII.1 Education

During the reporting period, space education activities world-wide have continued to grow and expand.

In 2009, 2546 Canadian students were able to partake in space-related learning initiatives through funding from the Canadian Space Agency's (CSA) Space Learning Grants Program. Students from primary school to doctoral candidates were awarded funding by CSA in order to facilitate their participation in international robotic competitions (FIRST Robotics) and to international conferences such as COSPAR and IAC 2010. Undergraduate and graduate Canadian students partook in an exchange programme with the Norwegian Space Agency, participating in a rocketry course held at the Andoya Rocket Range from 24-30 October 2010. The CSA awarded $250,000 to 4 science centres, 4 high schools, 2 universities and two not-for-profit organisations that allowed them to develop space-focused initiatives targeting Canadian youth. Finally, between May and August of 2010 the CSA hosted the Cosmomania exhibit at its headquarters which was visited by over 3500 students and educators during its stay.

The Victorian Space Science Education Centre (VSSEC), Australia, conducted curriculum-based programmes for more than 5500 students and 170 teachers. The Centre also received additional funding from the Telematics Trust to establish a mission programme for primary students and development of a web-based Robotics Mission by mid-2010. In November 2009, VSSEC was accepted as an Associate Member of the International Space Education Board.

NASA Mission Directorates and Center Education Offices have provided a variety of new educational programs and resources for NASA's elementary, secondary, higher education and informal education partners, both in the United States and abroad.

In 2009, NASA and the Arab Youth Venture Foundation in Dubai, UAE, partnered to provide three to 12 UAE engineering students each year the opportunity to work with U.S. students, scientists, and engineers on NASA missions. This summer, the first group of UAE students in the programme worked alongside their U.S. peers on an internship project at the Ames Research Center in California. Also during the summer of 2010 (June 1 to August 6), students from across the United States, as well as from Australia, Canada, France, Italy, and Japan worked directly with NASA scientists on cutting-edge research as part of the NASA Academy internship programme.

In November 2009, Miles O´Brien, a member of Challenger Center for Space Science Education´s Board of Directors, was appointed to the NASA Advisory Council, and will lead the Education and Public Outreach Committee. >> Furthermore, the Challenger Center announced that former astronaut Scott Parazynski, MD has been named Chair-Elect of its Board of Directors. >>

Also that month, ESA's Education Office awarded a contract to Surrey Satellite Technology Ltd (SSTL) of the UK to manage the development and testing of the first European student mission to the Moon. Launch is expected in 2013-2014. >>

The Andøya Rocket Range and the University of Oslo initiated a Norwegian-Canadian rocket cooperation intended for college and university students. The cooperation will result in student exchanges between Norway and Canada and included rocket launches from Andøya. >> Later, on 24 August 2010, high school students from different ESA Member States were able to watch their own satellites' soar into the sky aboard suborbital rockets during the first European CanSat competition, held at Andøya. >>

NASA and Microsoft launched an interactive website that allows Web surfers to become Mars explorers. The "Be a Martian" website invited members of the public to help scientists perform research tasks. >>

On 16 November 2009, Space Shuttle Atlantis launched a biological payload module containing larvae of two species of butterfly, whose development students on the ground will track from their classrooms. Another experiment by college students would study how microbes grow in microgravity. >>

In December 2009, NASA and the Arab Youth Venture Foundation in Dubai, United Arab Emirates (UAE) partnered to provide three to 12 UAE engineering students each year the opportunity to work with U.S. students, scientists, and engineers on NASA missions. >>

On 9 December 2009, the Bauman Moscow State Technical University (BMSTU) held a Round Table entitled "International Space Station operation." More than 250 young scientists, students and Ph.D. students from various aerospace universities in Moscow took part in this event.

The NASA-sponsored ISS EarthKAM programme (Earth Knowledge Acquired by Middle school students) continues to grow. During the latest EarthKAM mission onboard ISS Mission 10_04, launched 20 December 2009, 10,615 students from 164 different schools directed a camera onboard the ISS to photograph specific locations on Earth, (https://earthkam.ucsd.edu/).

In early 2010, 70 teams from 18 U.S. states, Puerto Rico, Canada, Germany, India and Romania competed in NASA's 17th Annual Great Moonbuggy Race at the Marshall Space Flight Center. The race challenges students to design, build and race lightweight, human-powered buggies that tackle many of the same engineering challenges dealt with by Apollo-era lunar rover developers at Marshall in the late 1960s.

Following the début of ESA's 'Fly Your Thesis!' programme in 2009, four teams of university students were selected in January 2010 to conduct their microgravity experiments during a second series of parabolic flights aboard an

aircraft. >> Then in May, ESA's Education Office again offered European students the flights of a lifetime with the third call for proposals for the 'Fly your Thesis!' programme. >>

Also in January 2010, NASA awarded approximately $1.4 million in cooperative agreements to enhance learning through the use of the agency's unique Earth science resources. >>

The International Space University (ISU) symposium in February, the fourteenth in a series of annual events, addressed space education and outreach in a very broad way. "Education should be seen here as developing the full human potential of the broader population, not just attracting young people into studying mathematics and science for the nation's technical and economic benefit" it said. >>

UNESCO in collaboration with the Science Education Institute (Philippines) held a Space Education Workshop in the Philippines from February 15-19, 2010. Experts were invited to present their areas of space expertise to University students at 3 different universities in the Philippines touching approximately 500 students. At two of the locations, 100 high school students were invited to launch their own water rockets (activity led by JAXA's education office).

On 3 March, a student rocket, REXUS 7, was successfully launched from SSC's launch facility Esrange Space Center. The rocket carried three student experiments onboard. The rocket reached an altitude of 83 km and landed north of Esrange Space Center. >>

On 9 March 2010, the inaugural winner of the VSSEC-NASA Australian Space Prize was announced making it possible for Elizabeth Blaber from the University of New South Wales to become the first Australian to participate in the NASA Academy Program (10 June -21 August 2010) who worked under a NASA researcher on the effects of radiation and microgravity on cell regeneration.

On 20 March, an international celebration of Sun-Earth Day took place with events around the world in connection with the Sun-Earth Day theme "Magnetic Storms". Social media networking groups were formed on Facebook and Twitter. A webcast highlighted the theme and some recent results from NASA Heliophysics missions. Since March, 500,000 downloads of the Podcast have occurred. >>

Between 30 March 30 and 6 April 2010, a contest for high school students was held at BMSTU entitled "Step into the Future, Cosmonautics" More than 2000 high school students took part in this contest with approximately 200 winners being offered scholarships in aerospace engineering at the leading Russian aerospace universities.

For the 40th Anniversary of Earth Day, NASA hosted a "NASA Village" on the National Mall in Washington, D.C. during the week of 17-25 April 2010. Hundreds of students and teachers visited the village tents with NASA researcher lecturers, multi-media and hands-on learning activities and exhibits. In addition, a special event was held on 19 April 2010 for this 40th Anniversary of Earth Day at NASA Goddard's Digital Learning Network (videoconference and webcast technologies to connect students from across the United States and the world to NASA educators and specialists.) A one hour show featuring director and musician, Kenji Williams and Bella Gaia (Beautiful Earth), followed by an informal lesson on polar ice and climate change by NASA Cryospheric scientist, culminated with live Q&A from 9 schools, including 500 students and their teachers (http://tinyurl.com/2ckg2rh).

On 21 April 2010, NASA and the National Science Teachers Association selected high school teachers from Alabama, Delaware, Georgia, Missouri, New York, North Carolina and Washington to fly an experiment in microgravity. >>

During the week of 17-22 May 2010, high school students were introduced to aerospace engineering as a career. Educational visits to various aerospace companies were organised by the BMSTU Youth Space Centre. The programme included visits to the Rocket and Space Corporation Energia Mission Control Centre, and the Memorial Museum of Cosmonautics. More than 350 students had a chance to talk to engineers, scientists and cosmonauts during this event. >>

Thanks to an Australia Japan Foundation Grant, 10 teachers from Australia visited Japan between 26 June and 5 July 2010 to work with the JAXA Space Education Office, visit significant space related facilities, meet Japanese scientists and engineers, and work with Japanese teachers to develop new education materials.

To facilitate on-going support to European educators to bring innovative and inspiring ideas to enhance their curriculum, summer workshops were held at ESA/ESTEC in the Netherlands from 28 to 30 June 2010. >>

In July, NASA sponsored U.S. graduate student researchers to present at the COSPAR meeting (18-25 July 2010). NASA also sponsored students to attend the IAC in September in Prague, Czech Republic. During these events, NASA co-hosted a series of educational programmes at the International Space Education Board's International Student Zone. Then, on 14 July 2010, NASA selected nine experiments, designed by students at seven schools, for astronauts to perform on the International Space Station this summer. NASA selected the proposals from among 132 received for the new Kids in Micro-g! Program. >>

Two Australian Space Research Programme (ASRP) education grants were awarded. On 14 July, the consortium consisting of the University of South Australia and the International Space University received a grant to establish a Southern Hemisphere Summer Space Programme.

An Education Symposium was held during the COSPAR meeting in Bremen, German (18-25 July 2010). Students presented their research and interacted with each other during special events and the ´Student Zone.´ >>

The first annual International Observe the Moon Night (InOMN) was held on 18 September 2010 at science centres, museums, schools, and backyards worldwide. The goal of InOMN is to engage the public in annual lunar observation campaigns that share the excitement of lunar science and exploration (www.observethemoonnight.org). >>

UN-declared World Space Week (www.worldspaceweek.org) occurs October 4-10 annually. World Space Week 2010 took place in over 50 countries with a myriad of events reaching students, the public, government leaders, and other audiences through attendance and media coverage. The theme for World Space Week 2010 was ‘Mysteries of the Cosmos.’ >>

In October 2010, the German Aerospace Centre DLR launched a support programme for students to develop, build and launch their own rockets. The programme goes by the acronym STERN from the German Studentische Experimental- Raketen, or Student Experimental Rockets. The programme is aimed at all universities that offer courses in aerospace technology. >>

VII.2 Outreach

Two key instruments from NASA's Hubble Space Telescope have a new home in the Smithsonian's National Air and Space Museum in Washington after being returned to Earth aboard space shuttle Atlantis in May 2009. Astronauts brought back the Wide Field and Planetary Camera 2, or WFPC-2, and the Corrective Optics Space Telescope Axial Replacement, or COSTAR, after more than 15 years in space. >>

An aerospace engineer from Maine, the reigning champion of NASA's Astronaut Glove Challenge, held onto his title to win first prize in a competition to build a better space glove. NASA's Astronaut Glove Challenge competition, with a $400,000 prize, test gloves that independent inventors designed and constructed for use in space. >>

JAXA held the "AKATSUKI Message Campaign" (sending people's names and messages to the planet) in order to enhance people's interest in Venus. >>

NASA issued a follow-up Request for Information for ideas from education institutions, science museums and other appropriate organizations about the community's ability to acquire and publicly display orbiters after the conclusion of the Space Shuttle Program. >>

The Space Generation Congress took place in late September in Prague. It is the annual meeting of the Space Generation Advisory Council. Participants are top university students and young professionals with a passion for space who are selected from among applicants from the Space Generation international network. >>

A LEGO space shuttle headed to orbit helped mark the signing of a Space Act Agreement between NASA and the LEGO Group to spark children's interest in science, technology, engineering and mathematics (STEM). >>

Russia announced that a United Cosmonaut Corps will be established. >>

VII.3 Cultural Aspects

ITACCUS seeks to promote and facilitate the innovative utilization of space by organizations in the cultural sectors of society internationally, including the arts and humanities, entertainment, popular culture and tourism.

ITACCUS is comprised of more than 40 members, from both, space and cultural fields. In the period between 1 November 2009 and 31 October 2010, ITACCUS has sought to support the various activities and initiatives carried on by its members. During the annual Spring Meetings in Paris earlier this year, we discussed the status of the member's activities in regard the cultural utilizations of space.

In 2009 the Committee decided to open one subcommittee group to explore the issues around water in space. The first outcome of this group is a joint session between the IAF Space Education and Outreach Committee and the IAA Commission VI on the topic "Water and Space: Societal, Educational and Cultural aspects" which will be hold during the 2010 IAC in Prague. This session will touch interdisciplinary issues about water in societal and cultural contexts as they are related to space.

On the topic of heritage, ITACCUS member Mario Hernandez from UNESCO has worked on different projects through the ESA-UNESCO Open initiative on the use of space technologies to support the World Heritage Convention. In December 2009 the exhibition What a Sight - Space Looking out for World Heritage took place

in Bonn, Germany. This exhibition showed the traces of human kind in cultural heritage areas through satellite images. Another planned exhibition for October 2010 is Space, heritage and climate change at the same time as the UN climate negotiations take place.

UNESCO has collaborated with Mexican authorities to preserve the ancient Maya city of Calakmul. The result was a 4D Geographic Information System project to allow authorities to have the necessary data to implement conservation activities. In parallel, a bicycle rally was organized using satellite images around the area to raise awareness on how space is protecting cultural heritage sites.

Other activities performed by UNESCO in this period are: a partnership with Planet Acton (Spot Image) to support local projects acting on climate change issues by providing geographic information and technology; in May and June 2010 UNESCO hosted the European Association of Remote Sensing Laboratories Symposium where 250 scientists participated and shared applications of space technologies for cultural heritage; and in April 2010 UNESCO and the Government of Belgium started a space project to support the Silk road documentation.

ITACCUS member Carlo Viberti from SpaceLand has worked on the field of space tourism and on a public tour dedicated to the 'space programme cultural outreach' co-financed by the Italian Ministry of Research, University and Education in Italy last Winter-Spring as President of the COSMO SpaceLand Cultural Association. The first SpaceLand Congress was organized in 2009. At this event, a special emphasis was given to the opportunities for science and technology experimentation involving the public and the benefits to the citizens through low cost aerospace flights such as open parabolic flight campaigns and upcoming sub-orbital flight programmes.

In early 2009, ITACCUS Co-Chair Nicola Triscott was approached by Century Films to work on a film project involving astronauts and poetry. This project is supported by the European Media Fund and has the support of the BBC for its future distribution. Currently this project is seeking the support and collaboration from the European Space Agency in order to access the video archives and get access to some astronauts scheduled to fly in the short term.

ITACCUS member Susan McKenna-Lawlor contributed (at the invitation of Ireland's Nobel Prize winning poet Seamus Heaney) a chapter for a book of essays on the Creative Imagination which is entitled "The fire i' the flint". This chapter, which describes the cultural contribution of the scientific imagination in the areas of early astronomy/space exploration, is called "Voyages at the edge of forever". Also, with co-author Damien O'Muiri, she compiled an English-Irish lexicon of over 3500 scientific and technical space related terms as a contribution to the celebrations attending the 50th anniversary of the founding of the International Academy of Astronautics.

ITACCUS is also endorsing a European tour exhibition entitled Republic of the Moon which will open at FACT, Liverpool, UK in 2011. The curators of the exhibition are the members Rob la Frenais and Mike Stubbs. Linked to this activity, the Global Lunar Conference took place in Beijing, China from 31 May to 3 June 2010. This event focused on one of the major challenges of the next decade: Moon Exploration. More than 400 papers were accepted for the conference covering lunar and other space exploration topics. Some topics covered navigation, communication and moon exploration.

Additionally, during 2010, various ITACCUS members have started working on the preparations for the Committee's participation in the IAC South Africa 2011. One example is Adrian Meyer from Space School Africa who has started working with Stanza Bopape Secondary School in Pretoria, South Africa to be the Ambassador for an ITACCUS programme in Africa. During the World Space Week 2010 Programme (4 to 10 October) they presented the 2nd Africa Space Fest where students received lectures on aspects of Space Science, and in particular, cultural aspects. Currently they are working on involving these countries on this project: South Africa, Australia, the USA, Algeria, Iraq, Saudi Arabia, Jordan, Syria, Romania and France. Furthermore, Space School Africa has also launched an Astronomy project focusing on poetry, and myths and legends from Africa. Magate-Loepe Primary School is the host in South Africa for these projects.

VII.4 Knowledge Management

As international collaboration in space increases across government and industry, the challenge arises in integrating information from multiple languages, disciplines, and missions. To date, this has been a laborious process that must be managed for each mission and international partner. The IAA Knowledge Management for Space Activities Study Group has published the first International Ontology for Space under as "Enabling Knowledge Sharing Across Space Organisations". This provide a single format for people to use in organizing the data on a mission and allows other organizations to easily integrate to that single format. The ontology describes the categories of activities, products, science data, and other types of information that is collected, used, and managed within a space mission. Each of these is also shown in relation to other items. For example, an image of Mars that is collected would be organized in such a way that it shows the mission, spacecraft, instrument, researcher, and papers that are related to it.

The approach has been to allow 'federation' of multiple existing and emergent ontologies that have been developed by organizations all across the world. Each portion of the ontology can be managed by different agencies or from different countries to allow a diversity of views to be represented and integrated.

The ontology represents the work of individuals from many countries, agencies, industry, and academia. The work is published in a paper, but more importantly will be released this fall on a web site that allows ongoing updates and contributions to expand the work and continue to make it relevant to space organisations.

An international conference on "Managing Knowledge for Space Missions" took place at the European Space Operations Centre (ESOC) from 21 to 23 June 2010. The conference addressed the methodology, technology and architectural challenges of capturing, organising, and sharing knowledge within and among space missions. During the three days of the conference, 49 presentations were given by space organisations (such as CNES, DLR, ESA, NASA) and by space industry companies coming from 11 countries from three continents. The list of presentations included several invited lectures, such as by Dr. Jay Liebowitz, who gained wide experience in knowledge management within NASA/GSFC, John Hopkins University and the University of Maryland and was ranked one of the top 10 knowledge management researchers out of 11,000 worldwide, on "Exploring Knowledge Management Methodologies: Present and Future Trends"; and by Dr. Klaus North, a

professor of International Management at Wiesbaden Business School and the founder of the German Knowledge Management Association as well as author of the leading textbook on knowledge management in the German language "Knowledge Oriented Business Management" who lectured about "Knowledge Management Approaches and Practices - An Overview." The conference was attended by almost 100 participants coming from 12 nations.

ESOC is located at Darmstadt, Germany, and is an establishment of ESA responsible for the operations of the ESA satellites. The conference, which was the third in series initiated by NASA Jet Propulsion Laboratory in 2007, was co-chaired by Roberta Mugellesi-Dow of ESOC and Jeanne Holm of JPL. The 2010 conference was the first one outside the US and was organised by the ESOC Knowledge Management Core Team, composed of representatives of the main technical domains and responsible for guiding and promoting the knowledge management initiative as well as developing a knowledge management strategy for the Directorate.

VIII. GLOBAL SPACE DEVELOPMENTS

VIII.1 Government Programmes

November 2009

The US and European space agencies signed a 'letter of intent' that ties together their Mars programmes. The agreement, between NASA and ESA, which was penned in Washington DC, gave the green light to scientists and engineers to begin the joint planning of Red Planet missions. The union will start with a European-led orbiter in 2016, and continue with surface rovers in 2018, and then perhaps a network of landers in 2018. >>

MacDonald, Dettwiler and Associates Ltd. (MDA), announced it had received funding from the Canadian Space Agency to advance key technologies to meet current and future needs of the Canadian space programme. The three contracts are funded under the Space Technologies Development Program. MDA will develop solutions for future space exploration missions including a universal docking interface that will allow lunar vehicles to share resources such as power and data, and a vision system to locate and capture sample containers on the Moon or Mars for return to Earth. The third contract will further develop MDA´s next generation Wireless Synthetic Aperture Radar (WiSAR) technology by advancing a critical component that measures the shape of the antenna of the satellite, once in orbit >>

The federal government of Australia announced it was spending $AUS 48.6 million, establishing a space science programme and a space policy unit, and plans to set up a special space council bringing together top experts in the sector. >>

The U.S. Federal Aviation Administration (FAA), Office of Commercial Space Transportation (AST), initiated creation of a new FAA Center of Excellence for Commercial Space Transportation - continuing a series of commercial aviation-related centres but in this case focusing on encouragement of commercial space. The Center involves an FAA funding commitment of one million dollars per year for 10 years and will facilitate collaboration of world class scientists and the leveraging of shared resources and capabilities to maximize the synergy amongst government entities, academic partners, and industry affiliates. >>

December 2009

ESA's bid-evaluation board failed for the second time to select a winner of the biggest satellite-construction competition in Europe. At stake was a contract for 1.4 billion euros to build six third-generation Meteosat meteorological satellites. Funded 75 percent by Europe's meteorological satellite agency, Eumetsat, and 25 percent by ESA, the Meteosat Third Generation (MTG) programme has a total budget of 3.3 billion euros including the satellites' construction and launch, the building of a dedicated ground infrastructure and two decades of system operations. >>

The U.S. Export-Import Bank agreed to help finance a broadband satellite for U.K.-based Avanti Communications. >>

January 2010

The European Commission communicated the decision to award to Thales Alenia Space Italia through a framework contract lasting from 2010 till 2016 for the "System Support" to ESA. The activities will be covered for the period 2010 till 2014 by the first work order for a value of about EUR 85 million.

The System Support framework contract is one of the six contracts through which Galileo will be developed to become operational in early 2014. With the System Support contract, Thales Alenia Space Italia, will perform the overall System Design, the System Security Design, the overall System Integration, Verification and In Orbit Validation. >>

SES ASTRA announced that it has been awarded a second contract by the European Commission to provide hosted payload services for EGNOS, the European Geostationary Navigation Overlay Service. The contract was awarded following a tender by the European Commission. >>

February 2010

NASA awarded $50 million through funded agreements to further the commercial sector's capability to support transport of crew to and from low Earth orbit. This step is the first taken by NASA consistent with the president's direction to foster commercial human spaceflight capabilities.

The Space Act Agreements are designed to foster entrepreneurial activity leading to high-tech job growth in engineering, analysis, design and research, and to promote economic growth as capabilities for new markets are created. Funding for these Space Act Agreements will stimulate efforts within the private sector to develop and demonstrate human spaceflight capabilities.

All Space Act Agreements are designed to partially fund the development of system concepts, key technologies, and capabilities that could ultimately be used in commercial crew human space transportation systems. The selected teams also proposed matching funds from other sources that would leverage the taxpayer investment.

The selected teams and awards are:
(a) Blue Origin to receive $3.7 million;
(b) The Boeing Company to receive $18 million;
(c) Paragon Space Development Corporation to receive $1.4 million;
(d) Sierra Nevada Corporation to receive $20 million;
(e) United Launch Alliance to receive $6.7 million.

The signed Space Act Agreements would fund performance milestones beginning in February 2010. The aggregate value of all of the Space Act Agreements is approximately $50 million. >>

Thales Alenia Space signed a contract with the French and Italian space agencies, CNES and ASI, to develop, construct, test and deliver in orbit a broadband civil and military telecommunications satellite.

Arianespace has been selected to orbit the Athena-Fidus satellite within the scope of the contract. An Ariane 5 or Soyuz vehicle is scheduled to launch this spacecraft - which will weigh about 3,000 kg. - from the Spaceport in French Guiana during the second half of 2013. >>

The number of nations with national space agencies has continued a sharp climb after a pause in the 1990s, rising from 40 in 2000 to about 55 in 2009, according to a survey by Paris-based Euroconsult. >>

March 2010

India's Parliament increased the Indian Space Research Organization (ISRO) budget for 2010 by about 38 percent over last year. >>

April 2010

NASA will pay $335 million to Russia for four round-trip flights to the International Space Station in 2013 and 2014 under the terms of a new deal announced by the American space agency. >>

NASA plans to open an office at Kennedy Space Center that would oversee development of commercial space taxis to fly astronauts to and from the International Space Station - a $5.8 billion enterprise over the next five years. >>

U.S. President Barack Obama announced a new course for the future of U.S. space travel, planning to send American astronauts into Mars orbit within the next three decades. >> >>

June 2010

The 2010 ESA Investment Forum, held in Stuttgart in June, attracted over 130 participants. The Forum brings together the finance and investment communities with startup companies using space technology, applications, or services in a non-space environment, to highlight the commercial benefits of satellite and space technology in applications on Earth. The 2010 Forum addressed satellite downstream applications such as navigation, communication, Earth observation, and location-based services. Out of a field of 36 business-plan presenters seeking funding, investor panels selected the six best companies and also provided valuable individual feedback. On October 4 and 5 2010 the sixth ESA Investment Forum was held in Milan, Italy.

Russia signed a deal to sell more than $500 million of space rocket launchers to the Arianespace company for flights from French Guiana. >>

August 2010

The U.S. Senate passed a NASA authorization bill that would add a space shuttle flight to the manifest in 2011, and require the space agency to get started immediately on a heavy-lift rocket capable of supporting manned missions beyond low- Earth orbit. >>

Canadian Prime Minister Stephen Harper announced support for the next phase of the RADARSAT Constellation Mission (RCM), a system of three advanced remote sensing satellites. >>

September 2010

NASA has extended the Space Program Operations Contract with United Space Alliance, LLC, of Houston to March 31, 2011. The $909,593,590 contract extension supports flight operations for the Space Shuttle and International Space Station. NASA´s Commercial Reusable Suborbital Research Program (CRuSR) has also awarded a total of approximately $475,000 to Armadillo Aerospace of Rockwall, Texas and Masten Space Systems of Mojave, Calif. The awards will allow the two companies to perform test flights of their experimental vehicles near the edge of space. >>

NASA has selected four companies to launch the space agency´s robotic Earth observation, astronomy and planetary exploration probes for the next decade. NASA announced it was awarding Lockheed Martin Space Systems Co., Orbital Sciences Corp., Space Exploration Technologies Corp., and United Launch Alliance a 10-year contract for rocket flights of agency spacecraft. >>

The Japanese government said it wanted to promote more private-sector space development by reorienting its spending away from its research focus and toward commercially oriented programmes and crafting a new law to permit commercial launch services, Japanese government and industry. Addressing the 61st International Astronautical Congress in Prague, these officials said the Japanese government's recent decisions to develop the Epsilon small-satellite launcher and to extend the annual operating window for the heavy-lift H-2A rocket to year-round operations are examples of this new focus. So is the start of development of a 400-kilogram Earth observation satellite >>

November 2010

The Hong Kong Polytechnic University (PolyU) and the China Academy of Space Technology (CAST) announced the establishment of the Joint Laboratory specializing in Precision Engineering Projects for use in Space. >>

China Great Wall Industry Corporation agreed to buy 20 rockets and eight telecommunications satellites from two Chinese technological institutes. >>

Thales Alenia Space, the Prime Contractor, and its partner OHB-System, announced the signature of an Authorization To Proceed (ATP) with the European Space Agency for the Meteosat Third Generation (MTG) system. >> The deal, worth 1.3 billion euros, will guarantee the first of six satellites to be launched in 2017, which will ensure weather data until 2037. >>

Space Exploration Technologies received the first-ever commercial license to re-enter spaceships from Earth orbit. The U.S. Federal Aviation Administration, which oversees commercial space transportation, granted SpaceX the one-year license. Though the FAA has issued licenses for more than 200 commercial launches, this was the first time it sanctioned a re-entry operation. >>

The German Federal Government adopted a new space strategy at its cabinet meeting on 30 November 2010. The paper defines the fundamentals of how the high-technology space sector is to develop over the next few years at a national level and in so doing, how it must respond to changing political and societal conditions on the

domestic as well as international stages. The strategy is being introduced by the German Ministry of Economics and Technology. The strategy paper was drafted jointly with the other ministries involved in space activities, and in consultation with scientific and business establishments such as the German Aerospace Center (DLR). >>

December 2010

An unmanned space craft of the U.S. Air force completed its classified mission and would return to Earth after a stay of more than seven months in Earth's orbit, US Air Force officials said. >>

The Technology Strategy Board and the South East England Development Agency (SEEDA) launched a £2 million funding competition to stimulate innovation across the space industry. >>

VIII.2 Commercial Enterprises

The Center for Space Entrepreneurship, eSpace, continued active development during the last year, having begun operations in January 2009 in Louisville, Colorado. eSpace is a non profit organisation with a mission supporting the creation of entrepreneurial space companies, commercialization of their technologies, development of a passionate workforce to fuel their growth, and growth of the aerospace industry as a whole.

The Space Foundation's annual economic Space Report, released in May 2010, contained for the first time a section entitled 'Angel Investors and Venture Capital.'

The report emphasized the benefits of angel and venture capital firm investment for the growth of the space industry in the past decade. Angel investors may act individually or in groups, often including retired executives, entrepreneurs, and other high net-worth individuals who invest less than $2 million to help a company get started. >>

Preliminary results from the Tauri Group (USA) annual report on the state of the commercial spaceflight industry signal revenue increases, modest maturation, and a blurring of lines with the greater aerospace community. Space Adventures launched two private space explorers in one calendar year for the first time in 2009, with Guy Laliberté launching in September, and repeat customer Charles Simonyi in April. In 2010, Space Adventures announced a partnership with Armadillo Aerospace, 2009 Lunar Lander Challenge award recipient (with winner Masten Aerospace), to provide commercial suborbital flights. Total investment in the commercial human spaceflight sector has risen by 20% since January 2008, reaching a cumulative total of $1.46 billion, according to the Tauri report. >>

Euroconsult, the leading international research and analyst firm specialising in the satellite sector, has forecast that an estimated 1,220 satellites will be built for launch over the next decade. >>

According to the NSR 2009 report “Global Satellite-Based Earth Observation”, the Earth observation industry was in the midst of a significant growth phase slated to generate revenues for many segments of the satellite industry. >>

Space entrepreneurs who have had a big influence on aerospace in the last two years are likely to increase their impact in years to come, possibly transforming access

to space. During a recent U.S. House Science subcommittee hearing, some witnesses criticized the Augustine panel as taking safety for granted in commercial human spaceflight, but proponents argue that risk is inherent in any worthwhile endeavour, and the space beyond Earth's atmosphere is never likely to become an integral part of mankind's economic and scientific sphere without it. At a hearing in March of the U.S. Senate Commerce, Science and Transportation subcommittee, Sen. Bill Nelson (FLA) and FAA Associate Administrator for Commercial Space Transportation George Nield disagreed about who should have oversight over commercial space companies. Nelson thought NASA should be in charge, while Nield thought it should be the FAA. NASA's safety and mission assurance officer, and a former astronaut also agreed with Senator Nelson.

The National Aerospace Training and Research Center (NASTAR) is providing a 3-day course to those who will travel on private suborbital spacecraft. Most of the eight trainees for August's Suborbital Scientist's Training programme are research scientists at US universities, although one participant has applied to join the European astronaut corps. The training helps participants become familiar with how their bodies respond and will work to make the most of the spaceflight experience. A special distraction exercise teaches the scientists how to pay attention to their experiments and get work done during the precious four minutes or so of microgravity.

ATK

Responding to initiatives directing NASA to reply on Ares rocket technologies for a new heavy-lift launch vehicle, rocket-builder ATK is fast-tracking work on parts of an extended five-segment solid-fuelled booster likely to be incorporated on future exploration missions. >>

Armadillo Aerospace

Armadillo Aerospace's suborbital vehicle could do research next year., according to NASA's Office of Chief Technologist, who published detailed information about suborbital vehicles that will be available beginning in 2011 for researchers to conduct microgravity experiments. The vehicles are being built by Armadillo Aerospace, Blue Origin, Masten Space Systems, Virgin Galactic and XCOR. The first post of a series included technical details of Armadillo's platform. It expects to make the first flight under the NASA funded Commercial Reusable Suborbital Research (CRuSR) programme in January, begin commercial cargo operations in 2011, and start human spaceflight by the end of 2012.

Bigelow

Engineers and a former astronaut have started human-in-the-loop testing of the environmental control and life support system (ECLSS) for Bigelow Aerospace's Sundancer inflatable orbital module, using a 90-cu.-meter chamber at the Orbitech facility. These tests currently last only eight hours, but will be longer as Bigelow works toward full-scale mockup ECLSS validation for the 180-cu.-meter Sundancer. Ultimately the company wants to simulate a full 30-day station cycle, including changing out the crew. Among test subjects who will evaluate the ECLSS system are a former NASA astronaut, and Bigelow's chief systems engineer.

Boeing

Boeing may lose as much as $271 million in government payments for satellite launch services if Pentagon auditors conclude it violated federal accounting rules, according to officials and documents. Auditors are reviewing whether Boeing "improperly billed" the Air Force for Delta IV rocket launches between 1998 and 2006. The Pentagon auditing agency began its new review of the Delta IV costs in September after the Defense Department's inspector general concluded that a May 2006 audit approving the billing was flawed and cannot be relied upon.

Boeing announced that it has received a contract from Inmarsat to build three Ka- band satellites to add to Inmarsat's current mobile satellite services fleet. >>

In late December, Boeing, the manufacturer of startup mobile US wireless broadband provider LightSquared's SkyTerra 1 satellite stated that it had successfully deployed its 22-meter-diameter antenna to 98 percent of its intended extension after a 10-day period in which managers thought the mission might be lost. In late November, Boeing encountered a “glitch" of unclear origin when deploying the antenna. Boeing declined comment on the problem beyond saying the antenna's deployment has been delayed. Furthermore, how Boeing later accomplished the deployment "remains unclear. But two industry officials said that with a 98 percent deployment, the antenna is all but certain to provide the power and coverage that LightSquared needs to meet its regulatory obligations

Boeing announced that NASA has awarded the company an extension to the International Space Station contract for sustaining engineering. The extension is valued at $1.24 billion over a five-year period. >>

Globecomm Systems has rolled out an operational commercial X-band service offering for U.S. military and coalition forces operating in Southwest Asia, the Middle East and Africa, the company announced on 3 December 2010. The end-to-end X-band offering combines licensed teleport assets, a global fibre network, commercial X-band space segment, a redundant iDirect IP services platform and a range of satellite terminal equipment options. This service is intended to support the demand for increased U.S. military and coalition forces’ bandwidth requirements in an IP-centric fashion. The Globecomm service caters to military application with high-bandwidth demands and is supported by a global network of high-power satellites connected through a deployment of small aperture antennas and man-portable units, such as the company’s TomCat ManPack, in the related regions. The company’s strategy has been to develop a comprehensive offering of X-band satcom terminal equipment and an organic capability for worldwide transport of government communications traffic between remote terminals operating in challenging conditions and C3centres located in or out of the theatre, satisfying stringent communications requirements, minimizing programme risk, and realizing cost-effective service delivery for government customers.

Jacksonville, Florida's *Cecil Field* became the country's eighth commercial spaceport in January, after a four-year effort to win an operator's license from the Federal Aviation Administration. Spacecraft will be able to take off and land horizontally from the site. Virgin Galactic is cited as a customer that could use the location. For now, Jacksonville is the only spaceport on the east coast licensed to fly these types of spaceships, but Kennedy Space Center is looking at commercial uses of the shuttle's landing runway, which won't be needed by NASA in the near future.

Spaceport operators at Cecil don't plan to limit themselves to suborbital operations.

Echostar

EchoStar Satellite terminated its stock purchase agreement to acquire the Mexican Satmex, according to documents EchoStar filed with the U.S. Securities Exchange Commission (SEC). But instead, it made a deal with SES, to lease satellite capacity to EchoStar after the Mexican government granted SES subsidiary Sistemas Satelitales de México (SSM) approval to offer fixed Ku-band satellite capacity into Mexico via the AMC-15 and AMC-16 satellites. EchoStar said it would use the capacity to offer full-time and occasional use space segment to authorized entities in Mexico through SSM while supporting broadcast services for the Dish Mexico direct-to-home service in Mexico and for the Dish Network direct-to-home service in the United States.

GeoEye

Satellite operator GeoEye has contracted with Lockheed Martin Commercial Launch Services of Denver to launch its GeoEye-2 imaging satellite aboard an Atlas 5 rocket, Lockheed Martin announced . >>

Globalstar

Globalstar signed agreements with its independent gateway operator Tesacom in December to launch distribution of Globalstar's Spot Satellite GPS Messenger in Argentina, Chile and Paraguay. The South American Patagonia region boasts some of the world's most popular and breathtaking hiking and skiing destinations but because of its harsh topography, communication can often be difficult. Globalstar expects Spot to provide recreational outdoor enthusiasts as well as enterprise and government customers working in that region with an easy to use way to stay in touch with friends, family and coworkers.

Globalstar began in January installation of satellite telemetry control unit (TCU) upgrades in preparation for the launch of its second-generation, 48-satellite constellation. The pre-launch software and hardware upgrades, provided by Thales Alenia Space, are being installed at Globalstar gateway ground stations in Argentina, Australia, Botswana, France, Republic of Korea and the United States. The installation is intended to provide Globalstar with the capability to globally monitor and control the orbital deployment of its new constellation. The upgrades help strengthen the company's outlook. They help pave the way for the launch and management of the new satellites and all the potential associated with its next-generation constellation. Once deployed, Globalstar will continue building upon its reputation as the leading provider of high-quality consumer Simplex satellite GPS and messaging products and also refocus its energies on providing world-class, two-way satellite voice and duplex data solutions.

Globalstar planned to launch six of its second-generation satellites during a 90-day window that opened on 5 July. The satellites were to be launched by Arianespace from the Baikonur Cosmodrome using the Soyuz rocket. The new Globalstar satellites, part of a constellation that secures Globalstar's space segment beyond 2025, will be integrated with the company's satellites launched in 2007, with a mission to provide legacy and enhanced next-generation satellite voice and data services for at least the next 15 years. Validation tests of the satellite subsystems and thermal vacuum tests have been successfully completed and all was on schedule to begin launching the satellites in July 2010.

The first three satellites in Globalstar's second-generation constellation were shipped to Arianespace for a scheduled October launch on a Soyuz launcher from Baikonur. The satellites will be launched in batches of six, and Thales expects to deliver three more satellites for the first launch by the end of August.

Globalstar contracted Thales Alenia Space for the design and delivery of 48 second-generation constellation low-Earth orbit satellites as part of its financing deal with French credit export agency Coface in March 2009. The second-generation satellites, which are fitted with 16 transponders from C-band to S-band and 16 receivers from L-band to C-band, will provide mobile phone and data satellite services and ensure continuation of Globalstar's coverage through and beyond 2025.

Globalstar signed a joint venture agreement in February with mobile satellite voice and data provider Arion Communication to form Globalstar Asia Pacific. The joint venture will operate the Globalstar gateway ground station in Korea and provide Simplex and duplex mobile satellite voice and data services, including Spot Satellite GPS Messenger products and services, to customers in Korea and the surrounding maritime region. Arion will provide services while Globalstar will provide engineering and technical training and personnel support required for Globalstar Asia Pacific to operate the Korean Globalstar gateway. The companies also confirmed that Globalstar Asia Pacific will work to acquire the existing gateway in Seoul from LG Telecom, which has been Globalstar's service provider in the region since 2001. The acquisition and license transfer are subject to approval by the Korea Communications Commission, which is expected in the next few weeks.

Globalstar acquired Spot LLC, and together they partnered with RaceTracker to provide a safety and tracking solution to competitors at the 25th annual Sultan Marathon Des Sables adventure race in Morocco. The enhanced next generation SPOT Satellite GPS Messenger(tm) will be carried by competitors in order for race organizers and fans to track their progress online between l 4 and 11 April 2010.

The new handheld SPOT Satellite GPS Messenger is the 2G in the SPOT product line following the *SPOT Satellite Personal Tracker*(tm) offering a robust and intuitive user experience in a smaller, more compact size. New features include advanced GPS, a new Custom Message mode and a dedicated button for GPS Tracking. Additionally, the new SPOT comes equipped with GPS acquisition and message sending LED confirmation. In an emergency, SPOT will transmit an SOS message alert to an International Emergency Response Center with the SPOT owner's GPS location updated every five minutes. Since market introduction, the SPOT product line has initiated more than 550 rescues in 51 countries and at sea.

Google - SpaceWorks Commercial

The Spaceport Field Guide (SpFG) is a Google Earth-compatible file developed by SpaceWorks Commercial that provides a database of worldwide launch sites and associated facilities. The tool offers information about global spaceports including location, current and potential facilities, current and potential launch vehicles, and a rating of operational readiness.

Hispasat

Spanish satellite fleet operator Hispasat has contracted with Space Systems/Loral to build the Amazonas 3 telecommunications satellite to be launched in late 2012 into Hispasat's 61 degrees west orbital slot for broadcasts in the Americas and Europe, Loral announced July 6. It is the second consecutive Hispasat satellite to

be built by Loral. >>

ICO Global Communications

ICO Global Communications CEO and CFO Michael Corkery resigned from the company, effective 31 December 2009. Corkery joined ICO in 2007 and was promoted to CEO in February. Benjamin Wolff, ICO's former director and acting chairman of its subsidiary, DBSD North America, will replace Corkery as interim CEO until ICO can find a permanent replacement. The company also appointed Wolff as permanent chairman of the board, effective immediately. Wolff replaces Craig McCaw, who will remain on the board of directors. ICO, under the leadership of Corkery, had been involved in a legal dispute with the European Commission (EC) over its decision in May 2009 to issue Inmarsat and Solaris Mobile exclusive licenses to operate MSS services over S-band in Europe.

International Launch Systems (ILS)

ILS, the U.S. company that markets Russia's Proton heavy-lift rocket, is aiming directly at a key sales advantage touted by its principal European competitor: it will launch a Western-built commercial telecommunications satellite alongside a Russian-built satellite on the same vehicle in 2011. ILS will launch the SES-3 along the Kazsat-2 satellite. Dual launches have been the "trademark" of Arianespace with its Ariane 5 rocket, and the Proton Duo configuration permits ILS to go after small-satellite business that normally would be out of its reach.

ILS launched the Intelsat 16 telecommunications satellite via a Proton-M launch vehicle and a Breeze-M upper stage in February. The satellite was to be sent "directly" to its orbital location, meaning that the satellite will conserve precious manoeuvring propellant, extending its useful life. The spacecraft may have enough propellant for up to 25 years, long beyond its 15-year design life, according to Intelsat engineers.

ILS announced the contract for the ILS Proton launch of two commercial satellites, YAMAL 401 and YAMAL 402, for Russian satellite operator, Gazprom Space Systems. Gazprom is the parent company of Gazprom Space Systems and is the world's largest producer of natural gas. The launches are scheduled for 2012-2013. The 3,150 kg YAMAL 401 satellite, to be launched directly into geostationary orbit will be built by Russian spacecraft manufacturer ISS Reshetnev with a Thales Alenia Space payload. It will weigh approximately 5,250 kg. YAMAL 402 will be launched into geostationary transfer orbit to provide fixed communications and transmission services over Russia, CIS, Europe, the Middle East and Africa. >>

ILS and Asia Satellite Telecommunications Co. Ltd. (AsiaSat) announced a contract for the launch of AsiaSat 7 satellite on an ILS Proton. >>

Intelsat

In December 2009 Intelsat transferred its headquarters from Bermuda to Luxembourg. The company is now known as Intelsat S.A.

In April satellite operators Artel, Caprock and Globecomm filed complaints with the U.S. Federal Communications Commission (FCC) and called for a congressional and regulatory inquiry over alleged unfair business practices employed by Intelsat, the operators confirmed. The companies claim that since Intelsat was privatized in 2000, the operator has dominated the U.S. bandwidth market. The operators referred to the FCC's mandate in the 2000 Orbit Act to annually review

Intelsat's business practices as the base for their proposed call for action. Intelsat stated that it is fully compliant with the Orbit Act, and that the complaints have no merit. Intelsat claimed that the operators' actions are motivated by the U.S. Navy's $536 million award to Intelsat General for its CBSP programme over Artel, Caprock and Globecomm. The comments filed at the FCC by the unsuccessful bidders for the CBSP programme have no merit and reflect a fundamental lack of understanding of the requirements of the Orbit Act. Artel, Caprock and Globecomm previously filed complaints with the U.S. Government Accountability Office (GAO) over the CBSP contract award. The GAO's review is underway.

The Intelsat 15 satellite was launched by Sea Launch, using a Land Launch vehicle at the Baikonur Cosmodrome in Kazakhstan in November. The Ku-band Intelsat 15 satellite, also known as IS-15, was built by Orbital Sciences Corp. The spacecraft aims to provide video and data services from the 85 degrees East orbital slot, replacing Intelsat's 709 satellite. Customers will use IS-15's capacity to distribute in-demand services that include cellular backhaul, wireless communications to remote locations, broadband networking for enterprise applications, IP trunking and video services for DTH programming.

Intelsat's Galaxy 15 "zombie satellite," which had been continuing to send out signals while out of control since April, has sprung back to life, resetting itself after its unexplained breakdown in space earlier this year. Owner Intelsat has been monitoring the satellite since then, working with others to make sure the signals did not interfere with other satellites. On December 23, the battery on Galaxy 15 - which relied on solar panels pointed at the sun to generate power - became completely drained, but once that happened, the satellite reset itself as designed and began accepting commands from Intelsat's control centre. There is a possibility that the satellite could become fully functional again.

Intelsat's IS-16, built by Orbital Sciences Corp., was launched by ILS in February; it will provide expansion capacity for Sky Mexico's DTH services, including HD programming, from 58 degrees West. IS-16 also will provide backup capacity for Sky Brazil. IS-16 is the first Intelsat launch of 2010 and the third in an 11-satellite investment campaign, the largest in Intelsat's history. Intelsat's next launch is expected to be the Intelsat New Dawn satellite, which will deliver new capacity for voice, wireless backhaul, Internet and media applications for customers serving Africa

Intelsat selected Orbital Sciences to build the Intelsat 23 (IS-23) communications satellite based on Orbital's Star-2 platform, it was announced in December. The IS-23 will provide communications services for Africa, Europe and the Americas through 15 Ku-band and 24 C-band transponders from 53 degrees West. The satellite is scheduled to be launched in late 2011. IS-23 will be the 10th Intelsat satellite built by Orbital.

A control processor on the Intelsat 4 satellite (IS-4) failed in January. The IS-4, a Boeing 601-model satellite located at 72 degrees East, is operating on its backup control processor, but the failure of the satellite was not expected to have an impact on Intelsat's financial position or its planned capital expenditures. Intelsat was conducting an investigation with Boeing to determine the cause of the anomaly, and customers were to be moved to other satellites. Launched in 1995, IS-4 was expected to reach its end-of-service life later in 2010.

Intelsat signed a multi-year contract with Etisalat UAE (United Arab Emirates) for Ku-Band capacity on the Intelsat 15 (IS-15) satellite. Etisalat will utilize IS-15 to expand its enterprise network platform beyond the United Arab Emirates and provide higher-bandwidth broadband services to enterprise customers throughout the Gulf region. The IS-15 provides Ku-band coverage that will further enhance Etisalat's market-leading and reliable network for its clients in the banking, energy, financial services, hospitality, retail and transport sectors. IS-15, launched in November, was expected to begin service in the first quarter of 2010 and replace Intelsat 709.

Iridium

Iridium Communications received interest rate commitments on the $1.8 billion credit facility it secured with French credit export agency Coface and a syndicate of international banks in June, to finance the construction of the company's next-generation satellite constellation, Iridium Next. The facility will bear an interest rate of less than 6 percent, the majority of which will be fixed rate and will have a repayment term from 2017 through 2024. Iridium expected to sign the credit facility in September and close shortly thereafter. This represents another important milestone for Iridium, which is pleased with the interest and support for Iridium. The development of Iridium Next is in full swing with prime contractor Thales Alenia Space, and is on target to launch the first Iridium Next satellites in early 2015.

Having secured a favourable interest rate on its Coface loan. Iridium's financing issue is now effectively solved. The only remaining questions are: When, exactly, will the deal close, and just how cheap will the package be? Questions over the financial feasibility of the Iridium Next constellation were answered by the securing of a $1.8 billion credit facility from Coface on June 2.

Iridium communication satellites are being used to warn high-speed ferries and other ships in the northwestern Mediterranean of the presence of whales, an unusual application of the satellite service's maritime capabilities. The warnings are provided to ships passing through the Pelagos Sanctuary for Marine Mammals. The system also protects the animals from death or injury, and to aid their conservation, includes a prohibition on using the warnings to hunt whales or otherwise harm them. A conservation group, *Souffleurs d'Ecume*, is involved in the Real-time Plotting of Cetaceans programme, stated that it is in the process of expanding the programme to encompass all types of vessels.

Iridium Communications announced in June that it set up Iridium South Africa, an entity that will allow Iridium to operate, provide and sell mobile satellite services (MSS) in the country. The authorization was provided by the Independent Communications Authority of South Africa, which regulates communications and broadcasting services. In addition to existing partners with export operations in South Africa, Iridium anticipates opportunities for more than 200 global distribution partners to form new partnerships to deliver services in the country.

Iridium ordered 81 spacecraft to upgrade its global network. Thales Alenia Space of France will build the satellites - 66 to form the operational constellation, the remainder to act as spares. The order makes the Iridium Next venture the biggest commercial space project in the world today. >>

Iridium Communications announced that it has entered into two comprehensive, long-term agreements with Boeing that redefine the relationship between the companies for maintenance, operations and support of Iridium's satellite

network. >>

Lockheed Martin

Lockheed Martin Space Systems Company was selected in March by GeoEye, Inc. to build the company's next-generation, high-resolution Earth imaging satellite system, the GeoEye-2. Lockheed Martin Space Systems designed and built IKONOS, the world's first commercial, high-resolution, Earth-imaging satellite, which has been providing 0.82-meter ground resolution imagery to GeoEye's customers around the globe for more than a decade. These map-accurate images are used for applications in national security, environmental monitoring, state and local government, disaster assessment and relief, land management and for many other geospatial applications.

NASA extended Lockheed Martin's ISS cargo contract. The extension raises the value of Lockheed Martin's Space Station Cargo Mission Services Contract to $405 million. >>

Orbital Sciences

Orbital Sciences was selected by NASA as the prime contractor under the Sounding Rocket Operations Contract 2 (NSROC 2) programme. The two contract carries a maximum total value of $310 million over a five-year term, with a current expected value of at least $125 million. Orbital's technical services division will be responsible for planning, coordinating and carrying out sounding rocket missions from locations in the U.S. and around the world. To support the programme, Orbital is developing a launch site project with NASA and the Mid-Atlantic Regional Spaceport to prepare the Wallops, Va., flight facility to accommodate final assembly and launch operations for the company's Taurus 2 medium-class space launch vehicle and Cygnus cargo logistics spacecraft for missions to the ISS. Initial launches are scheduled to begin in 2011. Sounding rockets are smaller-sized launch vehicles that conduct suborbital missions for high-altitude scientific and atmospheric research. Orbital served as a contract partner on NASA's NSROC 1 team from 1999 to 2009.

Orbital announced that it had signed a contract for a new geosynchronous communications satellite contract with OverHorizon, with offices in the U.S., Sweden and Cyprus. The spacecraft will be based on Orbital's industry-leading STARTM 2 satellite platform and will carry an on-board processing payload provided by Thales Alenia Space. >>

RapidEye

RapidEye announced that a frame contract had been signed with the European Space Agency to provide RapidEye satellite imagery for monitoring and change detection in areas prone to natural disasters. >>

Raytheon

Raytheon won a $886 million contract with the U.S. Air Force to develop and improve the accuracy of information from GPS satellites. The contract represents the first two development blocks, which will include anti-jam capabilities and improved security, accuracy and reliability and will be based on a modern service-oriented architecture to integrate government and industry open-system standards. The advanced control segment (OCX) aims to make it easier for operations teams to run the current GPS block 2 and all future GPS satellites, and will separate the control and space segments.

Sea Launch

Sea Launch, the commercial launch company that filed for Chapter 11 bankruptcy protection earlier in 2009 announced that it had secured financing to continue operations into 2010. An investor known only as Space Launch Services, LLC, has provided Sea Launch with up to $12.5 million in debtor-in- possession financing to keep the company operating as it continues with its restructuring. A major investor in Sea Launch, Boeing, was not expected to have a stake in the restructured company when it emerged from Chapter 11. >> On 9 May 2010, Space corporation Energia received preliminary approval from a U.S. court to pay the operating costs of Sea Launch, possibly with the intention of purchasing the company. >> In July, Sea Launch netted a contract to send an AsiaSat communications satellite to orbit between 2012 and 2014,strengthening the company's backlog as it hoped to emerge from bankruptcy. >> The same month, a Delaware (USA) bankruptcy court confirmed Sea Launch's plan to reorganize under majority Russian ownership Tuesday, clearing a key hurdle on the firm's path to emerge from bankruptcy. >>

In October 2010, the Sea Launch Company successfully completed its Chapter 11 reorganization process. >> This allows the company to emerge from Chapter 11 bankruptcy protection, subject to receipt of certain regulatory approvals. Sea Launch will be 95% owned by affiliates of RSC Energia of Russia, which will be investing more than $140m in capital to restart and fund ongoing operations. As part of the court-approved Plan of Reorganization, Energia Overseas Limited (EOL), a Russian corporation, will have acquired a majority ownership of the reorganized Sea Launch entity. The successor entity, Sea Launch S.a.r.l., will be responsible for corporate functions at its operations headquarters and will maintain some assets at Sea Launch Home Port, in Long Beach, California.

Sea Launch outlined future plans, including the revision of its supply chain management structure with its partner organizations, Excalibur Almaz and PlanetSpace, which are financing Sea Launch through Space Launch Services, and will have an equity investment in a reorganized Sea Launch. Space Launch Services is providing financing to Sea Launch in collaboration with Excalibur Almaz, and is working to provide exit financing, as well as equity investment in a reorganized Sea Launch, for the purpose of sustaining reliable commercial access to space.

Space Systems/Loral (SS/L)

Space Systems/Loral (SS/L) has been selected to provide a propulsion system to NASA's Ames Research Center for the Lunar Atmosphere Dust Environment Explorer (LADEE) spacecraft, SS/L announced in January. NASA's LADEE spacecraft is a small observatory intended to study the moon's thin atmosphere and dust above the lunar surface. The LADEE propulsion system will be a variant of the mission system used by SS/L's geostationary satellites for television, radio, broadband internet, meteorology and a host of other services. The LADEE mission is extremely important in helping researchers understand how the lunar environment will affect future explorers, according to NASA LADEE's Project Manager.

SpaceX

Space Exploration Technologies Corp. (SpaceX) is an American space transport company founded by PayPal co-founder Elon Musk. It has developed the Falcon 1 and Falcon 9 rockets.

SpaceX planned a February or March test flight of its first 180-foot-tall, nine-engine Falcon 9 rocket, which could play a major role in the U.S. space programme by delivering supplies to the ISS. The test flight was originally scheduled for the summer of 2009. After the Falcon 9 test flight at the Cape, the company hopes to launch three demonstration flights of the Falcon 9 and its Dragon cargo capsule before launching 10 flights that carry cargo to the space station as part of a $1.6 billion deal with NASA.

SpaceX's protest of NASA's contract with Orbital Sciences Corp. to launch a scientific satellite for NASA in 2012, was denied in February by the U.S. Government Accountability Office (GAO). SpaceX filed a protest with the GAO that the contract, which would see Orbital launch the Lunar Atmosphere and Dust Environment Explorer (LADEE) satellite on the new Minotaur 5 rocket, was not competitively awarded. SpaceX also claimed the contract violated the Commercial Space Act of 1998, which requires government agencies to buy commercial launch services from U.S. providers and disqualifies Orbital because the Minotaur rocket uses government-provided hardware. GAO found that NASA conducted proper contract procedures and that the Minotaur 5 rocket provided lower risk factors than SpaceX's Falcon 9. GAO also found that the Falcon 9 rocket would be too expensive for NASA at a price of $47 million compared to $27 million for the Minotaur.

SpaceX announced in March that it had received a contract to launch a Space Systems/Loral (SS/L) satellite into a geosynchronous transfer orbit aboard a Falcon 9 rocket as early as 2012. The contract represents SpaceX's 24th Falcon 9 mission on its future flight manifest. With numerous Falcon 9 launches on their manifest over the next two years, SS/L is assured of a successful flight history in advance of its mission, according to SS/L. >> SpaceX also signed a $492 million deal with a satellite phone company to launch a fleet of next-generation commercial satellites aboard its Falcon 9 rocket. >> SpaceX and EADS Astrium announced an agreement to bring Falcon 1 launch capabilities to the European institutional market . >>

Separately, SpaceX completed a successful static fire of the inaugural Falcon 9 launch vehicle at Space Launch Complex 40 located at Cape Canaveral, Fla. The launch sequencer commanded ignition of all nine Merlin first stage engines for a period of 3.5 seconds. The test validated the launch pad propellant and pneumatic systems, as well as the ground and flight control software that controls pad and launch vehicle configurations. The Falcon 9 is in preparations to carry a Dragon spacecraft qualification unit to orbit for NASA.

SpaceX activated its Dragon spacecraft communication hardware aboard the ISS as part of its Commercial Orbital Transportation Services (COTS) contract with NASA. NASA Space Shuttle Atlantis delivered the system hardware to the ISS during mission STS-129 in November. The COTS UHF communication unit, which has completed a series of testing phases, aims to allow ISS crewmembers to monitor and command approaching or departing Dragon spacecraft during cargo delivery missions to the orbiting laboratory.

SpaceX's Falcon 9 and Dragon spacecraft will transport cargo to and from the ISS on a minimum of 12 flights starting in 2011.

SpaceX reached two milestones, one in November 2010, the other in December 2010. In November, it received the Federal Aviation Administration's (FAA) first-ever commercial license to reenter a spacecraft from Earth orbit. Though

the FAA has issued licenses for more than 200 commercial launches, this was the first time it sanctioned a re-entry operation. The license is valid for one year. This was needed for SpaceX to conduct its demonstration flight, which took place in December, for NASA COTS programme to resupply the ISS.

SpaceX placed its Dragon spacecraft into low-Earth orbit atop a Falcon 9 rocket on Dec. 8 and the capsule splashed down into the Pacific Ocean about three hours later. The Dragon spacecraft completed nearly two orbits during its test flight. This is the first time a commercial company has recovered a spacecraft re-entering from low-Earth orbit, SpaceX said. The original launch was delayed due to cracks found on the rocket's second stage engine nozzle extension. This was the first flight under NASA COTS programme to develop commercial supply services to the ISS. Dragon's next scheduled mission is a fly-by of the ISS, where the Dragon will come within six miles of the orbiting station. The first manned Dragon mission to the ISS is scheduled to take place in 2011. This is the first in a new generation of commercial launch systems that will help provide vital support to the International Space Station and may one day carry astronauts into orbit. This successful demonstration flight is an important milestone in meeting the objectives outlined by U.S. President Obama and Congress, and shows how government and industry can leverage expertise and resources to foster a new and vibrant space economy, according to NASA Administrator Charles Bolden.

During the December test launch, the Dragon capsule was affixed to SpaceX's massive Falcon 9 rocket, which had made its first flight in June from Cape Canaveral, Fla. The Dragon capsule orbited the Earth, reentered the atmosphere and splashed down in the Pacific Ocean. This marks the first time a commercial company has successfully recovered a spacecraft reentering from low-Earth orbit. It is a feat performed by only six nations or government agencies: China, India, Japan, the Russian Federation, the United States, and the European Space Agency. The "top secret" payload on board the Dragon turned out to be a wheel of cheese!

Never before has a private enterprise attempted to launch its own spacecraft to orbit the Earth and splash back down intact, and SpaceX pulled off the operation perfectly, NASA and company officials said. The demonstration launch invigorated the US space agency and boosted confidence in the prospect of using commercial vendors to carry astronauts into space and to supply the International Space Station. The Dragon space capsule has room for seven crew and an ample cargo hold that could supply the ISS, after NASA closes down its space shuttle programme in 2011.

Should SpaceX's Falcon 9 and Dragon become the standard vehicle for NASA's trips to low orbit, it could be problematic for the Pentagon's Evolved Expendable Launch Vehicle (EELV), according to the Marshall Institute. If NASA used the EELV, it would reduce costs of the rocket, but the introduction of a new rocket could prove to be a 'double-edged sword'. Falcon could represent a new capability which the Department of Defense might be able to use. While more available launchers could be good, it was noted that the DoD poured a lot of money into the EELV and has much more control over it than SpaceX's Falcon 9. It may be reluctant (for both legitimate and illegitimate reasons) to make greater use of Falcon since that would mean less use of EELV.

According to a recent report of the U.S. Aerospace Safety Advisory Panel (ASAP), SpaceX and Orbital Sciences Corp.'s launch vehicles currently do not meet the required safety standards to transport NASA personnel for the Commercial Orbital

Transportation Services (COTS) programme. ASAP reviewed the programme's human rating requirements for potential commercial and international entities, extension of the shuttle beyond the current manifest, the workforce transition from the shuttle to the follow-on programme, the need for candid public communications about the risks of human spaceflight and more aggressive use of robots to reduce the risk of human exploration. The report stated that it would be unwise to abandon Ares 1I as a baseline vehicle for an alternative without demonstrated capability nor proven superiority (or even equivalence, while not having assurance that any current COTS can 'close the gap' or even provide an equivalent degree of safety is speculative. The report also stated that commercial entities and international partners will likely have a larger role in transporting both cargo and crew to orbit, and suggested that NASA establish safety certification requirements, a certification process for orbital transportation vehicles and a process for validating compliance.

Space Tourism

Burt Rutan, the man behind the SpaceShipTwo spacecraft destined to take tourists to space, announced his retirement in California in November. Rutan, 66, is the founder of the aerospace research firm Scaled Composites, located at the Mojave Air and Space Port in California, where he is currently chief technical officer. Upon retirement, Rutan will assume the title of founder and chairman emeritus. In 2004, Rutan designed SpaceShipOne, called the world's first privately-built piloted spacecraft to reach space. The craft won the $10 million Ansari X Prize, a competition created to spur the development of affordable space tourism. He has partnered with Virgin Galactic, which plans to use Rutan's SpaceShip2 in its sub-orbital flights.

The market for suborbital tourism will expand as the price per seat drops, according to a panel of experts, who estimate the price / cost to reach suborbital space would be between "$50,000 and $100,000 as the industry develops to offer hundreds or even thousands of flights annually.

An additional Soyuz capsule could be built especially for commercial space tourists, the head of Russia's Energia space corporation said in March. This work could start next year. Energia currently manufactures four single-use three-man Soyuz capsules a year, but when the number is raised to five, it could resume space tours that it has put on hold for now.

Space Adventures has a new project-planning the first commercial manned lunar mission. The company is working hard on the project with Russia, but no time line has been established yet. Space Adventures is developing two versions of the mission, with one of them having participants staying 10 days at the ISS. The company's CEO believes his company will continue to be the leading commercial human spaceflight marketing company, and that the market can grow a lot more.

The executive director of the FastForward Study Group in an interview spoke on Space Show about point to point space travel or high altitude and very fast transportation. The FastForward group is looking at the various technologies and regulations that exist and would need to be modified to facilitate point to point high speed travel. Also mentioned were ITAR issues and customs requirements that may need modification upon landing in another country.

On 1 March 2010, after unanimous passage by the state legislature, New Mexico Governor Bill Richardson signed Senate Bill 9, Space Flight Informed Consent Act, recognizing the emerging commercial space industry and the inherent

risks of space flight in New Mexico. >> On 25 October 2010, the dedication of the New Mexico spaceport's runway occurred. >>

Virgin Galactic

The United States launched a national security investigation into the proposed sale of a stake in Sir Richard Branson's Virgin Galactic space company to Arab investors, the Aabar Investments company. According to the press, it is unclear why the Committee on Foreign Investments in the United States (CFIUS) is reviewing the sale, as Branson's latest venture does not appear to have any national security implications for the US.

Virgin Galactic reportedly plans to spend some $400 million to build a fleet of five or six rocket planes. In July 2009, Virgin Galactic sold a 32% stake of the company, which is valued at about $900 million, to an Abu Dhabi-based investor raising $280 million to help fund future test-flight programme. Virgin Galactic stated that it expects the capital infusion to fully fund the company to its commencement of commercial operations. Branson said he planned to be on the craft's first passenger flight in some 18 months accompanied by his family and the American designer of the space ship, Burt Rutan. While Virgin Galactic enterprise will have competitors, it is likely to be the first to market, barring any problems arising in the test campaign.

SpaceShipTwo may fly soon: a Scaled Composites log entry showed a nearly 4-hour flight of the WhiteKnightTwo mother ship on March 4 that tested the launch pylon for the space plane. In February, Virgin Galactic said the first SpaceShipTwo captive flight would take place by the end of March.

Earlier reports said that SpaceShipTwo was expected to make its first test flights in the early months of 2010, as it has been undergoing flight tests since December last year. To date, 300 people have paid in full for their ticket, while a further 82,000 have registered their interest. Some reports state that Virgin Galactic is making slow progress. There are safety issues, and the company is stressing that it will take passengers only once it is sure the craft is safe. Even at that point, the first year's anticipated flight tempo is slower than originally planned by Branson and partner Burt Rutan.

In December 2009, Virgin Atlantic founder Richard Branson unveiled the new bullet-shaped commercial rocket plane that will give tourists the opportunity to take a ride into space and see the Earth while experiencing weightlessness. The spacecraft, about the size of a large business jet with wide windows and seats for six, represents a costly gamble on a commercial space tourism industry. The British billionaire said that he hopes to sell tickets for the Virgin Galactic spaceliner at $200,000 a piece, which is a fraction of what it costs to board a NASA shuttle or Russian spaceship. Branson added that he planned to be the first passenger in about 18 months. >> >>

Virgin Galactic has announced that it will be supporting Sierra Nevada Space Systems' (SNC) and Orbital Sciences Corporation's (OSC) work on commercial space vehicles. >>

Stratos Global

Stratos Global was contracted in February to supply Inmarsat BGAN mobile satellite data and voice services to the University of California San Diego (UCSD) to support archaeological research in remote areas of Mongolia. Stratos' equipment supplier ViaSat donated its VRT-100 rugged BGAN terminal for UCSD's project,

which is supported by the joint National Geographic Society/Waitt Grants Program. Access to BGAN from Stratos, with the rugged VRT-100 terminal, provides reliable connectivity in northeastern Mongolia's Forbidden Zone, one of the world's most remote regions. The service is playing a critical role in helping maintain the highest levels of safety and productivity while in the field, according to UCSD.

TerreStar Networks

TerreStar Networks became the latest mobile satellite services provider to seek protection from its creditors under U.S bankruptcy law and asked its bankruptcy court to allow EchoStar Corp. to invest $75 million immediately to enable TerreStar to remain operational while its reorganization proceeds. In a statement to the court, TerreStar CEO sought to portray TerreStar as a company on the threshold of building a successful business that needs only to secure the additional capital to complete the system's commercial roll-out and cover marketing costs.

Other developments

The director of Kennedy Space Center said the spaceport's two launch pads, mammoth Vehicle Assembly Building and other one-of-a-kind facilities will be upgraded and made available to private space companies after the space shuttle's retirement. >>

In Chicago, Illinois, the Space Investment Summit Coalition held its eighth summit, attracting approximately 100 participants. The coalition encourages funding of space-related startups by private seed-money and early stage investors. These conferences stimulate theme-based dialogue regarding emerging space markets and host investor oriented business-plan presentations. The Chicago summit explored space-related entrepreneurial opportunities in a wide variety of markets, including transportation, communications, biotechnology, materials, and education. >>

In November 2009, the Indian Space Research Organisation announced it was ready to outsource more high-end work to private companies - everything from building more complicated systems to assembling it. >>

Aerospace Propulsion Products (APP) signed a major production contract for Ariane 5 rocket engine ignition equipment. The contract was signed with the Snecma (Safran group) and included the production and delivery of pyrogen igniters and starters for the Vulcain(r)2 rocket engines of 35 Ariane 5 launchers. >>

Blue Origin selected three unmanned research payloads to fly on the New Shepard suborbital vehicle as a part of Phase 1 of the New Shepard Research Flight Demonstration Program. >>

The Danish high-tech company Terma is to head a European space project with the objective to take measurements and make observations from the International Space Station. >>

Global satellite operator SES and Astrium announced that SES has ordered four multi-mission satellites from Astrium to provide replacement as well as incremental capacity for its SES ASTRA and SES WORLD SKIES divisions. >>

Space Florida announced that it is currently engaged in dialogue with Lockheed Martin and ATK regarding the use of Space Launch Complex 46 at Cape Canaveral as a key Florida launch location for the next generation of Athena rockets. >>

Astrium Services signed a 10-year partnership with the Russian research and development centre ScanEx for the reception and distribution rights on the upcoming SPOT 6 and 7 satellites. This partnership, which also provides ScanEx the exclusive reception and distribution rights on the SPOT 5 satellite, is part of a long term cooperation programme between Astrium and Russian industry. >>

Russian Satellite Communications Company (RSCC) has signed contracts with Information Satellite Systems and Thales Alenia Space for the development of three new satellites. >>

A project was been announced to launch three new British spacecraft to image the surface of the Earth. The satellites, to be orbited in 2013, will be able to see details down to one metre at their best resolution. Nations that would not necessarily need their own dedicated satellites will be able to buy time on the spacecraft. The Guildford-based SSTL made the announcement at the International Astronautical Congress in Prague. >>

Global satellite operators SES S.A., Intelsat, Ltd., and Inmarsat plc announced that they have founded the Space Data Association Ltd. (SDA) >>

A new space centre at Australia's RMIT University will focus on developing low-cost satellite-based remote sensing products. >>

IX. INTERNATIONAL COOPERATION AND SPACE LAW

IX.1 Global Developments and Organisations

IX. 1.1 Status of UN Treaties

Since 1987, the International Institute of Space Law (IISL) compiles an annual report on the status of international agreements relating to activities in outer space. This report includes signature, ratification, as well as declaration of acceptance of rights and obligations that have taken place since January 2010. It is published on the IISL website and in its Proceedings.

IX.1.2 International Organisations

COPUOS (United Nations Committee on the Peaceful Uses of Outer Space)

The 49th session of the Legal Subcommittee of COPUOS took place from 22 March to 1 April 2010 in Vienna, Austria (see its report, document A/AC.105/942 at www.unoosa.org). During the session, several delegations spoke on their national laws and legislation. France presented its 2008 space law, which is now in force, but enabling legislation is being drafted. Germany presented its national law, focusing on the use and control of images obtained by Earth observation systems. Italy is in the process of drafting legislation related the registration of space objects. A table of countries and their national legislation related to outer space was made available during the 49th session of the Legal Subcommittee in document A/AC.105/C.2/2010/CRP.12.

The 53rd session COPUOS took place from 9 to 18 June 2010 in Vienna, Austria. The report is available as document A/65/20 at www.unoosa.org.

The United Nations/Thailand/European Space Agency co-sponsored a Workshop on Space Law "Activities of States in Outer Space in Light of New Developments: Meeting International Responsibilities and Establishing National Legal and Policy Frameworks", which took place from 16 to 19 November 2010 in

Bangkok, Thailand.

European Space Policy Institute (ESPI)

ESPI co-hosted, together with the IAA and IISL a conference entitled "Current legal issues for satellite Earth observation", which was held from 8 to 9 April 2010 in Vienna, Austria**.** Kai-Uwe Schrogl, Director ESPI, Tanja Masson-Zwaan, President IISL, and Jean-Michel Contant, Secretary General IAA delivered the welcome addresses. The topics addressed included Treaty monitoring and law enforcement through satellite Earth observation; Privacy conflicts from high resolution imaging; The European Convention on Human Rights and EC law - Two European legal approaches to privacy, as relevant to high-resolution imaging.

International Astronautical Federation (IAF)

The 61st International Astronautical Congress (IAC) took place from 27 September to 1 October, in Prague, Czech Republic. The IAC was organised by the International Astronautical Federation (IAF) and the Czech Space Office. The theme of this year's IAC was "Space for Human Benefit and Exploration." Some 3500 persons attended this year's IAC. >> The IAF General Assembly in Prague selected the host city for the 64th International Astronautical Congress (IAC 2013). It will be held in Beijing, China and hosted by the Chinese Society of Astronautics. >> At the IAC, the International Astronautical Federation welcomed 16 new members bringing its total membership to 205. >>

The twentieth UN/IAF Workshop on "GNSS Applications for Human Benefit and Development" was held in Prague, Czech Republic, from 24 to 25 September 2010, as an associated event of the 61st IAC. The Workshop was jointly organised by the UN Office for Outer Space Affairs (OOSA) and IAF, and it was co-sponsored by ESA and the International Committee on Global Navigation Satellite Systems (ICG). The event was hosted, on behalf of the IAC Local Organising Committee, by Ministry of Education, Youth and Sports of the Czech Republic. The Workshop discussed GNSS technologies, applications and services that contribute into sustainable economic and social development programmes, primarily in developing countries.

The IAF co-organised the Global Lunar Conference (GLUC) in Beijing, China from 31 May to 3 June 2010, in partnership with the Chinese Society of Astronautics (CSA). This event included the 11th International Conference on Utilisation of the Moon (ICEUM), organised by the International Lunar Exploration Working Group (ILEWG). GLUC focused on one of the major challenges of the next decade: lunar exploration. This event was extremely well-attended, and more than 400 papers were presented.

On 1 November 2010, IWSCFF 2010 convened in Taiwan, Province of China. It was the sixth in a series of specialist events organised by the IAF Astrodynamics Committee to address the growing interest of the international space community in the area of Satellite Constellation and Formation Flying. >>

International Academy of Astronautics (IAA)

The IAA and IISL held their First Symposium on 11 May 2010, in Washington, DC, on the topic of "Space Law & Policy 2010." This event was co-sponsored by the ESPI, the Secure World Foundation (SWF), and Arianespace. The discussion focused mainly on developments in the U.S., but also provided European and transatlantic perspectives. The Symposium examined the scope of space

regulations and their impact on the U.S. civil, commercial, and government activities. The event, held at the Carnegie Endowment for International Peace Building and attended by more than 100 persons, emphasized the importance of addressing the current space law issues by U.S. policy-makers.

The IAA hosted the first "Heads of Space Agencies Summit" on 17 November 2010, in Washington, DC. The event, co-sponsored by NASA and Lockheed Martin inter alia, brought together leaders of the world's space-faring community, as well as executives of national space agencies.

International Institute of Space Law (IISL)

The IISL celebrated its 50th anniversary since its establishment. Several special events were organized to celebrate its accomplishments, among them a reception in Prague, following a Poster Presentation by Young Authors. The IISL also plans to publish a book on notable people in the field of space law.

The IISL held its 53rd International Colloquium on the Law of Outer Space during the 61st International Astronautical Congress, Prague, Czech Republic, between 27 September and 1 October. The Colloquium opened with the Nandasiri Jasentuliyana Keynote Lecture on Space Law, delivered by Dr. Steve Doyle, who presented a brief history of the IISL. The second Young Scholars Session was also held during the same session.

The other 4 sessions addressed the following topics:

- 30 Years of the Moon Agreement: Perspectives;
- Legal Aspects of Space Security;
- Current Status of the Rule of Law with Regard to Space Activities;
- Recent Developments in Space Law.

In addition, two other sessions took place: the 25th IAA/IISL Scientific-Legal Roundtable focusing on "The new age of small satellite missions", and the Joint IAF-IISL session on the Legal Framework for Collaborative Human Space Missions, held on the last day of the IAC.

Manfred Lachs Space Law Moot Court Competition

Since 1992, the IISL has organized the Manfred Lachs Space Law Moot Court Competition. The 19th Space Moot Court competition was held in Prague, Czech Republic during the IISL Colloquium. Three regions were represented:, Asia -Pacific (29 teams), Europe (9 teams) and North America (10 teams). The finals were held on 30 September at the Regional Court of Pilsen, with Judges Abdul Koroma, Peter Tomka and Leonid Skotnikov presiding. The world finals were won by the team from George Washington University (USA); the team from the National University of Singapore finished as first runner-up and the team from the University of Cologne (Germany) as second runner-up.

The George Washington University team won the *Lee Love Award,* established in 2008 for members of the winning team. Ms. Ying Li Zanetta Joan Sit of the National University, Singapore, won the *Sterns and Tennen Best Oralist Award*, while the *Eilene Galloway Award for Best Brief* was won by the National University of Singapore.

Next year's case is available at http://www.iislweb.org/docs/2011problem.pdf. The world finals will be held during the IAC in Cape Town, South Africa, on 6 October 2011.

The *Isabella H.Ph.Diederiks-Verschoor Award and Prize for Best Paper by a Young Author* was awarded to Mr. Philip De Man (University of Leuven, Belgium), for his paper entitled "The Commercial Exploitation of Outer Space and Celestial Bodies – A Functional Solution to the Natural Resource Challenge".

The IISL also honoured three persons in Prague. Prof. V. Kopal (Czech Republic) received the IISL Lifetime Achievement Award. Prof. Kopal has a long and outstanding career in space law amongst others as Chief of the UN Office for Outer Space Affairs, Chairman of the Legal Subcommittee of COPUOS and General Counsel for IAF and IAA. In addition, he has taught space law for many years first at the Charles University of Prague, then at the University of Plzen. Prof. Kopal also is a Director and Vice-President of the Institute, and has published widely on many issues of space law.

Dr. S. Ospina (Colombia, United States) was awarded the Distinguished Service Award for her many contributions to the work of IISL, including the UN Highlights in Space Reports and the Manfred Lachs Moot Court Competition. Dr. Ospina is also a Director of the Institute, and a well-known author of many articles in the field.

Dr. J.M. Contant (France) received the Certificate of Appreciation. Dr. Contant serves as Secretary-General of the International Academy of Astronautics (IAA), and has contributed to the cooperation of IAA and IISL, through joint IAA/IISL conferences, and the IAA/IISL Scientific /Legal Roundtables at the annual International Astronautical Congresses.

Eilene M. Galloway Symposium on "Critical Issues in Space Law"

The 5th *Eilene M. Galloway Symposium* was held on 2 December 2010 at the Cosmos Club in Washington, DC. This symposium is organized, sponsored and coordinated by the National Center for Remote Sensing, Air and Space Law (University of Mississippi) in cooperation with the IISL, and is held in honour of Dr. Galloway and her long-standing contribution to space law. This year's symposium focused on Article IX of the Outer Space Treaty, which deals with cooperation and mutual assistance in outer space activities. It was attended by more than 150 persons, who heard panellists address a variety of issues (space debris, harmful interference, the need for international consultation) as they relate to Art. IX of the OST. For highlights of the symposium visit http://rescommunis.wordpress.com/.

IISL/ECSL Symposium for UN-COPUOS

The annual IISL/ECSL Symposium for delegates and staff of the COPUOS Legal Subcommittee took place at the 49th Session of the Legal Subcommittee of COPUOS, which was held from 22 March to 1 April 2010 in Vienna, Austria. The topic of the symposium was "National space legislation: crafting legal engines for the growth of space activities."

Chairs for this event were Tanja Masson-Zwaan, President IISL, and Sergio Marchisio, President ECSL. Prof. Armel Kerrest spoke on "The need to implement the Outer Space Treaty in national law in the light of current and foreseeable space activities." "Space legislation as enhancer of space activities and policies", was addressed by Henry Hertzfeld; "Matching detail with practice: what are the essential elements that need to be specified in national space legislation?", by Steven Freeland; "Considerations on space liability insurance", by Phillippe Montpert; "Economic impacts of national space legislation and the establishment of fair conditions for

commercial activities", by Matxalen Sánchez Aranzamendi; and "Accompanying space regulations: ensuring safe in-orbit operation and interoperability", by Heike Wieland. Concluding remarks were made by the Chair of the Legal Subcommittee and by the Chair of the Working Group on National Legislation Relevant to the Peaceful Exploration and Use of Outer Space.

The papers and presentations delivered during the symposium were made available on the website of the Office for Outer Space Affairs of the Secretariat (www.unoosa.org/oosa/COPUOS/Legal/2010/symposium.html).

European Centre for Space Law (ECSL)

Summer Course

The ECSL held its 19th Summer Course on Space Law and Policy at the University of Jaén, Jaén, Spain, from 30 August to 10 September 2010. The Summer Course attracts participants from an increasing number of European universities.

ECSL Practitioners' Forum

A one-day Practitioner's Forum has been organised every year since 1992. The aim of the Forum is to provide those working in the space sector with an informal forum for the exchange of views, knowledge and information. The 2010 annual ECSL Practitioners' Forum took place at ESA Headquarters in Paris, on 19 March 2010, on the theme "Galileo : Current Legal Issues". The Forum was co-chaired by Prof. Sergio Marchisio, President of the ECSL, and Prof. Frans von der Dunk, Univ. of Nebraska. Prof. von der Dunk opened the Forum, and spoke about the added value that the Galileo project brings to the existing GNSS environment as it adds to the value of GPS and EGNOS and raises the standards of a number of potential GNSS services. EC Regulation 683/2008 provides the legal framework for Galileo, while ESA has become the procurement agency for the EU; however, some major legal issues remain, such as the procurement- and liability-related questions.

Prof. Ir. R. Oosterlinck, ESA's Director of the Galileo programme and other activities spoke on "Institutional issues: ESA rules in the context of Galileo", and referred to EC Regulation 683/2008. Two speakers from the European Commission, Mssrs. Seité and Petrou added to the presentation by highlighting that the law applicable to Galileo procurement has as its basis the EU Treaty (Article 17), Regulation 683/2008, and the Financial Regulations and implementing rules. Dr. Heinrich, of BHO Legal, spoke on "The Procurement Law Background," elaborating on the EU framework for procurement law, discussing Directives 2004/18 and 2004/17 as applicable to EU member states, and the EU Financial Regulations and implementation rules applicable to EU bodies. He discussed the ESA procurement rules versus the EU procurement rules: the geographic return principle is the main differentiator between them.

The afternoon session, on Liability for Satellite Navigation Signals and Services, was chaired by Dr. P. Hulsroj, Director of Legal Affairs and External Relations at ESA. Prof. Dr. M. Couston, of the University of Lyon's Faculty of Law, spoke on "Galileo and the Work of the 'Groupe Responsabilité ANAE.' Prof. Dr. L.J. Smith, of Leuphana University in Germany, dealt with "Liability for Satellite Navigation Signals and Services", concluding that in view of the absence of a dedicated international regime for GNSS, the discussion focuses on navigational services and the applicability of some Articles of the 1972 Liability Convention, as well as the issue of contractual versus tort liability. Prof. Dr. A. Roma, of Studio

Associato AS&T, spoke on "Liability for Galileo Services: towards an EU Legal Act", and discussed several relevant efforts undertaken in 2007 and 2009 to arrive at EU regulation on the issue. Dr. H.G. Bollweg, Ministerial Counsellor of the Federal Ministry of Justice of Germany, presented on an interesting question: "Is an international instrument to cover liability for damage caused by malfunctioning in global satellite systems feasible?" He noted that the transition towards an environment for successful Galileo operations will be severely handicapped if the liability issues have not been resolved and addressed in detail, particularly in regard to private stakeholders' liability.

The ensuing discussion and the day's presentations were summarised by the Coordinator, Prof. Von der Dunk. He concluded that the situation has changed from one where the EU and ESA were at odds as to the applicability of their respective procurement regimes, to where the EU was the owner and ESA its procurement agency. This arrangement seems to be satisfactory to both the EU and ESA. Thus, procurement is no longer the main issue; liability questions are now the major legal obstacles awaiting the Galileo project.

International Law Association (ILA)

The International Law Association (ILA) Space Law Committee, a permanent observer to COPUOS since 1996, took part in the Legal Subcommittee of COPUOS last March-April and submitted a report as well as made an oral presentation on the work of the ILA during 2009. It concerned the results and recommendations adopted at the 73rd ILA Conference in Rio in August 2008 and work of the Space Law Committee for ILA's 75th Conference (the Hague, 15-20 August 2010). The work of ILA focused on remote sensing (with special reference to the use of satellite data in national and international litigation), national space legislation, registration, space debris (following the UNGA Resolution of 21 December 2007), and also introduced some basic questions on NEOs with a view to addressing the subject in its future work.

UNIDROIT

The International Institute for the Unification of Private Law (UNIDROIT) has been working on a *Draft Protocol On Matters Specific To Space Assets* for several years. In its most recent draft, the Protocol would apply only to the satellite itself, and not to more controversial items, such as licenses. In November 2007, UNIDROIT Assembly of Parties established a Steering Committee, with the aim of finalizing the Space Assets Protocol in a timely manner. At the 2010 Spring meeting of the Legal Subcommittee of COPUOS, UNIDROIT presented a revised version of the Protocol, following a meeting of governmental experts held in December 2009 in Rome. In the course of this meeting 2 alternative versions of the Draft Protocol were presented and discussed. Since many points were still under discussion, it was decided to hold another conference in May 2010, to attempt to come to an agreement on the final text. At the May conference, it was decided to hold yet another meeting in early 2011, prior to submitting the final text for signature and ratification. In the meantime, various delegations to COPUOS suggested that this item remain on the agenda of the COPUOS Legal Subcommittee.

Other International Endeavours

International Space Station (ISS)

2010 marked the 10th anniversary of the ISS operations. US President Barack

Obama hailed the 10th anniversary of crews aboard the ISS as an important milestone in the history of human space exploration. Thanking the astronauts, Obama said the ISS has brought disparate nations together for a common purpose - to better our lives on Earth and "as we look to the next 10 years, we can only imagine what's in store for our future astronauts, engineers and scientists." Obama also noted the extraordinary value of the space station and said the decision to extend the ISS to 2020 "will allow NASA to pioneer new frontiers in education and international cooperation that will maximize the scientific return of this important foothold in space."

The ISS crew marked the 10th anniversary of continuous human occupation of the orbiting science laboratory with a typical workday, pausing only briefly for a chat with NASA Administrator Charles Bolden and questions from international reporters;

During these 10 years a total of 297 cosmonauts and astronauts - representatives of 16 countries - worked onboard the ISS; their total flight time within the Station exceeded 13.3 thousand days including the women's flight time of about 1.7 thousand days. Activities for the ISS development started upon signing The Joint Statement on Space Cooperation by Prime Minister of the Russian Federation Viktor Chernomyrdin and U.S. Vice-President Al Gore on September 2, 1993; the Joint Statement envisaged the development of the Station consisting of two integrated segments (the Russian and the American).

The ISS gradually built up to include several other separate modules in orbit. Ten years ago the crew of Expedition 1 (the ISS-1) began to work onboard the ISS. This historical moment became possible due to the use of the Russian space technologies which were tested during many decades under the Soyuz, Salyut, Mir programmes and embodied in Service Module Zvezda and modern vehicles Soyuz TM, Soyuz TMA.

The basis for the successful implementation of the ISS project is the use of the world leaders' experience in manned cosmonautics, scientific - technical and production potential of all partners and participants, their close cooperation and mutual assistance, especially clearly revealed when the critical situations occurred which hindered the performance of the most important programme tasks. The ISS is a unique example of cooperation and partnership in outer space. With the retirement of the US Shuttle vehicles, it is likely that Russian vehicles will be used to ferry up the astronauts and supplies needed to ensure the sustainability of the ISS.

ESA Director General expressed the desire to extend the station to at least 2020, saying it would be a mistake to end it sooner. One of the biggest issues holding up an agreement on station-life extension was the human spaceflight review ordered by US President Barack Obama. According to ESA, it is essential to reduce costs and increase benefits derived from the station, and one way to reduce costs would be to bring in new partners outside the current five, which is something to be discussed further.

The 27-nation European Union and individual European nations that are not taking part in the international space station will be able to place experiments on the orbital complex for a three-year trial period that ultimately could provide a fresh revenue source for the project, ESA officials said. As for extending the station through 2020, the agency still expects to win its member states' formal support for the station extension operations to 2020.

Heads of the five space agencies in the ISS partnership have decided to try to expand participation by other nations in the orbiting laboratory, while not opening up the formal partnership to new members. NASA Administrator Charles Bolden announced the move in March, which was decided upon at an ISS partners meeting in Tokyo. A recent ESA 'presentation of opportunities' was cited as an example of the sort of work the heads of the partner agencies would like to see expanded beyond member states. China has informally expressed interest in sending astronauts to the ISS. There are no technical constraints to extending the operation of the ISS until at least 2020, according to top international space officials who met in March in Tokyo to review the prospects for cooperation over the next decade.They expressed their strong mutual interest in continuing operations and utilization for as long as there are demonstrable benefits to using the ISS. With the assembly of the ISS nearing completion and the capability to support a full-time crew of six established, the heads of the agencies noted the outstanding opportunities now offered by the ISS for on-orbit research and for discovery including the operation and management of the world's largest international space complex. The decision to extend the service life of the orbital station must be adopted by the governments of all 15 countries participating in the project. Upon its completion, the ISS will weigh 470 tons and be 109 meters long, 88.4 meters wide. Its total cost is expected to be $40 billion.

In December 2009, a tiny piece of a defunct Russian satellite zipped by the ISS, but was far enough away that the two-man crew did not have to strap into their lifeboat. While NASA detected the object too late to move the space station clear of the incoming space trash by firing its thrusters, an analysis of the object's trajectory found that, despite its close pass, the satellite remnant posed no danger of hitting the space station. This is the third time in less than a week that station managers kept a watchful eye on debris near the space station.

Engineers at NASA's Goddard Space Flight Center are developing an in-orbit test bed to validate techniques for refuelling satellites that weren't designed to be refuelled. The experiment would use Canada's Dextre robotic arm aboard the ISS. The experiment would simulate cutting into a spacecraft's insulation, tapping into its fuel plumbing, and refilling its tanks to extend its service life. Funding for the work was supplied by the US Congress to capture the lessons learned from the five Hubble-servicing missions, but the appropriation doesn't cover an actual flight test.

Space station resident Timothy (TJ) Creamer had been working with flight controllers to establish Internet access from his orbital post ever since he moved in, in December 2009. A month later, his effort paid off. He posted the first live Twitter post truly from space, when Creamer was able to send the first "live" Tweet from the station, which previously had to be sent through Mission Control. The astronauts will be subject to the same Internet access guidelines as other on-the-job government employees.

In November 2010, ESA reported that it would operate a small greenhouse for space voyagers. According to an Italian astronaut, growing plants in space will be crucial for the astronauts of the future. When flying to Mars or even further, it will be necessary to produce fresh food onboard and become partially self-sufficient. Setting up greenhouses on the Moon, Mars or other planetary bodies will also be an important part of future exploration missions, as greenhouses provide oxygen and also bring some life to the bleakness of space. The experiment will be launched in mid February 2011 with a live event linking together nearly 750 children in four locations in

Europe: the European Astronaut Centre in Cologne, Germany; ESRIN in Frascati, Italy; Cite de l'Espace in Toulouse, France; and Ciencia Viva - Agencia Nacional para a Cultura Cientifica e Tecnologica in Lisbon, Portugal.

Space Weather

The coming year (2011) will be an important one for space weather as the Sun pulls out of a trough of low activity and heads into a long-awaited and possibly destructive period of turbulence, according to NASA's Space Weather Prediction Center. It said current predictions place the peak of the current solar cycle in 2013, but there is a prolonged period of high activity, more like a season, lasting about two and a half years, either side of the peak. While the coronal mass ejections (CMEs) from the sun can cause problems for satellites and systems on Earth, a NASA spokesman said he thinks there is some hyperbole about the draconian effects although he added that there's a lot we don't know about the Sun.

Weather in space is becoming an important topic for airlines. Space weather can affect planes' communication and navigation, especially those that fly close to the Earth's poles where there is less protection. With more polar flights each year and the weather in space likely to get worse, it 's increasingly likely that air traffic controllers will have to divert flights that are already in the air, according to meteorologists with the US's Federal Aviation Administration.These diversions could be prevented if space weather predictions were as accurate as current terrestrial weather predictions.

Space investments/expenditures by Governments

Worldwide government expenditures for space programmes grew by 10 percent in 2009 over 2008, reaching an all-time high of $68 billion, according to French-based Euroconsult's report, released Feb. 23. The report, "Profiles of Government Space Programs: Analysis of 60 Countries & Agencies," states that both civil and defence spending have grown dramatically in 2009, with government expenditures for civil space programmes increasing 9 percent to $36 billion and spending for defence space programmes climbed to $32 billion, a 12 percent increase compared to 2008. Over 50 countries are now investing in domestic space programmes and annual budgets in six countries – the United States, Russia, Japan, China, France and Germany – were over $1 billion in 2009. U.S. national space expenditures alone totalled $48.8 billion in 2009.

However, Euroconsult analysts believe that the growth will not last long. In the U.S. defence sector, the FY2011 budget foresees an 8 percent decrease for the U.S. Department of Defense space programme due to the near completion of Satcom, Satnav and Reconnaissance programmes, combined with the cancellation of major initiatives such as TSAT. In addition, the decision to terminate NASA's Constellation programme and to put the future of US-based human spaceflight on hold demonstrates more careful management of government money than what was observed during the last decade.

Russia's national space expenditures grew at over 40 percent on average per year over the last five years, with its budget reaching an all-time high of $2.8 billion in 2009. However, according to Euroconsult, the country will experience more modest growth in the coming years. A total of 26 countries initiated a domestic space programme in 2009 with average investments between $5 million and $50 million.

The number of nations with national space agencies has continued to grow after a pause in the 1990s, rising from 40 in 2000 to about 55 in 2009, according to a

survey by Paris-based Euroconsult. Some of these are 'fragile' with only one project, and little budget. The U.S. remains the dominant player in space investment in dollar terms: Euroconsult set total U.S. civil and military space spending at $48.8 billion in 2009, or nearly 72 percent of the world's total government space outlays that year. Overall, growth was faster for the military space sector, with governments in 2009 increasing their spending to $32 billion, a 12 percent increase over 2008.

International Telecommunication Union (ITU)

The International Telecommunication Union (ITU) announced in March that it had set a series of new standards to enhance satellite communications in emergencies. These standards for satellite services aim to facilitate early warning, rapid response and relief operations in the event of natural disasters.

Recommendation ITU-R S.1001-2 provides information on the range of radio frequencies that can be used by fixed satellite service (FSS) systems for emergency and disaster relief operations. Recommendation ITU-R M.1854 provides information on the range of radio frequencies for mobile satellite service (MSS) in order to enable a variety of functions such as voice and data communication, field reporting, data collection, position information and image transmission.

Establishing communications in the aftermath of a disaster is vital to facilitate rapid and effective rescue and rehabilitation efforts. The new ITU Radio communication standards for satellite communication in emergencies will greatly improve the capacity to save lives. All stakeholders, including administrations, satellite operators and service providers are urged to support the development of robust, comprehensive, early warning and relief systems to mitigate emergencies and disasters at the national, regional and international levels.

Other organisations

Following the 7.0-magnitude Haiti earthquake that hit on January 12, international agencies requested satellite data of the area from the International Charter on Space and Major Disasters. Very High Resolution images from Earth observation satellites can help rescue efforts by providing updated views of how the landscape and the infrastructure have been affected. They can help generate emergency maps to provide rescue services with an overview of the altered state of the area. >>

On 21 January 2010, various parts of Gaza witnessed unusually heavy rains and severe flooding, fully swamping some of the region's agricultural lands, cutting off roads, washing away bridges, and forcing hundreds from their homes and farms. In response to this disaster, and at the request of the UNDP and UNOCHA offices covering Gaza, UNOOSA/UN-SPIDER activated the International Charter: Space and Major Disasters and alerted other satellite data providers about this disaster, as well as about the specific needs for post-disaster satellite imagery. Consequently, UNOCHA offered pre-disaster aerial imagery for any imagery-based assessment exercise, and pre and post-event radar satellite images (ALOS/PALSAR, RADARSAT) were soon made available by the Japanese Aerospace Exploration Agency (JAXA) as well as the Canadian Space Agency (CSA), both members of the International Charter. The Ukraine Space Research Institute (NSAU), soon to become a UN-SPIDER Regional Support Office, also offered to analyse and process the available radar images as a value-added provider, to assist any response or recovery efforts. >>

The heads of the ISS agencies from Canada, Europe, Japan, the Russian Federation and the United States met in Tokyo, Japan, during March, to review ISS cooperation. The heads of agency reaffirmed the importance of full exploitation of the station's scientific, engineering, utilization, and education potential. They noted that there are no identified technical constraints to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and that the partnership is currently working to certify on-orbit elements through 2028. The heads of agency expressed their strong mutual interest in continuing operations and utilization for as long as the benefits of ISS exploitation are demonstrated. >> In September 2010, the ISS partner agencies met again by videoconference to discuss continuation of space station operations into the next decade and its use as a research laboratory. >>

At the conclusion of the fourth India Brazil South Africa Dialogue Forum (Ibsa) summit in Brasilia, the leaders of the three countries - South African President Jacob Zuma, Indian Prime Minister Manmohan Singh and Brazilian President Luiz Inacio Lula da Silva - announced that they had agreed to set up a trilateral satellite programme. >>

On June 22, 2010, COSPAR Panel on Exploration (PEX) published a report titled “Toward a Global Space Exploration Programme: A Stepping Stone Approach”.

The 38th COSPAR Scientific Assembly took place from 18 to 25 July 2010 in Bremen, Germany >> COSPAR elected a new president, Prof. Giovanni Bigniami. >>

The 2010 UN-IAF Workshop was entitled GNSS Applications for Human Benefit and Development and held in Prague, Czech Republic on 24 and 25 September 2010. >>

In October, as countries around the world celebrated the 10th anniversary of the International Charter of Space and Major Disasters, the UK has confirmed that it will chair this important collaboration from April 2011. >> At an event in Paris to celebrate the tenth anniversary of its founding, Johann-Dietrich Wörner, Chairman of the DLR Executive Board, signed the charter, marking DLR’s accession. >>

A step forward in planetary defence was the establishment of a high-level Mission Planning and Operations Group, a body that was strongly advocated during a three-day meeting of experts held at ESA's European Space Operations Centre in Darmstadt, Germany. >>

IX.2 Africa and the Middle East

The first African monitoring of environment for sustainable development (AMESD) forum took place. The African Union programme of AMESD aims to increase the information management capacity of African regional and national institutions in support of decision makers by facilitating sustainable access to Africa-wide environmental information derived from Earth Observation (EO) technologies. >>

The third African Leadership Conference on Space Science and Technology for Sustainable Development launched two regional space partnerships on increasing space benefits for Africa's sustainable development. >>

ESA's TIGER II initiative selected 20 project proposals across Africa to receive support from Earth-observation technology to learn more about the water cycle and to improve water-monitoring resources. >>

Nearly 100 decision-makers and senior experts met from 6 to 9 July in Addis Ababa, Ethiopia, on a gathering organized by the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) to help tackle tragic threats to Africa's human and economic well-being. >>

From 20 to 21 July 2010, the kick-off meeting of the Europe-Africa Marine Earth Observation (EO) Network (EAMNet) Framework Programme 7 (FP7) project took place. It launched under the space theme as one of the three projects supporting the definition and implementation of the Global Monitoring for Environment and Security and Africa (GMES-Africa) initiative. >>

Africa is a step closer to setting up its own space agency, with the approval of a planned feasibility study by the 53 member states of the African Union. >> The African Space Agency, the Pan-African University Institute on Space Science and the Future of Space Technologies and the Applications on the African continent, were at the centre of discussion during the high level dialogue on space holding at the headquarters of the European Union Commissions in Brussels, Belgium. >>

Geo-information technologies in various fields have potential to improve the quality of life in Africa, the African Association of Remote Sensing of the Environment noted. >>

Brazil will provide technical assistance to help countries in Africa and Southeast Asia improve their forest monitoring capabilities. >>

A Dubai-based businessman, an upcoming space tourist said he planned to fly the flags of Kenya, Tanzania and Uganda on his out-of-world journey in honour of his childhood in Africa. He received flags from these countries, which he expects to take on his space voyage in 2011. Real estate magnate Ashish Thakkar is among 40 people who have paid US $200,000 for a trip on Richard Branson's commercial rocket plane, SpaceShipTwo.

The GMES Africa initiative aims to strengthen the capacities and to develop infrastructure for the intensive and coherent exploitation by African users of Earth observation data, technologies and services in support of the environmental policies for sustainable development in Africa and ACP countries. >> >>

Angola

Upstar Comunicações, a joint venture of Portuguese media group Zon Multimedia, the Angolan group Socip, signed a capacity deal for a new pay-TV platform in Africa with Eutelsat. It intends to launch a pay-TV platform Zap in Angola. The five-year contract covers the lease of five Ku-band transponders on the Southern Africa beam of Eutelsat's W7 satellite, which began service in January 2010. Eutelsat's W7 satellite meets the precise requirements for building a pay-TV network across Angola using small consumer terminals, according to the CEO of Zap.

Egypt

NILESAT 201 was one of two communication satellites launched early August by Arianespace. It will provide broadcast services in the Middle East and rural Africa.

The former head of Egypt's space programme proposed in December that Arab nations unite to develop a medium-resolution optical Earth observation satellite as part of an industry-government partnership that ultimately would lead to an Arab Space Agency. He stated there would be "no use" for a space agency until a concrete, multilateral programme with industrial and university participation with governments is under way. While interest in a space agency may be waning, the way to reignite it is to develop a modest space technology industry in Arab nations so that each nation could contribute to an observation satellite.

Ghana

STL Ghana awarded Gilat Satellite Networks in December a contract from to provide its SkyEdge 2 broadband satellite network to serve STL Ghana's customers throughout West Africa. Gilat delivered a network comprised of two SkyEdge 2 hub stations and nearly 1,000 VSAT terminals to STL Ghana, which will be used by West African enterprises, health care organizations and financial services firms. The network includes interactive data applications such as videoconferencing, virtual private networks, Voice-over-IP services, IP multicasting and broadband Internet connectivity. As West African economies expand, the need for cost-efficient, reliable satellite networking becomes more critical, as it represents one of the only available communications infrastructure in the region.

Israel

The *Israel Space Agency* signed a deal that will make it a member of the NASA Center for Moon Research and promote cooperation between the two agencies. The agreement was signed in January by NASA Administrator Charles Bolden and ISA Director Zvi Kaplan. NASA reportedly was eager for the agreement since the Israel Network for Lunar Science and Exploration offers important research involving lasers, the development of advanced sensors for solar system research tasks and automatic vehicle navigation. >> >>

Spacecom, an Israeli satellite operator purchased exclusivity on the AsiaSat 2 satellite from AsiaSat, and as a result, the C- and Ku-band satellite, formerly located at the 100.5 degrees East orbital slot, was renamed Amos-5i and relocated to 17 degrees East to provide a variety of services over the African continent until Amos-5 becomes available in mid-2011. Spacecom also contracted with AsiaSat to provide satellite operation and telemetry, tracking and control for Amos-5i.

Spacecom Satellite Communications in January signed a six-year contract with an unnamed customer to provide satellite communications services in Africa via its Amos-5 satellite. The contract, which Spacecom expects will generate $47 million in total revenues, begins from the start of the scheduled launch of Amos-5's commercial operations in 2011. The customer has the right to cancel the deal three years after the start of services. Spacecom will provide services via the Amos 5i satellite until when the Amos 5 is launched.

Spacecom and Israel Aerospace Industries signed a contract with SpaceX to launch a communication satellite into a geosynchronous transfer orbit aboard a Falcon 9 rocket as early as December 2012. Spacecom will use the satellite to provide broadcasting and communications services to operators and broadcasters. Spacecom said the SpaceX deal supports company plans to launch at least four additional satellites in the coming years to multiple orbital positions. SpaceX now has twenty three Falcon 9 flights on contract representing a variety of commercial and

government customers, for both LEO and GTO missions. >>

Kenya

Nairobi-based *Indigo Telecom* and Vizada launched the ThurayaIP satellite service in Kenya and other parts of East Africa, it was announced in March. The offering, includes a broadband mobile satellite terminal, airtime, prepaid billing and technical support. The A5-sized mobile satellite terminal provides broadband data connectivity at speeds of 444 kilobits per second and video streaming up to 384 kilobits per second. The offering allows customers to send e-mail, use internet and perform videoconferencing in remote areas and is intended for security companies, non-governmental organizations and media organizations operating primarily in Kenya, Southern Sudan and Somalia.

Nigeria

The *RASCOM-QAF1R* satellite was successfully launched by Arianespace in early August. It will provide broadcast services in the Middle East and rural Africa.

Rascomstar-QAF was to launch the Rascomstar-QAF1R satellite in May to boost its pan-African connectivity services and replace the Rascomstar-QAF1 spacecraft, expected to stop working by the end of 2010. Soon after Rascomstar-QAF1 was launched by Arianespace in December 2007, the operator discovered that the satellite had a helium leak, which reduced its lifespan from 15 years to three years. Arianespace has been contracted to launch Rascomstar-QAF1R as well. The insurance company will cover all the costs, as the company had envisaged such challenges. A Chinese firm, China Great Wall Industry Corporation, is to spend $230m (about N34.6bn) to replace Nigeria's failed communications satellite, NigComSat-1. >>

Qatar

Qatar Telecom (QTel), a licensed telecom operator for the state or Qatar, signed a contract to take capacity on the Intelsat 15 (IS-15) satellite, it was announced in March. QTel will use the capacity to expand international call capacity and for Ku-band coverage, enabling QTel to extend its broadband services in areas where there is no terrestrial infrastructure in place.

Saudi Arabia

Arabsat

Arabsat's second satellite of its fifth generation (5 A), was launched successfully in June from Kourou, French Guyana, aboard an Ariane – 5 Rocket. The spacecraft was built by the Astrium - Thales Alenia Space consortium, and covers the whole African continent for the first time, in addition to Arabsat's usual coverage of the Middle East and large parts of Asia and Europe from the orbital position 30.5 Degrees East. Using a variety of frequencies, it will provide all communication services, satellite television broadcasting, telephone connections, Internet (broadband) services, VSAT and interactive services. Arabsat now can serve customers in the African continent and to compete in the African market. Arabsat's headquarters are in Riyadh, Saudi Arabia.

Arabsat, Newtec, and the Arab States Broadcasting Union (ASBU) are expanding the Multimedia Exchange Network over Satellite (MENOS). Additional bandwidth will be provided on the new Arabsat 5A satellite, launched in June 2010, and will provide additional capacity to existing customers and facilitate service

expansion. ASBU, Arabsat and Newtec will be able to provide additional TV/radio contribution and exchange services to their existing users and facilitate services expansion to additional customers on this successful and growing network.

MENOS is an all-IP networking concept used to exchange multimedia content over satellite, allowing broadcasters to share video and audio material among scattered sites in a fully automated and cost efficient way. The MENOS system also provides a complete range of tools to facilitate the coordination of tasks and provide additional IP services across the network.

Telecommunication officials in Saudi Arabia have said they were planning to curtail use of the BlackBerry messaging service, but not other services on the phones. This announcement followed the decision by the UAE's telecoms regulatory authority to not allow BlackBerry's messaging service in that country.

NASA and the Kingdom of Saudi Arabia´s King Abdulaziz City for Science and Technology (KACST) signed a joint statement that allows for collaboration in lunar and asteroid science research. >>

India and Saudi Arabia signed five agreements after extensive delegation-level talks between the two countries. These included an agreement on scientific cooperation - a Memorandum of Understanding between ISRO and King Abdukl Aziz University of Science and technology on cooperation in peaceful use of outer space. >>

A group of Saudi Arabian and European partners completed a project to implement and provide satellite based environmental information products and services to the Presidency of Meteorology and Environment of the Kingdom of Saudi Arabia. >>

Saudi Arabia's fragile desert and coastal environments will now get help from above, thanks to an initiative by a group of Saudi Arabian and European partners (GAF AG and e-GEOS) who have completed a project to implement and provide satellite-based environmental information products and services to the Presidency of Meteorology and Environment (PME) of the Kingdom of Saudi Arabia. >>

South Africa

South Africa joined the growing list of countries with national space agencies. The National Space Agency of South Africa (SANSA) began operations in December 2010, and opened an office in Johannesburg with hopes to be fully operational by April 2012. SANSA will be under the auspices of the Ministry of Science and Technology. SANSA's role will be to implement a national space programme; it will have the responsibility of acquiring, assimilating and distributing space data to various state entities. >>

The national space strategy will promote research in the areas of astronomy, Earth observation, communications, navigation and space physics. The strategy will foster international cooperation in space-related activities, and advance scientific, engineering and technological competencies through outreach programmes. Emphasis would be placed on encouraging space science research and development.

The space industry is a big business and goes beyond just space travel. It is an industry with enormous potential future growth. Over the next five years, South Africa intends to develop a formal space programme. SANSA's efforts at enhancing South Africa's space capabilities will not only be of immense value to the scientific

community in the southern African region; it will also assist in addressing the persistent challenges of health care provision, water resources, agricultural mapping, and urban planning and communications. Further plans aim at strengthening the space sector, which include setting up a Centre of Competence in Optronics and Synthetic Aperture Radar.

Space science has contributed significantly in the sustainable development of the African continent and SANSA will help play a role in this regard, and has ushered in a new era in the science and technology landscape in South Africa and the continent.

The Minister signed a memorandum of understanding (MoU) relating to data access with the representatives of the Brazilian and Chinese governments.

According to the Caretaker CEO Sandile Malinga, the agency plans two new satellite projects: the African Resources Management Constellation, for co-ordinating four Earth observation satellites from SA, Kenya, Nigeria and Algeria; and a space weather satellite, which SA hopes to build with Brazil to monitor radiation over the southern Antarctic. >>

South Africa's Science and Technology Department is looking at the possibility of reactivating and re-establishing space rocket launch facilities in South Africa. The facilities were deactivated in order to comply with its nuclear non-proliferation programme. However, the country now wants the facilities to save on launch costs for the satellites it builds. The statement was made during a meeting at the Satellite Applications Centre (SAC) of the Council for Scientific and Industrial Research in which a live video feed from South Africa's new Sumbandila microsatellite was publicly shown for the first time. >>

The South African government in February purchased a majority share in SunSpace, a private, domestic spin-off satellite development research company, in an effort to boost the country's space programme. >>

The Republic of South Africa, Brazil, and India signed an agreement to develop and launch a new civil satellite programme into space, government officials from the countries confirmed in April '10 at the ISBA Summit, held in Brazil. South Africa will provide the platform for a pair of satellites, while most of the instruments will be provided and installed by Brazil. The spacecraft will be launched by India in 2012 and 2014. The first satellite will be used for Earth observation and the other for space weather and climate studies. A joint satellite could lend support areas like agriculture, education, energy, health, information and communications, trade and transport responding to the modern world, according to a South African statement.

Russia's space agency Roscosmos is in talks with SANSA with regard to the possibility of installing a Russian satellite tracking, telemetry and control (TTC) facility in South Africa. This would give the Russians TTC coverage for the southern hemisphere, which they currently lack. >>

The 2011 International Astronautical Congress will take place in South Africa.

Uganda

The department of Geography at Makarere University, Uganda in collaboration with the African Union and European Union acquired a GEONET Cast satellite system that will be used to detect weather forecasts and natural resources information in the move to monitor environment throughout the country. >>

United Arab Emirates

The Telecommunications Regulatory Authority (TRA) in the United Arab Emirates (UAE) awarded Al Yah Satellite Communications Company (Yahsat) a 10-year satellite services license to install, operate and manage a public telecommunications network and to provide satellite telecommunications services in the UAE. Yahsat now has a license to offer a wide portfolio of voice, data, video and Internet connectivity solutions designed to accommodate the demand for emerging applications in the satellite industry like HD and other broadband satellite services for both commercial and government for the Middle East, Africa, Europe and Southwest Asia. It is a good opportunity for Yahsat, a satellite company with firm roots in the UAE, to address the satellite communications requirements of not only the nation but the region as well.

Late July the UAE's Telecommunications Regulatory Authority (TRA) announced that users of BlackBerry mobile phones would no longer be able to access messaging services in the UAE. The regulator said the service suspension would apply to all 500K users in the country, as well as to visitors using roaming services on foreign BlackBerry devices. The TRA contends some BlackBerry features operate outside the country's laws, "causing judicial, social and national security concerns." At the heart of their concerns is the way the BlackBerry handles data, which is encrypted and routed through servers overseas, where it cannot be monitored.

The three-day Global Space Technology Forum (GSTF) took place in Abu Dhabi and was expected to accelerate the establishment of a pan-Arab space agency. >>

Yemen

21 April 2010: The Ministry of Communications and Information Technology has completed processing the first atlas of satellite images of Yemen, to be an important reference for researchers and specialists, reported Yemeni news agency Saba. >>

IX.3 Asia and the Pacific

Piracy is a plague that has an impact on pay-TV operators worldwide, in particular in Asia. The Cable & Satellite Broadcasting Association of Asia (CASBAA) estimates that in 2008, piracy cost pay-TV operators in Asia nearly $2 billion in revenues and more than 34 million subscribers in 2008. Countries that have been hard hit include Thailand, the Philippines and Indonesia, where there are substantial black market cable industries, featuring operators who take DTH signals from one source or another and distribute them to millions of homes across these three territories without any payment. While the piracy situation may have an impact on analogue cable TV operators more, there are many cases of satellite pay-TV operators feeling the negative effects of piracy.

There are satellite systems in Asia which have been compromised. There have been massive numbers of cloned cards that have been distributed throughout Asia. The nature of the satellite business is that it doesn't respect national borders, so one broken satellite system in one market can impact markets around it. It can indeed spill over. The technology situation is worse for cable than satellite in Asia. In general, the satellite systems are newer and have more effective conditional access controls. For cable systems (old analogue systems) there are no effective conditional access

mechanisms. Older cable systems are the weakest link in the piracy chain in Asia.

Australia

As part of Australia's celebration of the 50th anniversary of Australian and US space relations, NASA has confirmed plans to build two new dish antennae at Tidbinbilla, just outside Canberra, as part of the support network that tracks all of NASA's deep space missions. The new dishes would be used for NASA's New Horizons mission once it reaches Pluto in 2015, with two more built by 2025. The relationship between the two countries is very reliable, and something worth preserving and growing.

A researcher at Macquarie University found an ancient meteor impact crater in a remote location of Australia's Northern Territory by searching Google Earth and following clues from an ancient dreamtime legend told by the indigenous Arrernte people. The Arrernte had a tale about a "star" that fell in the region. A date for the impact that caused the newly found Palm Valley crater has not been reported, but is certainly millions of years in the past. It is probable that the people's intimate knowledge of the land allowed them to form the story despite not having witnessed the event.

A project to enable satellite-based broadband communications technology for use in the Antarctic is one of four projects to win the first round of $10 million in funding under the *Australian Space Research Programme (ASRP).* Another project, which will be conducted by a consortium of several universities, provides the first phase of a stepping-stone-based roadmap to develop a scramjet-based access-to-space industry. The ASRP is part of the government's $1.1 billion Super Science Initiative, which aims to support projects that build on Australia's research strengths. The University of Queensland will lead a $14 million international consortium to help develop scramjet-based access-to-space systems, flying an autonomous scramjet vehicle at eight times the speed of sound - Mach 8, or 8600 km/h. Scramjets are air-breathing engines capable of travelling at hypersonic speeds, greater than Mach 5. Scramjet-based launch systems offer considerable promise for safe, reliable and economical access to space. The project would answer key scientific and technological questions and build an industry-ready talent pool for a future Australian scramjet-based access-to-space industry. The ultimate aim is to reach high technology readiness levels for access to space.

Partners in the new programme include four Australian universities – the University of Queensland, the University of Adelaide, the University of New South Wales, and the University of Southern Queensland; and the University of Minnesota in the USA. It also includes three international aerospace organisations - DLR in Germany, JAXA of Japan and CIRA of Italy, and several Australian entities: the Defence Science and Technology Organisation; the Australian Youth Aerospace Association; and industry partners including Teakle Composites Pty Ltd, AIMTEK Pty Ltd, BAE Systems Australia, and Boeing Research and Technology Australia.

Proponents state that safe, economical and environmentally responsible access to space is a major technological challenge of the 21st century for all nations due to the dependence of the global economy on assured and secure access to space-based services. The most promising way to meet this challenge is to extend aeronautical technology to hypersonic vehicles powered, at least partially, by supersonic combustion air-breathing engines (scramjets). Scramjets can be combined with

rockets to produce a more fuel-efficient hybrid launch system. Another aim of this programme is to inspire young people to study aerospace engineering and related disciplines and to look towards the Australian space sector for their career.

Australia and the United States also signed an agreement to cooperate in surveillance of space, possibly expanding the reach of a US military network tracking satellites and space. >> >>

Brunei

The Brunei Authority for Info-communications Technology Industry (AITI) in January selected U.K.-based Analysys Mason to develop a broadband strategy to support access to highly developed information communication technology infrastructure. Analysys Mason will undertake a review of the country's existing broadband policy and strategies and provide tools, plans and recommendations addressing both supply and demand of broadband and approaches to investment for the construction of next-generation broadband infrastructure. The firm will prepare an implementation plan for Brunei. Demand for broadband services will encourage investment in the supply of new infrastructure and new services, which in turn further promotes demand, which is key to the development of a successful broadband market.

China

To make breakthrough in fields like the aerospace projects, China will redouble its efforts in the research and development of core technologies and basic advanced components. China's first lunar probe programme has been delayed as the country had to wait for the belated arrival of an imported component, according to an official in charge of the country's moon probe mission. About 20 percent of components of China's first lunar probe, the Chang'e-1 satellite, were imported, and the chip used in the Satellite's CCD camera arrived more than six months behind schedule. Not all domestically-developed instruments can meet the special requirements for exploration in outer space. China sent its first lunar probe Chang'e 1 into space in 2007. China launched Chang'e-2, the country's second lunar probe, at the end of 2010.

January's Long March rocket launch in China validated the corrective actions taken following an upper-stage failure aboard a similar vehicle in August, according to the China Great Wall Industry Corp. It also proved that China can correct problems with its rockets and commercial satellites. Early DFH-4 spacecraft had problems once in orbit, but the third one launched in October 2008 so far has had none. The DFH-4 is especially important for China's Long March rocket builders because of a decade-long U.S. government policy barring the launch of U.S. satellite components on Chinese rockets.

Chinese TV and satellite company Hunan Television has signed a partnership deal with ITV Studios, a division of U.K. broadcaster ITV to develop and license content for original broadcast on Hunan Satellite Television in 2010. Hunan aims to leverage the new content in its efforts to extend its broadcasting reach to more than 58 million viewers in China and abroad. ITV Studios will represent the worldwide rights outside China for the finished and format versions.

ZN Animation, one of China's biggest animation producers, signed a deal with GlobeCast to bring more Mandarin content to Chinese communities throughout Europe. Globecast signed a video-on-demand (VOD) distribution deal with as well as general and popular entertainment content from Shanghai Media Group's subsidiary,

WingsMedia. The deal will add content to DTH and pay-TV bouquets GlobeCast delivers throughout Europe.

Beijing UnifiedNet, and Hughes Network Systems signed a joint venture agreement, and created a new business unit, HughesNet China. HughesNet China will operate together with its licensed partner, to offer a range of managed broadband network services to telecom carriers and enterprise customers in China. HughesNet China also will focus on providing broadband access to rural areas as part of a Chinese government programme to invest in education for rural development.

China announced that it would launch a French-made communications satellite for the Hong Kong- based APT Satellite Holding Limited in the first half of 2012. The satellite, dubbed APTSTAR-7 and made by the Thales Alenia Space, will be sent into space by China's Long March 3B/E carrier rocket at the Xichang Satellite Launch Centre in southwestern China, according to a statement issued by the China Great Wall Industry Corporation (CGWIC), the contractor of the launch. >>

In November 2009, the United States and China agreed to discuss expanded cooperation in space science and to start a dialogue on human space flight and exploration, according to a joint statement released in Beijing. The U.S.-China Joint Statement said both nations looked forward to reciprocal visits by the NASA administrator and appropriate Chinese space leaders in 2010. >>

The China Manned Spacecraft Programme (CMSP) selected LDRA, the leading provider of automated software verification tools, and the LDRA tool suite to analyse complex safety-critical applications related to the Tiangong 1 spacecraft. >>

China pledged to build and launch a communications satellite for Bolivia to help link up remote and isolated areas of the Latin American country as part of an overall development plan, officials said. >>

A German aerospace contractor and a Chinese research agency have signed a deal to jointly develop a satellite fleet to monitor greenhouse gases contributing to climate change. The memorandum of understanding is just a framework agreement for the so-called CarbonSat constellation. Officials still need more partners, including other European nations and the United States, to implement a network of multiple satellites, said Steffen Leuthold, a spokesperson for OHB System AG of Bremen, Germany. >>

The Chinese Sinosat-6 satellite sprung a leak in its helium-pressurization system, reducing its operational life. >>

Chinese Minister for Science and Technology Wan Gang called for more international cooperation to boost research capabilities and the level of Earth observation in developing countries. Cooperative efforts under the framework of the Global Earth Observation System of Systems (GEOSS) will help achieve the strategic targets set in the GEOSS 10-Year Implementation Plan by 2015, Wan said at the Group on Earth Observations (GEO) Beijing Ministerial Summit in Beijing. >>

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) set up its regional office in China in a bid to promote international cooperation in disaster management by using space-based information. >>

Taiwan, Province of China will launch FORMOSAT-5 satellite in 2013. The satellite will carry a high-resolution optical remote sensing instrument for Earth

sensing and Earth observation. >> Space Exploration Technologies (SpaceX) and the National Space Organization (NSPO) of Taiwan, Province of China signed a contract for the launch of NSPO's Earth Observation Satellite, Formosat-5. >>

Indonesia

Indonesia is intensifying efforts to map forest areas nationwide using remote-sensing satellite technology, to maximize on their role in absorbing greenhouse gas emissions. The announcement was made as the country hosted a three-day symposium of the 4th Asia-Pacific Group on Earth Observation Systems in Bali. >>

Indonesia's National Institute of Aeronautics and Space (Lapan) moved a step forward in its plans to build an integrated space centre on an island off the southwestern coast of Bengkulu province, signing a memorandum of understanding that the centre would be built on Enggano Island. The Bengkulu Regional Planning Agency administration welcomed Lapan's decision, adding the centre would have a positive impact for the locals, especially in terms of technological development.

An Indonesian government test rocket took a rather less lofty trajectory, missing its target and plunging into a prawn farm. Poor weather was blamed for the crash, so the rocket missed its target. Fragments of the rocket did not reach the residential area, and nobody was hurt. The 122-millimetre RX 1210 rocket was developed by state arms contractor PT Pindad, and tested at the air force facility in the Tempeh subdistrict of Lumajang. The rocket has been under development for a year and the accident was meant to be the final day of trials.

In February 2010, NASA offered Lapan participation in research at the ISS. >>

India

The Gujarat National Law University (GNLU) announced in November 2009 that it was launching a degree course on Space Law beginning in 2010. The course is being coordinated with ISRO and aims to put the Indian space programme in accordance with the international context. As India is increasingly taking up projects in collaboration with other countries, the course will also look at the liabilities in the context of space applications.

Indian Space Research Organisation (ISRO)

ISRO will aim at launching between six and eight missions every year to meet its objectives in the areas of national development and space science, ISRO Chairman K. Radhakrishnan said. >> ISRO is not expecting to see a much anticipated Commercial Satellites Launch Agreement (CSLA), inked during the visit of US President Barack Obama, as the US is still in the process of finalizing export reforms on commercial satellites by restructuring the US Munitions List on spacecraft. Such an agreement has been on the negotiating table for high technology partnerships between the two countries for a long time now and is considered by ISRO officials to be close to agreement. India can only launch civil or non-commercial satellites with US components. Commercial satellite launches are on a case by case basis and the CSLA is expected to change this to cover all future commercial satellite launches.

In February ISRO prepared to zoom into higher orbit, following a nearly 35% hike in its budget. According to ISRO, this is the highest increase in recent years. India's human space flight programme and the moon mission have gotten booster shots. The amount for the manned flight project has increased from Rs 30 crore in

2009 to Rs 150 crore.

India has begun searching for its first astronauts or 'vyomanauts' (vyoma means ‘space’ or ‘sky’ in Sanskrit). Two of the four selected vyomanauts will go on India’s first manned space mission scheduled to lift off in 2015. The other two will be reserve astronauts. The astronauts will be selected from the Indian Air Force. While the selection procedure will begin soon, the final phase (when the four finalists will be selected) will be in 2012 as the selection criteria are very strict. Candidates will have to answer an extensive questionnaire before being subjected to physical examination.

ISRO this year launched 3 major satellites - communication satellite GSAT-4 and remote sensing satellite Cartosat-2. While the launch of GSAT-4 and GSAT-5P were failures, Cartosat-2 was placed successfully in orbit.

India’s Insat-4B communications satellite suffered a power glitch in one of its two solar panels in July, forcing a shutdown of half of its transponder capacity. The satellite, launched in 2007, supports broadcasters Doordarshan’s and Sun Direct TV’s direct-to- home services. Insat-4B carries 12 Ku-band and 12 C-band transponders, and had to switch off six of each type of transponder following the anomaly. An expert team is studying the possibilities of partial utilization of some of the transponders that were switched off and restoring the services at the earliest possible time.

ISRO’s Satish Dhawan Space Centre (SDSC) in Sriharikota initiated the process of creating a Third Launch Pad for human transportation into space. The pad is required for the 2015 Human Space Flight Mission and beyond and will launch India's planned space shuttle, the Reusable Launch Vehicle (RLV). ISRO officials said that the preliminary design for the third launch pad is complete. It will be able to take care of all future programmes of the ISRO.

ISRO stated that trouble with a new cryogenic engine was delaying India's plans to début an updated all-Indian version of its Geosynchronous Satellite Launch Vehicle (GSLV), the most powerful rocket in the country’s inventory. Previous reports have stated that the ISRO would have determined in January when the GSLV Mk.II rocket would launch, and officials confirmed they were reviewing the rocket's performance and test results but they were not discussing what triggered the analysis. The GSLV was launched in April, but the launch of the first Indian-made cryogenic powered rocket, a complex technology mastered by just five countries, failed soon after lift-off from India's space centre at Sriharikota in the southeastern state of Andhra Pradesh. In the past decade, India has bought cryogenic engines from Russia and five of them have been used on missions, but the country wanted to showcase its ability to develop the technology itself, according to ISRO. India aims to launch its first manned space mission in 2016 and wants to grab a larger share of the multi-billion-dollar market for launching commercial satellites.

ISRO plans to launch a satellite in 2011 to provide S-band satellite phone services in India. The organization is building the satellite’s high-beam antenna, which will be deployed on board for service to handheld devices. The service will be deployed in one of the communication satellites with an S-band transponder, according to ISRO. India currently depends on foreign satellites for mobile voice service.

India’s satellite communication regulations are being questioned by some service providers, who allege that they lack transparency. China and India both

generally require that foreign satellite capacity be sold through an intermediary-ChinaDBSat or the Indian Space Research Organisation (ISRO), respectively. India and other countries require mobile satellite operators to install local gateways as a condition for providing satellite services into their territories. These requirements are considered burdensome and unnecessary from a technical standpoint to address the security concerns these countries have raised. Mobile satellite services (MSS) refers to networks of communications satellites, such as Iridium, Globalstar, Inmarsat, which are intended for use with mobile and portable wireless telephones.

India's Earth observation capabilities are set to get a boost with the launch of indigenously-developed RISAT-1 early next year. The launch was mentioned at the IGNOU silver jubilee lecture. RISAT-1 will be a major milestone for the country and a boon for regions perennially under cloud cover. The weather satellite could also be used to keep an eye on the country's borders round-the-clock and to help in anti-terrorist and anti-infiltration operations.

ISRO plans to launch a series of satellites to improve basic services in the country and also to augment technological development. The organisation would launch RISAT-1, INSAT-3D with imager and sounder for retrieving water vapour, wind and temperature and SARAL for sea surface altimetry and small satellites for measuring aerosols and trace gases. >>

NASA signed an agreement with ISRO to use data from Indian satellite Oceansat-2, for various American agencies for research activities, including weather forecasting. >>

France and India issued a call for proposals from the international scientific community to exploit data from AltiKa, a high-resolution altimeter dedicated to measuring oceans, continental waters and ice. >>

India and Russia put in place a legal framework for their cooperation in ISRO's manned space programme, which involves use of Russian Soyuz spaceship. >> Indian and Russian companies signed a deal that will see Indian buses guided by the Russian Glonass satellite navigation system, India's HBL Power Systems and Russia's Navigation Information Systems (NIS) agreed. >>

India and Saudi Arabia signed five agreements after extensive delegation-level talks between the two countries. These included an agreement on scientific cooperation - a Memorandum of Understanding between ISRO and King Abdukl Aziz University of Science and technology on cooperation in peaceful use of outer space. >>

ISRO renewed a five-year contract with EADS Astrium, Europe's leading satellite system specialist, for joint marketing of satellites. >> >>

Bharti Airtel struck a deal with All India Radio to replace the 10 WorldSpace satellite radio channels on its DTH platform in India with 10 All India Radio Channels. Bharti said that the replacement channels would come at no extra cost for subscribers who were already receiving the WorldSpace channels as part of their subscription pack. WorldSpace, a pioneer in satellite radio broadcasting, announced in December 2009 that it had closed down its Indian operation and filed for bankruptcy protection in the US courts.

Iran

In November 2009, it was reported that Iran planned to launch a communications satellite by late 2011 with no outside help, after Italy and Russia declined to put it into orbit. In December 2010, Iran announced that it would launch a reconnaissance satellite dubbed the 'Fajr' in the next few months. The Defence Ministry also said Iran would launch the 'Rasad 1' satellite about the same time.

Iran planned to unveil 'Toloo', its new national satellite, in early February 2010, according to a statement released on 22 December 2009 by the Iranian Defense Ministry. 'Toloo' was under construction by the Iranian Electronics Industries Co. The satellite is Iran's second following the launch of Omid, its first lightweight telecommunications satellite, in February 2009. According to Iran's defence ministry, the great achievements made by Iran in the electronics field has both increased Iran's deterrent power and ended the monopoly of some countries in this complicated field. The United States has been highly critical of Iran's satellite programme, claiming that it was a cover-up for a nuclear weapons programme while urging the international community to tighten sanctions on the country.

Iran announced in early February the successful launch of a home-built satellite carrying a rat, turtles and worms, the first such experiment by Iran in space technology. Iran's space programme has sent alarm bells ringing in the international community, which has voiced concern over the Islamic republic's development of technology that could be used for military purposes. According to Iran's President, it is a great job that living organisms can be sent into space, experiment on them and they return to Earth. The biological data on the animals will be sent to Iran's Defense Ministry for evaluation.

The Iranian government blocked the British Broadcasting Corp.'s (BBC) satellite broadcast signals. The BBC claimed that Iran blocked various Eutelsat Hot Bird satellite signals since late December, following its reporting of the death of a reformist cleric. BBC Persia, and Voice of America from the United States, are among the services immediately affected.

Iran's jamming of signals led the French regulators (ANF) to ask the International Telecommunication Union (ITU) to intervene with the Iranian government, to persuade Tehran to stop jamming satellite signals from the BBC World Service's Persian-language broadcasts into Iran. The ANF made the request after numerous French requests to Iran. In other instances, including requests for the US to stop jamming Cuban broadcasts, the alleged offending administrations have refused to acknowledge the ITU requests. The jammed signal was coming from the Eutelsat Hot Bird 6 satellite. For the BBC, a solution to the problem involved using replacement capacity on Eutelsat satellites whose beams make it impossible for Iranian authorities to uplink interference to the satellite.

The ITU in March stepped into the interference dispute between Eutelsat and Iran, according to the ITU Radio Regulations Board (RRB). The ITU RRB urged Iran to end interference hampering Eutelsat satellite operations. The Administration of France, on behalf of Eutelsat, had notified the RRB of the interference emanating from the territory of the Islamic Republic of Iran. The RRB has determined that Eutelsat satellite networks, operating at 9 degrees East, 13 degrees East, 21.5 degrees East and 25.5 degrees East orbital positions are receiving harmful interference. The board noted that the interfering signals appear to be of a nature that is prohibited

under ITU Radio Regulations No. 15.1. The RRB urged Iran to continue its effort in locating the source of interference and to eliminate it as a matter of the highest priority.

Joining the fray against Iran, European Union foreign ministers in March called on Iran to cease censorship and jamming activities directed at satellite broadcasts coming from Europe. The EU claims that Iran violated an international treaty and has been jamming satellite broadcasts from the BBC and VOA and restricting Iranian customer access to the Internet since late 2009.

Japan

Japan has adopted a new space policy, which includes the reduction and eventual elimination of space debris. As part of its policy, the Japanese Space Agency JAXA applies its standards on debris mitigation to both governmental and private space activities. JAXA also follows the policies established by the Inter-agency Committee on Space Debris and COPUOS guidelines. JAXA's main goal is avoid the collision and possible explosion and destruction of spacecraft in outer space.

JAXA selected a name for its first GNSS satellite 'Michibiki', meaning "to guide or show the way." JAXA received more than 11,000 entries in its recent contest to raise national awareness of the GPS augmentation programme. The system is a Japanese satellite navigation augmentation programme that will vastly improve GNSS accuracy over Japan and the rest of East Asia.

JAXA and the Asian Development Bank have agreed to cooperate on promoting the use of satellite technology for disaster management, climate change mitigation and adaptation, forest monitoring and water resource management. The space agency will provide technical assistance to bank-supported projects using satellite data. In addition, JAXA will train people at national institutions in Asia and the Pacific region to make use of satellite data for disaster response, climate change monitoring and natural resource management.

JAXA will be able to increase the number of launches throughout the year beginning in April 2011. Under the previous arrangement between the fishery council for the Tanegashima area and JAXA, launches from Tanegashima Space Centre and the Uchinoura Space Centre were allowed to take place only during a total of 190 days per year, due to concerns about their impact on fishermen near the launch sites. The new agreement will expand that period to provide launch opportunities whenever necessary and establishing a more open launch site system that is comparable to that in other countries. The number of launches will be limited to 17 per year, and the launch plan will be discussed with fishermen each year.

Toyota Tsusho Corp, the trading affiliate of Toyota Motor Corp., will begin growing 'jatropha' next year as the company sees the plant as a profitable alternative fuel. Jatropha, a plant found in subtropical countries that isn't edible and can grow in arid lands unsuitable for farming has already been successfully used in a Boeing 747 flight last year, and with Toyota Tsusho's investment in Singapore-based seed researcher JOIL(S) Pte., and rising oil prices worldwide, project manager Makoto Hattori believes that by dramatically increasing the plant's yield, it can make the plant economically viable. The company is currently in negotiations with a Philippine banana plantation to grow the plant.

A government panel approved trial production of equipment to be loaded on the Hayabusa-2 space probe, the successor to the unmanned Hayabusa probe that

returned to Earth in June after a seven-year voyage to the asteroid Itokawa. >>

In October 2010, JAXA signed an inter-agency cooperation agreement with the Italian, Norwegian, and French Space Agencies. >> During the report period, it was also announced that Russia's Federal Space Agency Roscosmos and JAXA would draft an agreement on space cooperation. >>

Kazakhstan

SES World Skies and Astel have teamed up to provide mobile broadband and phone services on trains in Kazakhstan, SES World Skies announced in November. Astel is using the Middle East beam on SES World Skies' NSS-6 spacecraft to deliver Internet access, email and other communications. >>

Kazakhstan was to announce international tenders for future satellites, after the launch of its KazSat-2, the head of the Kazakh space agency said in February. Kazakhstan launched its first satellite, KazSat-1, in June 2006; however, its control systems failed in June 2009. KazSat-1 was to have a lifespan of 12.5 years. It was equipped with 12 active transponders, including four for TV-broadcasting and eight for fixed telephone services.

KazSat-2 will be made at the Khrunichev R and D centre in Russia under a contract signed in 2006, and over 86% of work to build the satellite has already been performed. Kazcosmos has taken measures to improve KazSat-2 characteristics and enhance its security and control systems, and a feasibility study was developed for the production and launch of KazSat-3.

Astana is also planning to invest $100 million in a project to use Russia's Zenit booster rocket. The investment would be used to pay for the initial stake, upgrade Zenit and a loan to replenish the company's floating capital. Russia currently uses Kazakhstan's Baikonur space centre, which it has leased since the collapse of the Soviet Union. Moscow planned to use its Svobodny rocket launch site in the Far East as a replacement for Baikonur, a plan which was ditched over financial problems.

In April 2010, the upper chamber of the Kazakh parliament, the Senate, ratified a 2004 agreement to extend Russia's use of Baikonur. >>

In February 2010, President Tachikawa of JAXA and Chairman Musabayaev of Kazcosmos signed an agreement "Establishment of Cooperation in the Field of Space Activities for Peaceful Purposes" paving the way for the future cooperation between the two agencies. >>

Malaysia

Malaysian satellite pay-TV operator Astro All Asia Networks (Astro) posted $39.1 million in profits in the 2009 third quarter, driven in part by a 13 percent increase in revenue to $254.3 million, according to results issued in December. Astro's reported a profit of $8.2 million in the 2009 second quarter. The company planned to launch its Malaysian satellite HD service in December.

Putrajaya Corp, of the city of Putrajaya, Malaysia in March selected GMV to supply a GSM/GPRS/UMTS-powered urban transportation fleet control system for the company.

GMV will partner with Raisevest to provide advanced, real-time urban-transportation passenger information to 150 urban and metropolitan buses, with plans to extend the system's reach to 400 units. The information posts and control centre

will use GSM/GPRS/UMTS technology from Celcom, the Malaysian telephone operator. GMV's M-20 onboard unit will track the buses equipped with the technology. The project also will include ticketing systems, driver interfaces, on-board and ATM fare-collection systems and a parking system.

Measat Satellite Systems' AfricaSat-2 entered into service in January. The satellite provides both C and Ku-Band capacity for telecommunications and broadcasting services across Africa, Southern Europe and the Middle East from an inclined orbital slot at 5.7 degrees East. The African market is emerging as a key market for satellite communications, and the commissioning of AfricaSat-2 strengthens Measat's network coverage in this key region.

In November, Measat Satellite Systems reached an agreement with Rainbow Media and Ascent Media to distribute Rainbow Media's Sundance and WE TV channels across the Asia-Pacific region via the Measat-3a satellite.

According to Measat, Malaysia's sole satellite operator, Malaysian billionaire Ananda Krishnan in July was negotiating with Measat to purchase and secure full control of the satellite operator for US $207 million. The bid sent Measat's stock soaring to its highest level in more than six years. Krishnan already controls Measat Global Network Systems as a private company and holds a 59.6 percent stake in Measat Global, and plans to buy out the 40.4 percent Measat shares that he does not own, which would make the operator an entirely private entity. Measat said Krishnan's offer is 10 percent above the trading price of Measat Global shares. In March, Krishnan bought pay-TV operator Astro All Asia Networks for $758 million. Krishnan also controls Malaysian mobile operator Maxis, which he purchased for $3.3 billion dollars in 2007.

The Ministry of Communications and Information Technologies of Azerbaijan and Measat signed a long-term contract on leasing an orbital position for Azerbaijani satellite Azerspace, the ministry reported. >>

In November 2010, Measat said that it was planning to acquire two commercial communications satellites from US defence and space company Boeing. >>

Mongolia

Orbitnet, the Mongolian Internet service provider signed a multi-year agreement with Telesat (Canada) to purchase Ku-band capacity on the Telstar 18 satellite, it was announced in January. Obritnet will use the capacity to offer broadband connectivity to business, government and cellular operators in Kazakhstan, Mongolia and surrounding regions in Asia. Orbitnet began using Telstar 18 in 2008, and the customers are very impressed with the quality of service delivered. Orbitnet's business in Mongolia is going so well that it expanded into Bhutan and Kazakhstan and will provide broadband satellite services to more countries in 2010.

New Zealand

New Zealand space company Rocket Lab secured a deal which will see its rocket technologies commercialised in the United States. >>

Pakistan

Pakistan plans to launch its first indigenously developed communications satellite on 14 August 2011, from a facility in China. The Paksat-1R satellite was

developed as a result of an agreement between the Space and Upper Atmosphere Research Commission (Suparco) and China Great Wall Industry Corporation (CGWIC). Pakistan and China have agreed to enhance strategic coordination, advance pragmatic cooperation and work together to meet challenges in pursuit of common development.

PakSat is optimistic that the DTH market in Pakistan will see some movement in 2011, as the operator gets ready to launch its Paksat-1R satellite. However, generating this pay-TV movement may require a complex strategy. Part of the problem Pakistan faces is illegal Indian DTH Boxes, which may hamper pay-TV growth in Pakistan, as Indian DTH services may be less expensive than proposed rates for Paksat -1R services.

Earth observation aided disaster relief in Pakistan after serious flooding in 2010. Data from a range of Earth Observation satellites were being used, both through the International Charter Space and Major Disasters and the Global Monitoring for Environment and Security (GMES) initiative. >>

Philippines

Philippines-based satellite operator Mabuhay Satellite Corporation was to be acquired by ABS. The acquisition includes the entirety of Mabuhay's assets, including the Space Systems/Loral-built Agila 2 satellite and the Subic Ground Control Center. Closing of the transaction was to take place following receipt of U.S. government approvals.

Republic of Korea

2010 would be the year that Republic of Korea manifests itself as the definite fourth Asian player, according to the chief of the country's space agency KARI. While a space race has been underway in Asia, so far all the talk has been about China, Japan and India, but 2010 was more critical than last year because of three satellite launches, one of which included the second launch of the Korea Space Launch Vehicle (KSLV-1). The country wants to reach a level of self-sufficiency in core technologies, rather than relying on others to do the important parts for the Koreans. KARI is also looking to further integrate itself in international space efforts by engaging in joint projects with other major space agencies.

The Republic of Korea will work closely with the United States and other space technology leaders to build its indigenous Korea Space Launch Vehicle-2 (KSLV) rocket. The Science and Technology Ministry stated that this was necessary to speed up development of the rocket. Cooperative tie-ups with Russia are still underway and Korea could expand such tie-ups to countries like Japan, a leader in space exploration and rocket technology.

The Republic of Korea will significantly expand tax breaks for aerospace-related research and development (R&D) to bolster the country's competitiveness in this cutting edge sector. The Ministry of Education, Science and Technology is offering the breaks in order to spurt rocket and satellite development, among other areas. Tax deductions for local aerospace companies will be maintained up till 2012, with authorities to decide whether or not to extend the benefits afterwards.

The *Korea Meteorological Administration (KMA)* prepared to launch a meteorological satellite to improve its capacity to gather weather information. The KMA's Communication, Ocean and Meteorological Satellite (COMS) was launched

in November on an Ariane 5 rocket. The agency has been criticized for the accuracy of its forecasts. Korea relies on Japanese U.S. and Chinese satellites for 11 kinds of weather information. In the future, the KMA says it will improve the accuracy of forecasts because it can monitor the Korean Peninsula at eight-minute intervals. However, whether the satellite will improve accuracy remains to be seen. While it will be possible to gather more real-time data through the satellite, converting them into accurate forecasts is another matter, experts say.

The Republic of Korea and India signed a Memorandum for Space Cooperation in January, with the aim to boost bilateral relations to a strategic partnership, and to expand cooperation in science and technology, and space exploration.

Singapore

Singapore's Senior Minister of State for Trade, Industry and Education stated that the Asian space industry is poised to grow rapidly as many Asian nations set ambitious targets for their national space programmes. China hopes to put its space module in orbit by the end of the year, Japan plans to put an astronaut on the moon by 2030, and India and South Korea also hope to have successful space launches within the next five years. Singapore can leverage its traditionally strong aerospace precision engineering and electronic ecosystems to help clients, and Singapore's pro-business environment, technology, and market-savvy workforce have helped complement the growth of satellite service providers in Asia.

Sri Lanka

Sri Lankan Telecommunications Regulatory Commission in November contracted Surrey Satellite Technology Ltd. (SSTL) to help the country develop its own space capability and its first communications satellite. SSTL will design and produce an Earth observation satellite for Sri Lanka. With the spacecraft in orbit, the country would become a member of the Disaster Monitoring Constellation (DMC) with the ability to participate in international disaster relief support activities coordinated by the United Nations.

The *Sri Lanka Space Agency* (SLASA) will also be set up with SSTL's assistance, which will also advise the Sri Lankan government on the establishment of its national space programme. The programme includes training, development and collaborative activities between the University of Surrey and Sri Lankan academic institutes, which aim to promote academic, industrial and socio-economic development. >>

Thailand

Thai-based satellite operator Thaicom reported a net loss in 2009 of $14.16 million despite growing its year-end revenues to $216.90 million, the company announced in its 2009 financial results. However, revenues from Ipstar, Thaicom's satellite broadband operation, increased almost 30 percent compared to 2008, reaching $81.5 million in 2009. The operator said Ipstar's performance is due to the growth of its services in Australia, Indonesia, New Zealand, China, Cambodia, and Malaysia. Thaicom said that in 2010 it would place more emphasis on the Ipstar bandwidth service rather than user terminal sales.

The Thailand government spent 6.4 billion baht on its first Earth observation satellite called THEOS (Thailand Earth Observation Satellite), which currently has

over 100,000 images stored in its database since the satellite was launched in June 2009, according to Surachai Ratanasermpong, Deputy Executive Director of the Geo-Informatics and Space Technology Development Agency (GISTDA). The satellite, which provides resolution at two metres and has a map accuracy of 1:10000 scale, will benefit the country by generating income and providing data for economic and social purposes. >>

Tonga

The king of Tonga gave the go-ahead to a couple of space entrepreneurs pursuing a dream to develop a private space port in Tonga and build a small rocket launch site on the king's estate on the southern tip of 'Eua this year, with the aim of launching a rocket.

Roderick Milliron of InterOrbital Systems (IOS) predicts he can launch the company's IOS Neptune 30 rocket soon. But the Prime Minister's Office said they still had to work on details of the project, including the aviation issues and the frequency of launches, and the allocation of the land. If successful, the company hopes this will set the stage for them to compete in the Google Lunar X-Prize as part of the Synergy Moon Team.

Vietnam

The Vietnam Academy of Science and Technology (VAST) signed an agreement with Astrium of France to study an optical Earth observation satellite system, its associated ground infrastructure and training of Vietnamese engineers in Earth observation data handling and analysis. >>

Vietnam's Ministry of Information and Communication announced that it expected to launch the country's second satellite in 2012. The state-owned Vietnam Post and Telecommunication (VNPT) is the investor of the project of the second satellite, named Vinasat-2, with a total investment of about US$350 million. >> U.S. aeronautical manufacturer Lockheed Martin Corp. then signed a contract to build and launch Vietnam's second telecommunications satellite. >> Jean-Yves Le Gall, Chairman and CEO of Arianespace announced that Arianespace has contracted with Lockheed Martin Commercial Space Systems (LMCSS) to launch the VINASAT-2 satellite for Vietnam Posts and Telecommunications Group (VNPT) in the second quarter of 2012. >>

Vinasat-2 follows the country's first satellite Vinasat-1, which was built by Lockheed Martin and launched in April 2008. According to a government statement, the $300 million spacecraft is operating at 70 percent of its capacity, providing data and broadcast coverage to Southeast Asia, China, India, North Korea, Japan, Australia and Hawaii, with regional oil and gas companies as its major customers.

SES World Skies has signed a deal with An Vien Group (AVG) to provide transponder capacity on the NSS-6 satellite for a new DTH service in Vietnam, the operator announced. >>

In 2009, the Vietnamese government chose France to supply the technology for its second earth observation satellite, VNREDSat-1. France also will provide $100 million in financial aid for the VNREDSat-1 project, scheduled to be operational in 2012. In July 2010, VAST signed a contract with Astrium to manufacture and launch the Vietnam Natural Resources, Environment and Disaster Monitoring Satellite (VNREDSat-1). >> It will be capable of capturing images with a resolution of 2.5

metres, and Astrium also will provide the associated ground control, image receiving and processing stations, which will be integrated in Vietnam's Environment and Natural Resources Monitoring System monitoring station, a multi-satellite ground facility operated by the Ministry of Natural Resources and Environment. The contract follows an intergovernmental agreement on space cooperation signed in November between France and Vietnam. The deal includes a cooperation and training programme for 15 Vietnamese engineers that will help build the satellite.

IX.4. Europe

The French and German governments said they would jointly build an Earth observation satellite to measure atmospheric concentrations of methane, a contributor to the greenhouse effect linked to global warming, to be launched by 2014. >>

The European Commission announced the establishment of a Partners Board to assist it in the overall coordination of the Global Monitoring for Environment and Security (GMES). GMES will produce Earth observation data collected from space- and ground-based infrastructure. The Space Component features 5 satellite missions, called the Sentinels, which are being developed by ESA. The In-Situ Component comprises sensors on the ground, floating in the oceans or carried on aircraft. These facilities already exist and are located both inside and outside the EU. >>

Marking another significant step in the GMES initiative, ESA and Thales Alenia Space signed a contract worth 270 million euro to build the second Sentinel-1 and Sentinel-3 satellites. >>

New photos of the Soviet-era, but privately owned, Lunokhod 2 rover on the moon caused a legal stir over lunar ownership. >>

EUMETSAT resolved a lengthy dispute between France and Germany over their roles in the next-generation weather satellites to cover the continent. >>

A delegation from the National Meteorological Service (NMS) of the former Yugoslav Republic of Macedonia (FYROM) visited EUMETSAT on 8 July on the occasion of the new license agreement for the official duty use of Meteosat data. >>

Europe's vision for launching astronauts and robot explorers out into the Solar System came into sharper focus on 21 October when the ministers responsible for space activities met in Brussels to discuss Europe's goals for space exploration. Ministers from the 29 ESA and EU member states met in Brussels for their second International Conference on Space Exploration as the next step towards creating a future European exploration strategy. >> European countries that are not a part of the ISS programme will be allowed access to the station in a three-year trial period. >>

Ministers in charge of space activities representing the Member States of ESA and the EU met in Brussels for the Seventh Space Council. >>

Germany, Luxembourg, Hungary and Slovenia have joined the countries voting in favour of the Meteosat Third Generation (MTG) Programme Resolution. >>

The Space Telescope European Coordinating Facility, a unique collaboration between the European Space Agency (ESA) and the European Southern Observatory, closed on 31 December 2010 after 26 years. ESA's continuing partnership with NASA on the Hubble mission ensures that European astronomers will continue to have access to observing time. >>

Regional Organisations

European Anti-Piracy Association (AEPOC)

The European Anti-Piracy Association (AEPOC) appointed Philippe-Olivier Rousseau as president in February 2010. Rousseau replaces Jean Grenier, former director general of Eutelsat**,** who retired after leading and developing the first pan-European industry initiative against audio-visual piracy over the last 13 years. AEPOC unites some of the industry's finest firms and experts in the name of a healthy, secure and striving European media and telecommunications market. Safeguarding innovation and growth has to be one of the key issues of European industry policies, according to the new president.

Eumetsat

Member states of the European Organization for the Exploitation of Meteorological Satellites (Eumetsat) agreed to subscribe to the Jason-3 ocean altimetry satellite programme. Eumetsat and the U.S. National Oceanic and Atmospheric Administration (NOAA) are partners in managing the Jason-3 project. Denmark, France, Germany, Italy, Spain, Sweden and the United Kingdom are among the 19 countries that will collectively contribute 63.6 million euros ($88.5 million), to the 252 million euro ($350.1 million) programme cost of Jason-3. NOAA secured $138.92 million in funding for the Jason-3 programme in 2009 and gave it top priority for securing climate-related measurements. Nearly 80 percent of Eumetsat members, including all its largest member states are participating, showing the importance they attach to continuing the mission begun so successfully by Jason-2 and that the solidarity among Eumetsat Member States continues to prevail. The Eumetsat Special Council meeting in Darmstadt, Germany, voted in favour of the Programme Proposal and Programme Resolution for Meteosat Third Generation (MTG) with two Member States reserving their vote which was expected no later than 30 June. >>

Eumetsat welcomed the Czech Republic as its 25th Member State. >>

European Space Agency (ESA)

In August, ESA reported that it was facing economic hardships and some disagreements among its member states that could impact its work. There was even a disagreement among European countries on the need to update the Ariane 5 rocket.

ESA and the European Union (EU)/European Commission (EC) are struggling to decide on which institution should be in charge of over-all European Space Policy. Investing the European Union with more say over how space investment is distributed has been the backdrop to many contentious issues over space programmes in the past few years. Some ESA members are wary of giving the EU /EC a greater role in space policy and spending, preferring to have ESA remain in charge. The controversies over a next-generation meteorological satellite contract award and the 14-satellite contract to build Europe's Galileo satellites are caught up in the issue over whether strict value-for-money criteria should be used to decide contracts, or whether other criteria should be taken into consideration. These issues were debated at an October meeting on "A New Space Policy for Europe," at the European Parliament in Brussels, organized by Business Bridge Europe.

ESA was looking at proposals for using the ISS as a platform for climate science. A call for proposals, which was to expire at end January 2010, generated 17 submissions. Some space scientists were critical of the project, describing it as a cash

burner that provides negligible value for money compared with unmanned missions.

ESA froze its overall spending in 2010 and 2011 at 2009 levels and modified its contract-payment policy to accommodate stresses on the national budgets of some of its 18 member governments, All the programmes already approved will go forward; there will be no cancellations. But ESA will scrap its longstanding policy of paying contractors a “princely” sum at the time of a contract’s signing.

In January 2010 ESA selected Arianespace to launch the first 10 Full Operational Capability (FOC) satellites in Europe’s planned Galileo satellite positioning system. The contract, managed by ESA on behalf of the European Union, will see Arianespace launch the 10 FOC satellites into a circular orbit in pairs starting in December 2012. Arianespace will use five Soyuz launchers operated from the Guiana Space Center to orbit the satellites, which are currently being built by OHB Technology of Germany and Surrey Satellite Technology of the United Kingdom. Arianespace will also launch the first four operational satellites in the constellation, within the scope of the In Orbit Validation (IOV) programme from Guiana starting at the end of 2010. Arianespace and its subsidiary Starsem already orbited the Giove-A and Giove-B satellites and secured the frequencies allocated to the Galileo constellation.

ESA signed a contract with Arianespace defining the legal responsibilities and operational services that Arianespace will provide during the combined testing and integration of the Vega launch vehicle. Vega, co-financed by Belgium, France, Italy, Spain, Sweden, Switzerland and the Netherlands was to undergo testing at Arianespace’s Guiana Space Center starting in April 2010. The tests were to use a representative launcher model in order to validate ground and launcher interfaces as well as the procedures for launcher operation and control. Following the qualification phase, the first five Vega launches, set to begin at the end of 2010, will be part of the Verta (Vega Research and Technology Accompaniment) development support programme set up by ESA under a contract framework signed with Arianespace in December. The Vega launcher primarily will be used for scientific and Earth observation missions.

ESA and the European Defense Agency (EDA) issued two contracts to Astrium to enhance the performance of Arianespace's Ariane 5 launch vehicle and put together a new preparatory study aimed at coordinating the future military communication needs of the EU. EADS Astrium was awarded 150 million euros by the ESA to increase the payload capacity of the Ariane 5 by 20 percent to 12 metric tons following the development of a new upper stage. The enhanced rocket will be named Ariane ME and is scheduled to enter service in 2017.

ESA signed an agreement to relocate the Agency's High-Power Radio Frequency Laboratory from ESTEC in the Netherlands to Valencia, Spain. The laboratory will now be hosted by the Valencia Space Consortium (VSC), a non-profit organisation set up by Valencia's two universities, its regional government and municipality. ESA and the VSC will contribute similar levels of resources to the Laboratory, with its existing equipment transferred on loan to the new locations. The facility will become the latest addition to ESA's Europe-wide network of specialist external laboratories, such as Spasolab in Spain, Millilab in Finland, the European Space Tribology Lab in the UK, and the Microelectronics Technology Support Laboratory in Ireland. Its existing equipment transferred to the VSC, the Laboratory will be run by a basic team of technicians overseen by its current ESTEC manager.

Europe's Ice research satellite CryoSat-2, which was built by Europe's leading space company Astrium, is now in orbit; it was launched from the Baikonur Cosmodrome (Kazakhstan) on board a Dnepr launcher which has placed the 720 kilogram spacecraft into a polar orbit. CryoSat-2 will measure the ice coverage at the Earth's poles with previously unattained precision for at least the next three and a half years. Its predecessor - CryoSat-1 - was lost in 2005 due to a failure of the launcher.

CryoSat-2 will be vital in enabling scientists to accurately monitor climate change. The CryoSat mission is intended to measure the polar ice sheets and the sea-ice cover which together greatly affect the radiation balance on Earth. If the ice caps of Greenland and Antarctica melt significantly, the runoff could cause changes to the great ocean currents with unforeseen consequences for the world's climate.

Astrium has been the prime contractor for CryoSat-2 with responsibility for an industrial consortium consisting of approximately 31 companies from 17 countries including Thales Alenia Space for the SIRAL instrument. Astrium in Friedrichshafen built the satellite platform and integrated all the instruments. Astrium is also responsible to ESA for the satellite's performance. The industrial contract is valued at approximately euros 75 million. Astrium was also responsible for the satellite's launch.

As 2010 drew to a close, ESA was unable to win its member governments' approval of NASA's proposed five-year extension of operations of the ISS because of an unrelated dispute over financial support for Europe's Arianespace commercial launch services consortium, ESA and European government officials said. As a result, no decision approving the station's extension to 2020 will be made before a March meeting of ESA governments. ESA already is committed to supporting the station through 2015, though the details remain to be worked out. >>

European Defence Agency (EDA)

European Defence Agency (EDA) awarded Astrium Services a contract for a new preparatory study aimed at coordinating the future military communication needs of the EU. Astrium considers this deal to be very important, because it is a new partnership that is being established, even if it will not bring in a huge amount of revenue to Astrium. This stage is about mapping out various needs, according to Astrium.

EDA signed a contract with Astrium Services to produce a study to support the creation of a centralized system for the procurement of satellite communications on commercial space capacity, such as Ku-, Ka- and C-bands. Over the next year, Astrium Services will map out the satellite communications requirements of the European member states' respective armed forces, whilst developing an operational framework for the European Satellite Communication Procurement Cell (ESCPC). Astrium Services will enable the EDA to develop a flexible procurement process across the EU. Over the next year, it will be working closely with member states to assess their satellite communications requirements and needs, and will propose solutions.

EGNOS

EGNOS (European Geostationary Navigation Overlay Service) is managed by the European Commission (EC) on behalf of the EU, and is Europe's first contribution to satellite navigation and a precursor of Galileo, the global satellite navigation system that the EU is developing. SES Astra has been awarded a second contract by

the EC to provide hosted payload services for the European Geostationary Navigation Overlay Service (EGNOS), SES announced in January 2010. The payload will operate in L-band and be located onboard SES Astra's new Astra 5B satellite. The satellite, which will be built by EADS Astrium, is scheduled for launch in the second quarter of 2013 and will be positioned at SES Astra's 31.5 degrees East position. SES Astra also will provide the related ground infrastructure. Financial details of the contract were not disclosed.

Galileo

In mid December, the Kiruna (Sweden) Galileo Station in the Swedish Arctic was inaugurated. It will be one of two Telemetry, Tracking and Command (TT and C) Galileo stations during the In Orbit Validation (IOV) Phase, - the other is in Kourou, French Guiana near the equator -, to monitor the satellites and relay new commands as required from Galileo's ground controllers at Oberpfaffenhofen in Germany and Fucino in Italy. The Kiruna facility was formally inaugurated by Rene Oosterlinck, ESA Director of the Galileo Programme and Navigation-related Activities and Javier Benedicto, ESA Galileo Project Manager, together with Paul Verhoef, Programme Manager of EU Satellite Navigation Programmes at the European Commission, and Lars Persson, President and CEO of the Swedish Space Corporation (SSC).

On 25 October 2010, the development of Galileo, the future European satellite navigation system, reached another important milestone as ESA and Spaceopal GmbH signed a contract for the operation of 18 Galileo satellites. Spaceopal is a joint venture between the DLR Space Applications Company (Gesellschaft für Raumfahrtanwendungen mbH; GfR) and the Italian company Telespazio S.p.A. DLR GfR was founded in 2008 in Oberpfaffenhofen, and is a wholly owned subsidiary of the German Aerospace Center DLR. The signing of this contract demonstrates the strong commitment and the clear political will to create an independent global satellite navigation system in Europe.

The first two European Galileo satellites intended to form part of the future 30-satellite navigation constellation will not be ready for shipment to their launch site until early 2011, with the second pair to be ready three months later, European government and industry officials said in March. These validation satellites were supposed to be ready this year, which now leaves less than two years before the main Galileo satellites start launching in 2012. Officials attending the Munich Satellite Navigation Summit said that the system is unlikely to be fully operational before 2016 to 2019. Meanwhile, some programme officials are concerned that the EU will fund only the necessary 18 satellites, which would provide limited service.

Global satellite operator SES S.A. became a key partner in the future operations of Europe's Galileo satellite navigation system in November. ASTRA TechCom Services, an SES company, signed a contract with Spaceopal, the company providing ground-based services required to operate the Galileo constellation until it has been fully deployed. The agreement is encompassed in one of the six Galileo Work Packages (WPs) identified by the EC and ESA as necessary to develop Galileo's Full Operational Capability (FOC). The WP6 Framework Contract is dedicated to preparation activities as well as to all the operation services the fully-deployed Galileo system requires.

ASTRA TechCom Services' contribution to WP6 covers engineering support to Spaceopal and a leading role in the In Orbit Testing (IOT) of the Galileo FOC

Satellites. To this end, ASTRA TechCom Services will work through its subsidiary, Redu Space Services, to utilise the Galileo IOT infrastructure in Redu to deliver this critical service. The Framework also prepares the ground for the future development of the Galileo Data Distribution Network (GDDN). Redu Space Services is a joint venture between ASTRA TechCom Services and the space systems manufacturer QinetiQ and operates the ESA centre in Redu.

Thales Alenia Space completed platform integration testing on ESA's Galileo satellites, Thales Alenia Space announced on 3 December 2009. The Galileo platform is now in functional testing with delivery of the engineering model payload from Astrium U.K. expected in December. The proto-flight and three flight model satellites also were integrated and tested at Thales Alenia Space's facilities in Rome. They will be carried into orbit in pairs by Arianespace on a Soyuz ST-B / Fregat rocket. The first two Galileo launches were scheduled for late 2010 and early 2011. Functional testing began in December 2009 on the platform engineering model of the Galileo In-Orbit Verification (IOV) satellites, which are supposed to demonstrate Galileo's performance and provide a blueprint for the following Final Operating Capability (FOC) spacecraft, expected to be ordered by year's end.

The Galileo project took a major step forward in January, issuing contracts to the companies that will build the satellites. Arianespace was the only tender for the launch contract, worth over a half billion euros. A batch of at least 8 satellites will be ordered from a consortium led by OHB System of Germany, but EADS Astrium may not receive an order, even though it has helped develop much of the technology and know-how for the satellite navigation system.

The EC and ESA issued three of six Galileo programme contracts in its satellite tendering process that began in September 2008. The EU gave a consortium led by Germany's OHB System AG and Surrey Satellite Technology Ltd. (SSTL) a euro 566 million (US $810 million) contract to build and test the first 14 satellites for Galileo, expected to be operational by 2014. OHB-System will assume the role of prime contractor with responsibilities to oversee the development and overall integration of the satellite platform. SSTL, which built Giove-A, the first Galileo satellite, will build and integrate the navigation payloads and support OHB with the final integration. The 14 satellites will be assembled at OHB's facilities in Bremen, Germany.

Thales Alenia Space Italia won an 85 million euro ($121.7 million) framework contract to provide Galileo system support to the ESA. The company will provide the overall system design, the system security design, the overall system integration, verification and in-orbit validation for the Galileo system, scheduled for operational launch in early 2014. Arianespace will launch the satellites, starting in 2012. The programme was almost cancelled in 2008 after European governments disagreed about how work on the programme would be shared. The German government welcomed the order for OHB, saying it was a great success' for German industry. The total cost of setting up the final network is expected to be euro 3.4 billion, or more.

Technology that depends on satellite-navigation signals is increasingly threatened by attack from widely available equipment, experts say. Each satellite in a sat-nav constellation is putting out less power than a car headlight, which means they can be easily swamped with Earth-bound equipment. The immediate solution to the problem is not clear, since the existing US GPS and Russian Glonass systems, and the forthcoming European sat-nav effort Galileo, are equally susceptible.

Countries

Albania

Albania's Starsat signed a deal SES Astra to market Astra2Connect service in Albania. Starsat is part of an initiative of the Albanian government, enacted in 2003 to equip Albanian schools with satellite-based broadband data connections. The company will use Astra2Connect to install a satellite broadband connection for nearly 600 schools in the rural areas of Albania. The project will be administered by the Albanian Ministry of Education and financed by the Albanian government and the World Bank.

The school project in Albania is an example of how Astra2Connect can deliver broadband connections to remote locations and facilitate modern teaching.

Armenia

Armenia and the Russian Federation have held discussions over releasing a cooperative satellite. >>

Azerbaijan

Azerbaijan signed a deal with Arianespace to launch its first satellite into space, according to a statement in November by the Communications ministry. Azerbaijan, an energy-rich mainly Muslim republic on the Caspian Sea, is spending 213 million dollars (151 million euros) in total on the satellite, which will be used to provide telecommunications services when launched in 2012. >> >>

The Dnipropetrovsk-based Pivdenne Design Bureau had submitted an application to enter its Zenit rocket in a tender conducted by Azerbaijan's Communications Ministry to place the country's first communications satellite, AzerSat 1, into orbit. According to some reports, Russia's Khrunichev State Research and Production Space Center with its Proton rocket, and ESA with its Ariane launcher were also competing to launch AzerSat 1. An announcement of the winner was to come in March, but came in November 2010. >>

All major subcontract partners for the Azerbaijan's first commercial communications satellite, Azerspace/Africasat-1a, are in place, as prime contractor Orbital Sciences Corp. selected GMV to provide the satellite's ground system, GMV announced late December 2010.

The Ministry of Communications and Information Technologies of Azerbaijan and the Malaysian satellite operator Measat signed a long-term contract on leasing an orbital position for Azerbaijani satellite Azerspace, the ministry reported. >>

Azerbaijan has commenced the process of coordination of satellite networks with Indonesia. Upon completion of the coordination process the national satellite will be relocated from position at 46 degrees east longitude, leased from Malaysian satellite operator Measat, to its own positions in 43.2, 58.5 and 96 degrees east longitude. >>

Belarus

In 2010, Belarus started creating a national space agency, according to First Deputy Chairman of the Presidium of the National Academy of Sciences of Belarus (NASB). This new space agency will address all the issues related to space exploration, including with the help of the new Belarusian satellite that will be

launched in 2010. No name has yet been determined for the agency, although it will be run by the Presidium of the National Academy of Sciences of Belarus. >>

Czech Republic

The Czech Republic's Office of Space was one of the co-organizers of the International Astronautical Congress (IAC), held in Prague in late September 2010, which was attended by some 3500 participants.

In December 2010, the Czech Ministry of Transport hailed a EC Decision to host GSA in Prague. The EC selected Prague as the future location of the European Global Navigation Satellite System (GNSS) Agency (GSA). The decision will see the first major European institution related to Galileo hosted on Czech Republic soil.

Estonia

In November 2009, ESA Director of Legal Affairs and External Relations, Peter Hulsroj, and Estonian Minister of Economic Affairs and Communications, Juhan Parts, signed a Cooperation Agreement in Tallinn. >>

France

Centre National d'Etudes Spatiales (CNES)

The French Space Agency (CNES) contracted Thales Alenia Space to build the Jason-3 weather satellite based on the Proteus platform, the manufacturer announced in February 2010. The satellite, expected for mid 2013, will be placed in the same orbit as Jason-2 to provide coverage over ice-free ocean surfaces. Soil Moisture and Ocean Salinity (SMOS), also built by Thales Alenia Space and launched in November 2009, will work with Jason-3 to provide regular maps of sea surface salinity, showing where and when large amounts of fresh waters are introduced in the cycle, for instance through rains, about 90 percent of which are estimated to fall over open sea. The Jason-3 operational oceanographic mission is a collaborative effort of Eumetsat, NASA and the U.S. National Oceanic and Atmospheric Association.

In addition to the CNES, many member states of Eumetsat agreed to subscribe to the Jason-3 ocean altimetry satellite programme. Denmark, Germany, Italy, Spain, Sweden and the United Kingdom are among the 19 countries that will collectively contribute 63.6 million euros ($88.5 million), to the 252 million euro ($350.1 million) programme cost of Jason-3.

Eumetsat and NOAA are partners in managing the Jason-3 project. NOAA already secured $138.92 million in funding for the Jason-3 programme in 2009 and has given it top priority for securing climate-related measurements. The fact that nearly 80 percent of Eumetsat members, including all its largest member states, are participating shows the importance they attach to continuing the mission begun so successfully by Jason-2 and that the solidarity among Eumetsat Member States continues to prevail.

The Indian Space Research Organisation (ISRO) and CNES sought research proposals on data to be generated from a payload on the AltiKA satellite to be launched in 2011. >> >>

CNES notified Astrium that the DGA, the French arms procurement agency, has awarded the company a EUR 795 million contract for two satellites for the optical space component (CSO) that will replace the current HELIOS 2 military observation satellites. The first satellite is scheduled to enter orbit in December 2016. The contract

also includes an option for a third satellite. >>

Arianespace

Arianespace concluded its sixth and final mission of 2010 with the successful orbiting of 2 satellites, the Hispasat-1E and Koreasat-6 satellites. The vehicle's first outing of 2011 is likely to be a re-supply mission to the ISS.

Arianespace is warning members of its supply chain and European governments that they must bear more of the operating costs for Europe's expanding panoply of launcher systems if the systems are to remain viable in the face of growing competition and a tightening launch market. Arianespace CEO Jean-Yves Le Gall is confident the different measures, if implemented, could return Arianespace to profitability and keep it competitive, not only with respect to new arrivals like SpaceX and reborn operators such as Sea Launch, but also against a resurgent-and much more competitive services.

An Ariane-5 carrier rocket with the French defence ministry's reconnaissance satellite was launched in December 2009 from the Kourou launch site in French Guiana. A technical issue with the liquid helium subsystem on Ariane 5's cryogenic main stage prevented the launch as originally scheduled. The Helios 2B satellite is designed to gather images that would help France to draw maps, prepare missions and perform other tasks in the areas of military interest. Helios 2B, built and developed by EADS Astrium and Thales Alenia Space, was placed into a Sun-synchronous orbit and will be managed by the French Defense Procurement Agency (DGA), which assigned contracting authority for the space segment to CNES. Helios 2B is the second satellite in France's next-generation space-based observation system for military applications that will be used together with Belgium, Greece, Italy and Spain.

Arianespace was contracted by OverHorizon to launch its first communications satellite, OHO-1, on an Ariane 5 rocket, it was announced in March. The deal with OverHorizon represents Arianespace's fourth launch contract of 2010. OHO-1, which will be built by Orbital Sciences and Thales Alenia Space, will be based on the Star 2.3 platform and launched in mid-2012 from the Guiana Space Center in French Guiana. The satellite will incorporate a Ku-band regenerative payload for two-way broadband communications with small terminals installed on moving vehicles, including cars, trucks, boats, aircraft and other vehicles.

Arianespace was chosen to orbit the first geostationary satellite built in Argentina, Arsat-1 for ARSAT (Empresa Argentina de Soluciones Satelitales Sociedad Anonima), following an international competitive bid. >>

Arianespace announced plans to co-market its long-term associate ISRO's PSLV, as a future back-up for its third rocket, the new light-lift Vega. >>

Eutelsat

Eutelsat plans to extend its presence in Africa, which, along with Europe and the Middle East, is a core part of its overall footprint and well served by its range of orbital slots which provide strong coverage and interconnectivity with other regions of the world. Expansion in Africa came in early 2009 with the W2A satellite which fortified the C-band and increased capacity in Ku-band professional video, data and broadband services. C-band take-up is exceptional for telecommunications and data networks in particular. Eutelsat plans to expand pay-TV platforms, including the DSTV platform. Future satellites will also incorporate reach over Africa.

Eutelsat Communications announced that it is likely to strike partnerships with other satellite operators in the future regarding Ka-band, using capacity on other systems, rather than building its own K-band satellite. Due to the level of interest from potential partners and customers in Ka-band, it is likely in the coming years that Eutelsat will have some satellites that it will share with partners, not just in Ku-band, but also Ka-band.

Eutelsat's W2 telecommunications satellite, which operates at one of the company's fastest-growing orbital slots, suffered an unexplained on-board failure and placed itself into sun-pointing safe mode late January 2010. The satellite has been in service since it was launched in 1998. Eutelsat and W2's prime contractor, Thales Alenia Space, were working to determine the cause and seriousness of the failure. In the meantime, Eutelsat aimed to place all W2 customers on the other three satellites at 16 degrees east, at least temporarily, if W2 cannot be returned to operation.

Eutelsat will reallocate the launch of its W3C spacecraft to China between June and September 2011.

The W3B and W3C satellites aim to enable Eutelsat to renew and expand video service resources at the 16 and 7 degrees East orbital slots over Europe, Turkey and the Indian Ocean region. Eutelsat also announced the launch of its European Ka-band satellite, Ka-Sat. The pan-European Ka-band satellite aims to deliver optimized consumer broadband services to more than 1 million homes beyond the range of high-speed terrestrial networks.

Eutelsat signed a multi-year deal with Telespazio in February to renew leased capacity on Eutelsat's Atlantic Bird 1 and W3A satellites. The Italian satellite operator renewed leases on two satellites for professional video contribution services and for broadcasting services directed to RAI, Italy's national public broadcaster. RAI said permanent availability of this capacity gives the broadcaster full flexibility to manage short news items broadcast in SD, as well as premium events in HD. It also guarantees RAI access to premium choice bandwidth with no notice.

Separately, Eutelsat denied allegations from Georgian broadcaster GPB that it had conducted improper commercial practice towards the broadcaster by awarding W7 capacity to one of its competitors in the Russian region after an alleged deal was finalized between the two companies. Eutelsat said negotiations were pursued in 2009 with several customers in advance of W7's entry into service and that it selected to award capacity to a European telecommunications operator after receiving a firm commitment for a larger order. Eutelsat said it informed GPB that the solution offered on W7 no longer was available, and that it could satisfy GPB's requirements with the W2A satellite - a solution which GPB refused.

Météo-France renewed its agreement with Vizada to provide professional digital weather information and software to the maritime community, Vizada announced in December. The partnership renewal will see the release of a new version of Vizada's SkyFile Weather solution, initially launched in October 09, is based on Météo-France's Navimail2 software to deliver meteorological information to maritime crews through a direct Internet connection established via a mobile satellite terminal. The new solution will support a range of IP-based maritime services, including Inmarsat FleetBroadband and Iridium OpenPort. Vizada will also introduce a monthly subscription option at the beginning of 2010, which aims to enable customers to download up to three weather files per day for a fixed amount, as opposed to paying

per file download.

The French and German governments in February 2010 said they would jointly build an Earth observation satellite to measure atmospheric concentrations of methane, a contributor to the greenhouse effect linked to global warming, to be launched by 2014. During talks between the two governments, the countries also agreed to ask their respective space agencies to map a strategy for a next-generation Ariane rocket, with recommendations due by the end of this year. Furthermore, France and Germany called for the development of a common ground network for the different optical and radar Earth observation satellites that France, Germany, Italy and Spain plan to launch in the coming years.

Germany

Despite a tight budget, Germany aims to increase investment in space science and technology to fuel innovation and growth through the auspices of the European Space Agency rather than its own national space programme. >>

Earth observation satellite operator RapidEye signed in March a reseller partnership agreement with US's Harris Corp. Government Communications Systems to offer imagery data to the government, defence and commercial sectors. RapidEye's 5-meter resolution data has been incorporated into Harris' TrueTerrain true-colour orthomosaic product line for the visualization-simulation and mapping markets. Its unique satellite constellation of five-band multispectral 5-meter data provides a new source of commercial imagery that will allow the companies to build a suite of value-added products to better serve their commercial and governmental customers alike.

RapidEye entered into a contractual partnership agreement with Swedish distributor Metria to distribute RapidEye satellite imagery in the Scandinavian, Baltic and Icelandic data markets in April. The contract represents RapidEye's entrance into the European imagery market. RapidEye is in the process of completing a worldwide network of distributors in order to facilitate access to RapidEye products in its customers' own language and region. The company has also entered into an agreement with a Colombian firm to distribute its images in Colombia and other South American countries.

DLR and the National Space Agency of Ukraine (NSAU) have confirmed their mutual interest in the development of cooperation in the sphere of data exchange on remote Earth-sensing, primarily in crisis situations >>

The first 3D images from the TanDEM-X satellite mission are now available. One month after the launch of TanDEM-X, which took place on 21 June 2010, DLR researchers created the first digital elevation model. A group of Russian islands in the Arctic Ocean was selected for the first test. >>

ESA and DLR signed a new agreement which paves the way for the development of an advanced type of optical data relay terminal The state-of-the-art device should fly on the Sentinel 2 satellite, which ESA will launch soon. The two organizations signed a Memorandum of Understanding together in Paris, at the ESA Headquarters. >>

Hungary

Judge Géza Herczegh, the immediate successor to Judge Manfred Lachs at the International Court of Justice (ICJ), died in Budapest at the age of 81. He served in the ICJ from May 1993 until February 2003. He was a Judge in the IISL's Manfred Lachs Space Law Moot Court competition in 1994 in Jerusalem, and again in 1996 in Beijing.

Italy

Telespazio has chosen Arianespace to launch the Sicral 2 satellite in the framework of a turnkey contract that the Italian Defense Ministry and the French DGA armament agency (*Direction Generale de l'Armement*) have with Thales Alenia Space Italy. >>

Lithuania

Lithuanian business and science will be able to participate in the development of new space technologies and will have the right to use these technologies in their research activities and production as it is provided for in the agreement on cooperation signed between the Government of Lithuania and ESA. >>

Luxembourg

Intelsat S.A.

On 15 December 2009 Intelsat, Ltd. changed its corporate domicile from Bermuda to Luxembourg and as a result of this migration, the company is now known as Intelsat S.A. While Intelsat is incorporated in Luxembourg, Intelsat Global Sales & Marketing Ltd., its global sales and marketing headquarters, is organized under the laws of England and Wales. Intelsat Global Service Corporation and Intelsat Corporation, are Delaware corporations, and provide technical, marketing and business support services to Intelsat and its subsidiaries. Since its privatization in 2000-2001, Intelsat is a privately-held company; it does not have publicly-traded common stock.

SES Astra

SES S.A. in March announced that its affiliate Sistemas Satelitales de México (SSM) received approval from the Mexican government to offer Ku-band satellite capacity into Mexico from its AMC-15 and AMC-16 satellites. EchoStar Satellite Services L.L.C., a subsidiary of EchoStar Corporation acquired the rights to use this capacity from SES and now plans to offer full-time and occasional use space segment to authorized entities in Mexico through SSM. The authorizations to use the Ku-band spectrum at these orbital positions for fixed satellite services (FSS) were recently granted by the Mexican government to SSM.

AMC-15 and AMC-16 are used primarily by enterprise customers in the United States. Positioned at 105 degrees West Longitude and at 85 degrees West Longitude, respectively, AMC-15 and AMC-16 can transmit video, audio or data with full coverage of Mexico and the United States. Also, upon launch in 2011, EchoStar is expected to use capacity on QuetzSat's QuetzSat-1, a high power communications satellite to be located at 77 degrees West Longitude, with coverage of Mexico and North America. EchoStar intends to use QuetzSat-1 for broadcast services for the Dish Mexico direct-to-home service in Mexico and for the DISH Network direct-to-home service in the United States. This initiative brings together the strengths of SES and

EchoStar in extending the reach and capability of AMC-15 and AMC-16 to accommodate new growth markets, as well as the experience of SSM in the Mexican market. With SSM's receipt of the authorizations from SCT and COFETEL to offer services into Mexico, EchoStar will be able to serve a growing regional demand for satellite services. EchoStar is well positioned to leverage its satellite operations and uplink expertise in the U.S. to expand its fixed satellite services throughout Mexico, including the delivery of satellite Internet services to rural communities.

Global satellite operator SES and the University of Luxembourg announced that they had entered into a multi-year partnership agreement to jointly develop Luxembourg as a European centre of excellence and innovation for advanced information communications technology in satellite systems, and to create a chair in satellite, telecom and media law. >>

Astra Broadband Services and Intersat Africa were set to launch satellite broadband to customers in East and Central Africa in early February, following up on an agreement they signed in September 2009. The Get2Net service was launched in countries such as Burundi, Kenya, Rwanda, Tanzania and Uganda. Astra Broadband and Intersat also agreed to expand the service offering in West African countries such as Ghana, Guinea, Ivory Coast, Nigeria and Senegal. Intersat Africa is using the Astra2Connect broadband platform to market Get2Net. Customers need a 100-centimetre antenna and a satellite modem to connect to the Internet regardless of their geographical location. Get2Net can also be used for VoIP telephony. Get2Net provides connectivity to underserved markets and rural Africa and also enhances the service delivery offered by ISPs. It will overcome the limitations of terrestrial last mile connectivity and will be able to serve all customers irrespective of their geographical location. Get2Net will also power Intersat's Rural Internet Kiosk initiative by offering a real broadband experience to users in remote areas, according to Intersat Africa.

SES Astra took full ownership of SES Sirius in March 2010, acquiring the remaining 10 percent of SES Sirius shares from the Swedish Space Corp. SES became a shareholder in SES Sirius in October 2000 with a 50 percent stake. Over the last decade, SES Astra gradually increased its stake to 90 percent by 2008. SES Sirius operates a satellite system in the Nordic and Baltic countries with a strong market position in Central and Eastern Europe, and offices in Latvia, Romania, Sweden, the Russian Federation and Ukraine. The Sirius satellites are positioned at 5 degrees East.

UPC Broadband, based in Luxembourg, consolidated its European DTH businesses to create a new company, UPC DTH, the company announced in February. The consolidation will combine UPC Direct's activities in Hungary, the Czech Republic and Slovakia, as well as UPC's FocusSat activities in Romania with a minimum of impact for customers. This consolidation coincides with a recent agreement for a long-term satellite position and transponder capacity with Norwegian partner Telenor (moving UPC Direct to the Thor 5 and 6 satellites) and an agreement with SES Astra Techcom for uplink services from SES Astra's home base in Betzdorf, Luxembourg.

Netherlands

SES World Skies updated its naming convention for future satellites in January 2010. Three of SES' new Orbital Sciences-built satellites will be named SES-1, SES-2 and SES-3. The satellites are intended to replenish and expand SES World Skies' North American fleet.NSS-14, under construction by Space Systems/Loral (SS/L) and

scheduled for launch in the first quarter of 2011, has been renamed SES-4. The C-band payload of the Sirius 5 spacecraft, also under construction with SS/L and scheduled for launch in the fourth quarter of 2011, will be named SES-5 and reside with the Ku-band payload of Sirius 5 at 5 degrees East. The NSS-806 replacement satellite, under negotiation with vendors, will be named SES-6. Upon closing of the Protostar-2 acquisition, announced in late 2009, the satellite will be integrated into SES World Skies global fleet and renamed following the SES satellite naming pattern.

SES in February agreed to adopt training services from Global VSAT Forum (GVF) in order to help prevent RF interference (RFI). The services would help the company in its efforts to refocus the industry's approach to managing and prevent RFI by engaging with other operators on a series of specific initiatives. The operator initiative programme, which was launched at the SATELLITE 2009 Conference, aims to promote the use of best practices and training by all satellite operators, installers and customers.

Dutch Space BV and Surrey Satellite Technology Limited (SSTL) joined forces to develop and exploit an innovative small geostationary platform that is specifically designed to utilize excess launch vehicle capacity, creating opportunities for lower cost geostationary missions. >>

Dutch Space signed two large space contracts together worth more than 50 million euro. For the supply of solar panels for 14 satellites of the European navigation system Galileo, Dutch Space signed an agreement amounting to more than 20 million euro with the German prime contractor OHB-System; as prime contractor of the Dutch space instrument TROPOMI, Dutch Space signed a contract worth more than 30 million euro with the European Space Agency for development activities that Dutch Space shall realise together with foreign suppliers. >>

The Netherlands Space Office and JAXA concluded a Memorandum of Understanding (MoU) between Japan Aerospace Exploration Agency and Netherlands Space Office on Cooperation in the Field of Space Activities for Peaceful Purposes. With this MoU, the two organizations will identify potential areas for mutual cooperation to promote our collaborative efforts. >>

The Netherlands is preparing enabling legislation for its national space law, which was adopted in September 2009.

Norway

Telenor signed an IPTV distribution deal with Viasat Broadcasting in March. The agreement will allow Viasat, which operates a DTH platform throughout Scandinavia, to distribute its premium pay-TV channel packages to Telenor's broadband customers. Telenor had 623,000 broadband customers in Norway and 574,000 in Sweden at the end of 2009. Viasat's channel packages will continue to be available to Telenor subsidiary Bredbandsbolaget's subscribers in Sweden and also will be included in Telenor's IPTV offering in Norway, which is expected to be launched for fibre-connected broadband customers in 2010.

Andøya Rocket Range and the University of Oslo initiated a Norwegian-Canadian rocket cooperation intended for college and university students. The cooperation will result in student exchanges between Norway and Canada and includes rocket launches from Andøya. >>

Spain signed a deal with Norway to build a telecommunications satellite, to be launched in 2014 and used for both civilian and military purposes. >>

Norway gave the European Union the right to site two satellite navigation base stations on territory it holds in the Arctic and Antarctic for Galileo. For maximum efficiency, the system needs ground control stations close to the top and bottom of the globe. >>

Poland

The Space Research Centre of the Polish Academy of Sciences (CBK PAN) and Astrium created Astri Polska, a joint venture that will focus on developing space technologies, applications and services for both Polish and international customers, Astrium announced. The Astri Polska subsidiary hopes to expand Astrium's European footprint.

Russian Federation

The Russian Prime Minister Vladimir Putin said that the output of the national space industry from 2009 will increase by about 18%. >>

Russia, which is set to hold a monopoly on flights to the ISS, wants to charge more for rides on its Soyuz rocket. At a meeting of the space agency chiefs in Tokyo, Roscosmos wanted to discuss the maintenance of transport to the ISS, for which Russia will be responsible for until 2012. But after that, the prices are likely to change considerably. When NASA retires its shuttle fleet as planned in early 2011, the United States and other countries will be dependent on Russia to fly the station's crew to and from orbit.

NASA has signed a deal worth 306 million dollars (224 million euros) with Roscosmos for six rides to the ISS in 2012 and 2013, or a charge of 51 million dollars per US astronaut. But with space now limited aboard the Soyuz rocket, Russia looks to curb its lucrative space tourism service, for which it had charged 35 million dollars (28 million euros) for the ultimate adventure. The floating ISS research station was to be closed in 2015 and ditched in the ocean, like its predecessor the Russian Mir station, but the 16 countries involved are in talks to extend the station’s life to 2020. Russia’s head of Roscosmos stated that international cooperation in space was increasingly important. China and India expressed their readiness to cooperate with Russia and so have the United States. Russia believes that responsibilities must be shared, in cooperation between Roscosmos and NASA.

In November 2010, Russia and China announced that they had finalized arrangements during the Russian–Chinese Space Cooperation Subcommittee meeting. Both countries will cooperate to accomplish the goals of the programme. These include Mars and Phobos exploration, using the Russian spacecraft Phobos-Grunt and Chinese microsatellite Inkho-1, which are to be launched in 2011. Both countries stressed that only through united efforts of the states involved in space programmes can predefined, mutually beneficial goals be accomplished.

Roscosmos gave a wide-ranging Q&A interview to Novosti Kosmonavtiki magazine in February 2010, concerning the current state and future plans of the Russian space programme, including the planned Soyuz replacement spacecraft, the new spaceport in the Far East, Russo-Chinese cooperation, and other topics. As for ventures with China, under their Space Cooperation Programme for 2010-2012, the two countries will work on 53 topics, including exploration of the Moon and other

planets of the Solar system. Roscosmos stressed that future full-scale space exploration is feasible only by international cooperation. Due to this approach, space projects and programmes of all interested parties and organizations gradually become more and more integrated.

Russia has taken on China as a partner rather than a competitor, due to China's rapid development in space technology in the last 10 to 15 years, according to the chief representative in China for the Russian Federal Space Agency. The Chinese Society of Astronautics and Russia's K. E. Tsiolkovsky Astronautics Institution signed an agreement in December 2010 aiming to promote space exchanges at the academic level.

The 11th meeting of the Russian-Chinese Space Cooperation Subcommittee took place in Beijing. An agreement was signed whose purpose is to establish a reciprocal notification mechanism for planned and executed launches of ballistic missiles and space launch vehicles in Russia and China in order to avoid any unclear and unforeseen situations. >>

Roscosmos signed a decree to reserve, for seven years, a 103,546-ha site in the Amur Province for the construction of the Vostochny spaceport. Construction of the spaceport is expected to begin next year. In 2015 the first unmanned launch will take place, and the launch of the space shuttle is planned for 2018. The construction of Vostochny will require an investment of €8.7bn.

A spaceship of the new generation will be named by winners of a childrens' contest, Roscosmos announced. The new "Rus-M" spacecraft will launch at the Vostochny spaceport once completed. Only children were allowed to participate in the naming contest because "only little ones have open minds and no limits in imagination."

The Russian government was to allocate 500 million roubles ($16.7 million) in 2010 on a project to build a spaceship with a nuclear engine. The majority of the money would fund work by the Rosatom state nuclear corporation, with the remainder going to Roscosmos.

A study by Russian investigators claims to have pinpointed the circumstances around the mysterious 1968 death of Yuri Gagarin, the first man to go into space. An investigation into the training flight found that as instructed, Gagarin sent the Mig-15 fighter he was flying into a dive when an air vent that was supposed to be sealed was discovered to be open. Plummeting towards the Earth, Gagarin and his trainer Vladimir Seryogin blacked out and crashed into the forest below. A person on the original investigation panel emphasized that in 1968 it was not known that descending too quickly could cause blackouts, adding that Gagarin and Seryogin followed their training to the letter, and to their death.

Russian Satellite Communications Co. (RSCC) signed a cooperation deal in February with Romantis to develop joint business packages for the EMEA region based on RSCC satellite capacity and Romantis hardware products and solutions. The companies jointly promote and sell RSCC satellite capacity for the Middle East and Europe, specifically the Express-AM44 satellite, which was deployed at 11 degrees West in early 2009. Together with Express-AM44 capacity RSCC can offer one of the most competitive solutions in the Middle East as well as in Europe and North Africa in the region both for government and enterprise customers.

SkyWave Mobile Communications (SkyWave) introduced a Glonass navigation capability to its DMR-800L satellite data communication terminal, targeted to its shipping customers in Russia, the company announced in December 2009. The DMR-800L with integrated Glonass aims to provide the capability to compute its exact location using either or both the Glonass and GPS systems. SkyWave said the dual-navigation capability is designed to benefit fleet owners who are mandated to use Glonass but do not want to incur the costs and reliability issues associated with the use of an external Glonass module.

In December 2009, the international press carried stories on the sighting of some phenomenon seen in the skies above Norway. It turned out that the Russian military had sent out a notice several days before, warning of a rocket launch and to stay away from the White Sea. When the rocket motor spun out of control, it likely created the heavenly spiral of white light near where the missile was launched from a submarine in the White Sea. Moscow admitted that a submarine-fired Bulava missile failed its 13th test, an embarrassing mishap for a rocket that had already failed six of 13 previous tests. But that didn't stop the alien-hunters from burning up the blogosphere with theories of hypnotic rays and alien signals.

Russia will use extensively the new Angara class carrier rockets to deliver military satellites into orbit, according to Russia's Space Forces. Angara rockets will complement, and eventually replace, the existing line of Rokot and Proton launch vehicles. It will be available in a range of configurations capable of lifting between from 2 to 24.5 metric tons into low-earth orbit, and its creators say it will have a low environment impact. While the first Angara launch is currently scheduled for 2011, the maiden launch of the Angara carrier rocket could be postponed for at least one year due to shortage of funds.

The head of a top Russian spacecraft manufacturer suggested that Russia construct a nuclear-powered military spaceship. The craft could carry a strike capability as well as serve as a communications hub and gather intelligence. However, this view contradicts official government policy strongly opposing arms in orbit. There was no indication of time scales or costs, nor was there immediate reaction from the Russian space agency. Russia intends to keep up with the U.S. in the space race and launch a new manned spacecraft by 2017, but an unmanned version of the spacecraft would be ready by 2015 and it will likely be launched from the new Vostochny space centre. Russia will finalize in August 2010 the design of a new booster rocket for a manned spacecraft it is planning to launch in 2017, a design bureau chief stated.

Intersputnik

The International Organization of Space Communications (Intersputnik) signed a long-term contract to lease 16 transponders from Eutelsat in January 2010. Intersputnik was to use broadcast capacity from Eutelsat W7 for the entire in-orbit life of the satellite, progressively joining the four transponders already leased by Intersputnik on Eutelsat's W4 satellite. Eutelsat is co-located with W4 at 36 degrees East. Intersputnik was to deploy the new capacity to support digital TV expansion in Russia and provide new resources for the Gazprom Media Group to boost the range of channels offered in its NTV Plus and Tricolor platforms. The transponders also will enable new satellite broadband access offers to be provided to homes beyond range of terrestrial broadband networks.

Intersputnik signed a long-term capacity deal with Asia Broadcast Satellite (ABS) for capacity on the ABS-2 satellite, ABS announced in March '10. The multi-transponder lifetime lease agreement means Intersputnik becomes the largest customer to date for capacity on the ABS-2 satellite, which is scheduled to be placed in orbit in 2012. ABS-2 will be the most advanced satellite in the Asia-Pacific region and will start its commercial service in 2012. Considering the acute shortage of satellite capacity, this spacecraft's resource is indispensable for the rapidly growing telecommunications market in Russia.

ScanEx of Russia finalized a distribution agreement with MDA Geospatial Services Inc. to be an official distributor of Canada's RADARSAT-2 satellite. The application of RADARSAT-2 images will expand the possibilities of radar satellite monitoring of natural and man-made objects and phenomena in Russia. >>

Slovakia

In April 2010, the Slovak Republic signed a Cooperation Agreement with ESA. This agreement will allow the Slovak Republic and ESA to create the framework for a more consolidated relationship in the future. >>

Slovenia

In January 2010, Slovenia became the sixth European country to sign the European Cooperating State Agreement with ESA. >>

Spain

Hispasat 1E, built by Space Systems/Loral using an LS 1300 platform, was launched at end of December 2010 on an Ariane 5 rocket. It carries 53 Ku-band transponders to enable Hispasat to offer a broader range of video and data transmission services with European and pan-American coverage from 30 degrees West.

Hispasat and RRsat Global Communications Network are launching a Spanish and Portuguese language content distribution platform in Europe over the Hispasat 1D satellite. A Spanish-language version of Moscow-based news channel Russia Today is RRsat's first customer for distribution through this platform. Demand for this particular service is expected to grow among the European Spanish and Portuguese audiences.

Sweden

The Swedish Space Corporation is host to the Kiruna Galileo Station at the Esrange Space Center, and as of 30 December, the facility's 13 m-diameter high-speed antenna and all the Galileo TTC equipment have been commissioned and are ready to support the initial operations of the first Galileo satellites. With Galileo soon to become a reality - the first Galileo satellites are scheduled to be launched in 2011 - bringing ground stations online is just as essential as getting the satellites ready to fly. The high-precision Galileo service requires a global network of ground stations to oversee the Galileo satellites in space - comprising a final total of 30 satellites in medium orbits, including three spares.

The Kiruna station serves as a satellite ground station for control and tracking and launch site for sounding rockets and long duration stratospheric balloons. Kiruna's extreme northerly latitude - 200 km north of the Arctic Circle, in the forests of Swedish Lapland - gives it good visibility of medium- orbit satellites, ensuring

continuous coverage for exchanging data between the ground and Galileo satellites. The remote location avoids any signal interference from built-up areas.

The satellite station at Esrange Space Center performs control and tracking duties for a variety of satellites, and was previously used for the launch and early operations of the second Galileo testbed satellite, GIOVE-B, in 2008.

The Kiruna Galileo Station contains baseband and RF equipment, monitoring, control and network connections. In order to meet the stringent availability requirements for the Galileo system, all equipment is configured to include internal and external redundancy. The TTC station provides the space-ground interface for telemetry acquisition and telecommand uplink and two-way ranging. The telecommand and telemetry data, together with the TTC monitoring and control data, are exchanged between the TTC stations and the Galileo Control Centres. In normal operation, the TTC station is autonomous. Technicians are needed for the purposes of maintenance and anomaly investigation.

The Swedish Space Corporation and the Canadian company Iunctus Geomatics jointly formed a new company PrioraNet Canada. This will pursue business opportunities related to ground stations in Canada. The initial venture is a station that is being built at Inuvik, north of the Arctic Circle in the Canadian Northwest Territories. >>

Two sounding rockets with microgravity experiments were launched from Esrange Space Centre, the operational space facility of the SSC. The Brazilian motor VSB-30 was used during both flights. >>

Turkey

Turkish operator Turksat signed an agreement in March with Intelsat to provide enhanced satellite capacity serving the Middle East region. The agreement provides Turksat with satellite capacity on the Intelsat system while Turksat finalizes details of its new satellite. In addition, Intelsat will have the option to participate with Turksat in its plans for continued growth in the region.

In late December 2010, Turkey announced that it planned to send 3USAT, the nation's first homemade communications test satellite, into orbit in September, according to satellite communications operator Turksat.

Telespazio and Thales Alenia Space announced the official start of the Gokturk observation satellite system for the Turkish Ministry of Defence. The original contract was signed by Telespazio and the Turkish Defense Ministry in 2009, and the programme now officially enters the design and construction phase. Satellite launch is planned for 2013. >>

Ukraine

MacDonald Dettwiler and Associates (MDA) signed a $254 million contract that will see it provide a communication satellite to the National Space Agency of Ukraine. >>

The National Space Agency of Ukraine (NSAU) and the German Aerospace Center (DLR) have confirmed their mutual interest in the development of cooperation in the sphere of data exchange on remote Earth-sensing, primarily in crisis situations >>

Amongst documents signed by Ukrainian President Viktor Yanukovych´s state visit to China are a programme on Ukrainian-Chinese cooperation in the exploration and use of the outer space for peaceful purposes for 2011-2015. >>

Kazakhstan, Ukraine and the Russian Federation will work together as part of the Cosmotrans space cooperation project, Ukrainian First Deputy Prime Minister Andriy Klyuyev said. >>

In October 2010, the head of the Russian Federal Space Agency Roscosmos arrived in Ukraine to discuss space cooperation issues with Ukrainian colleagues. >> Russia and Ukraine will establish a space navigation joint venture in 2011. >>

United Kingdom

UK launched its own space agency in March, aimed at boosting the country's multi-billion-pound space technology industry. Britain is a world leader in areas such as robotics, satellites and telecommunications, which contribute about six billion pounds (nine billion dollars, 6.7 billion euros) a year to the economy. The new UK Space Agency, will manage what is now a loose partnership of government departments and research councils dealing with space. The new agency replaces British National Space Centre (BNSC) and will initially operate out of the BNSC headquarters in Swindon, west of London. About 68,000 people are employed directly or indirectly in the industry, the kind of high value-added industry the government needs to support. >> >>

The UK space industry can become a much bigger global player, employing thousands more highly skilled workers and turning over perhaps £40bn a year, according to the findings of the Space Innovation Growth Strategy (SIGS) report. The Space IGS wants to see R&D spending within industry increase by £5bn, and for the government to double its annual civil space budget to £550m over the next 10 years. Another recommendation in the report is the formation of an executive national space agency and a national space policy to coordinate efforts. The study warns that unless the government and industry itself start investing more in space, current competitiveness will be undermined.

The new UK space agency could lead at least three missions by 2030, either with European partners or the U.S., India or China. There also is a "shortlist" for the names of the agency, including the UK Space Agency and Her Majesty's Space Agency (MASA). The details were revealed at the launch of a 20-year strategy, designed to make Britain a major player in space science. The Space Innovation and Growth report, also recommended that rules preventing the launch of spacecraft from the UK be swept aside.

The new UK Space Agency will implement the national space policy. The agency will be resourced and empowered to maximise the growth of the UK space industry. Surrey Satellite Technology Ltd (SSTL) is particularly pleased with the Government's announcement that under UK Space Agency, Britain will launch *TechDemoSat*. Funded by the government's *Technology Strategy Board* (TSB), with support from the *Regional development Agencies* (RDAs), the mission will demonstrate the advanced capabilities of state of the art small satellite technology for scientific and commercial applications — something that SSTL has pioneered over many years.

The UK's Secretary of State for Business, Innovation and Skills, in March announced a programme of support that included the launch of the UK's first national

space agency, a small satellite programme to showcase state of the art technologies to the world, and the formation of a working group to give serious consideration to a dedicated UK Earth observation system.

Space in the UK is an economic success story with more than 10 years consistent growth. It is estimated that the UK space sector could be worth £40 billion by 2030 and companies such as SSTL have proven their resilience achieving 20 percent growth in the current economic climate. Space is a proven economic enabler, which enhances commercial opportunities for Britain's high technology, engineering and ICT sectors. The *Space Innovation and Growth Strategy* report identifies areas where targeted government support and investment will help the UK to increase its international market share while supporting government objectives.

Coinciding with the launch of the U.K Space Agency, the *International Space Innovation Centre (ISIC)* was created. ISIC is intended to provide a central hub for British space activity and ensure that the United Kingdom maintains a world class space capability. The ISIC is being supported by a 12 million pound ($18 million) investment from the BIS Strategic Investment Fund and will be located with the ESA facility opened in July in Harwell.

According to a government spokesman, the U.K. space industry is one of Britain's real success stories. Year on year, it provides more jobs both directly and indirectly to the U.K. workforce. This is exactly the kind of high value-added industry needed to support and rebalance the economy, creating sustainable growth and the jobs of the future.

The UK Minister of State for Universities and Science David Willetts announced that the UK Space Agency and NASA have agreed a statement of intent for potential cooperation in civil space activities. >> The UK concluded an historic agreement with Russia leading the way to greater collaboration in space between the two nations. >>

The new UK minister in charge of space says he will study the feasibility of providing Britain with an independent remote sensing capability. While the UK has funded the development of monitoring satellites and payloads, unlike other leading European countries, the UK has no full-fledged operational Earth observation capability of its own. The system would likely be patterned after EADS Paradigm's Skynet 5 satellite telecom system, which provides secure communications to British armed forces on a private funding basis. (Remote sensing and telecoms satellites operate in different orbits and radio frequencies.)

The UK involvement in the Swarm project, which will measure the Earth's magnetic field using three spacecraft - academia and industry tied together in excellence to produce world-leading research and product. Since science received a "flat-cash settlement" during a recent Spending Review by the government, there is now something of a mad scramble from the different areas of UK research as they seek to claim a good slice of the flat cash. There is reason to believe that space will come out better than average because it is still growing in revenue despite the recession.

Skynet 5, the UK single biggest space project, is to be extended. The £3.6bn system, which provides secure satellite telecommunications to British armed forces, will be boosted by the addition of a fourth spacecraft. Skynet 5D will be built in Portsmouth and Stevenage for a launch in 2013, most probably on an Ariane 5

rocket. >>

The UK and French governments agreed to take a fresh look at whether to combine their next-generation military satellite telecommunications programmes to save money, a long-discussed idea that up to now has always found ways to be set aside for later. British Prime Minister David Cameron and French President Nicolas Sarkozy met to discuss the matter along with other agreements. European governments could save hundreds of millions of euros or pounds by building a common military satellite telecommunications system.

Ofcom, the U.K. communications regulator, has asked the U.K. Competition Commission to investigate concerns regarding BSkyB's sale and distribution of subscription premium pay-TV movies. In August, the regulator said that it was concerned in about the way in which these movies are sold and distributed, creating a situation in which Sky has the incentive and ability to distort competition. Ofcom outlined two issues for investigation: one is how the rights to movies are sold by the major Hollywood studios to broadcast films for the first time on pay TV. The second relates to the wholesale supply of pay-TV packages containing movies channels, which are based on those rights.

The Competition Commission has a maximum of two years to investigate and reach a decision on the concerns raised by Ofcom. BT, BSkyB's pay-TV rival, said the commission should consider all potential remedies, including operational and structural separation, as this would benefit consumers by offering them increased competition, greater choice and lower-priced options for premium sports, and premium movies.

ICO Global Communications

ICO Global Communications lost its judicial review action against the U.K. Office of Communications regulator Ofcom, which the company filed in 2009 after Ofcom announced its intent to request that the ITU remove ICO's global medium-Earth orbit satellite system from the ITU Master International Frequency Register (MIFR). The court ruling allows Ofcom to move forward with its request. While the decision is not binding with the ITU), the outcome may increase the likelihood that the ITU will follow through with initial proceedings to cancel ICO's MIFR assignments, which it threatened to do in February 2009.

ICO has had several recent regulatory battles with Ofcom. In June 2009, Ofcom notified ICO that the satellite operator had to show progress toward the launch of its ICO-P mobile satellite system by the end of that month or face loss of its spectrum assignment. ICO plans to use a constellation of 12 satellites to provide mobile satellite services but has not placed a satellite in orbit since the 2001 launch of ICO-P F2. Ofcom is responsible for ICO's spectrum assignments because it is the ITU representative for the Cayman Islands, where ICO is based. (ICO also has offices in Virginia, USA).

Reaction Engines, the British firm aiming to build an enhanced 'Skylon' space shuttle, which would take off from a runway without external tank or boosters, says it expects to test its revolutionary 'SABRE' rocket/jet engine within three to four years. The engine is said to be the key to the system but needs to be tested before more progress can be made. The tests could take place in this time frame if the testing for the necessary cooling technology is completed by the German space agency DLR in 2011. The space plane could become a reality in 20 years. Reaction Engines has been

in operation since the 1980s, when the proposed UK 'HOTOL' space plane project foundered.

Solaris Mobile experienced technical problems on the W2A satellite, a major setback for the company. Solaris Mobile, a joint venture between rivals SES Astra and Eutelsat Communications, launched W2A in April to target the mobile services market in Europe. The satellite then experienced an anomaly in July. Solaris needs to move on quickly to the next satellite, a key requirement to move the company into a fully commercial phase.

In July 2009, a technical investigation of Solaris Mobile's S-band payload on Eutelsat's W2A satellite revealed significant non-compliances from its original specifications, according to a Solaris Mobile statement. As a result, the company and its shareholders, Eutelsat and SES Astra, filed a claim for the full-insured value of the payload and downgraded their confidence that the payload would be able to fully meet the commitments made to the EU on its awarded S-band spectrum to provide mobile satellite services to the continent. The W2A was placed in orbit in April, shortly before Solaris and Inmarsat were tapped by the European Commission (EC) to operate mobile satellite services in Europe using 60 megahertz of S-band radio spectrum. Some of the losing bidders filed lawsuits seeking to overturn the European Commission decision. Solaris Mobile said that, despite its payload findings, it remained entirely committed to provide these services to the European market.

Surrey Satellite Technology Ltd. (SSTL) is restructuring its business and splitting into two separate business units. SSTL will now have a telecommunications and navigation business unit, as well as an Earth observation and science business unit. The telecommunications and navigation business unit was responsible for Europe's first Galileo navigation satellite, Giove-A and SSTL's geostationary communications satellite programme. The Earth observation and science business unit was responsible for the medium wave infrared and TopSat remote sensing missions. The two focused business units will enable SSTL to grow, whilst preserving this ethos and maintaining its unique and cost effective methodology which is built on a common foundation of engineering and a programmatic approach. SSTL is involved in a remote sensing mission for Kazakhstan and the launch of the NigeriaSat-2 and NX satellites.

UK is leading a programme of systematic, wide-area forest monitoring in Indonesia coordinated through the European Space Agency. SSTL subsidiary DMCii is currently heading up a team that includes members of the University of Leicester and the World Resources Institute (WRI) to show how satellite imagery can be combined with other data and expert knowledge to provide more powerful tools to tackle deforestation >>

SSTL and Dutch Space BV have joined forces to develop and exploit an innovative small geostationary platform that is specifically designed to utilize excess launch vehicle capacity, creating opportunities for lower cost geostationary missions. >>

Early in January 2010, Sir Ian Brownlie, a prominent English international lawyer and great internationalist, was killed in an automobile accident, aged 77. Among his many accomplishments, he was elected to the United Nations International Law Commission in 1996 and later became its chairman. His membership was a particular success, recognized when he was re-elected for the third time, receiving the

highest ever number of votes. Prior to that, he was involved in many well-known cases, ranging from defending Nicaragua at the International Court of Justice, to representing Amnesty International in its case against Pinochet. A prolific writer, his most famous work was *Principles of Public International Law*, first published in 1966 and now in its seventh edition, and which has been translated into other languages. Brownlie was a Fellow of the British Academy and other memberships included the International Law Association and the Institut de Droit International. In 2006, he was awarded the Wolfgang Friedmann Memorial Award in international law.

Isle of Man

The Isle of Man was chosen as the headquarters for the newly established Space Data Association (SDA). Satellite operators SES, Intelsat and Inmarsat were among the 3 founders of the SDA. The non-profit, satellite operator-led organization is dedicated to sharing critical operational data in support of satellite operations, improving flight safety and preserving the space environment. ManSat, a space company based in the Isle of Man, will provide administrative services for the association that will be open to all satellite operators and other participants. The SDA will establish a satellite data centre which will aim to provide an efficient, reliable and secure means for participants to share key operations data. The SDA anticipated that its electronic data centre would become operational in 2010.

IX.5 The Americas

The relationship between Latin America's capacity demand and capacity supply continues to amaze analysts who project growth for operators despite a slowly recovering global economy and limited financing resources. Several studies and articles have addressed these issues.

Convergencia Latina stated in November 2009 that the lack of satellite capacity in the region is increasingly noticeable. While in 2008 the capacity installed was 91.782 MHz, in 2009 it reduced to 91.45 2 MHz. Although 17 new launches are planned over the next three years, some of them "relocalizations", this would not be enough to accommodate the increasing demand for services, such as broadband, HDTV and backhaul for cell phones, among the main ones. Thus, operators will have to resort to various ways of maximizing the use of capacity by appealing to compression techniques, like the MPEG 4 and the search for Ku-band offers – which is more available than the C-. Additionally, agreements may be entered into to share infrastructure, although this last option will not turn out to be that attractive for operators in their business schemes.

As to the television market, the (soccer) World Cup 2010 was an opportunity for mass HD broadcasting. However, TV operators were not planning to contract new capacity, as they worked with the one they already had. As to satellite operators, this sports event required them to have between one and two additional transponders. But their plans may change considerably with the 2016 World Cup to be held in Brazil. The truth is that beyond an occasional event, the video "Premium" orbital positions are saturated, so a price-rising trend per MHz is expected to reserve the space on new satellites to the "best bidder".

Universalization of broadband will be one of the major objectives to be focused on by the States that, with projects such as Tupac Katarí in Bolivia and the satellite of the Andean Community, are gaining significance in the satellite market. Of all, the most advanced initiative is that of the Andean Community that will operate in

the 67º West orbital position and is in the process of signing an agreement with SES World Skies.

Another study states that the commercial geostationary satellite transponder market produced total revenues of $708.5 billion in Latin America in 2005, and that figure will reach more than $1 trillion by 2012, Frost & Sullivan announced in October. Though the expansion of terrestrial networks such as fibre, wireless and mobile poses a challenge to the satellite market, the demand for satellite transponders is likely to keep growing due to the need for video and corporate networking applications, Frost & Sullivan said in "Latin America Geostationary Commercial Satellite Transponder Market." According to another article, there looks to be an upswing in the number of satellite-related opportunities in Latin America, but with the global economy continuing to struggle, will the availability of financing have on impact on satellite plans in a region that seems on the verge of living up to its long-discussed potential? According to the article, there is a fair amount of private capital to invest in Latin American telecoms, which has seen a fair amount of consolidation. Telefónica has acquired so many companies around the region, and has not had a problem gaining financing for its projects. But many other operators are moving in, resulting in an evolution of telecom companies expanding and consolidation of all telecom activities.

The number one driver for Latin America satellite services seems to be banking and finance, next would be oil and gas, and then IP connectivity. There appears to be a strong return for economic stability and an ascending growth cycle in the Latin American region where satellite services are sure to grow. Operators seem to be consistent in diversifying beyond their traditional services such as basic video distribution and basic telecommunication services. (Several countries have digital internet programmes, primarily to rural areas and government outposts.) Operators are creating greater value propositions such as value added services and reaching out for end-users. E-government, long distance learning, DTH services, video distribution and wireless backhaul will drive demand in the future. It is clear that the region is building on a lot of strengths in the underlying foundations of telecom services and video services businesses to expand profits for the satellite industry.

Andean Community

The Andean Community of Nations (CAN), which consists of Bolivia, Colombia, Ecuador and Peru, reached an agreement in February 2010 with SES WORLD SKIES regarding the long-term use of the 67 degrees West orbital position, with the aim of developing this position into a prime orbital neighbourhood for the region. This position offers an extensive Ku-band satellite frequency range and excellent viewing angles for coverage of the Americas and the Caribbean. One of the CAN's objectives has been the development of the 67 deg. W geostationary orbital position with the International Telecommunication Union (ITU), for the benefit of the Andean people. Through this agreement, the Andean Community expects to deepen and strengthen the economic integration and socio-cultural cohesion of its Member Countries, as well as expand communications throughout the region.

According to SES WORLD SKIES, this agreement allows it to assist the Andean Community in developing this orbital slot, and offers an additional opportunity to SES WORLD SKIES to efficiently serve Latin America and the Caribbean with state-of-the-art satellite solutions for television distribution, broadband connectivity and government services. Under the terms of the contract, the

Dutch company is given the right to commercially exploit orbital position 67° west, while the Andean countries will receive, in return, a portion of that satellite capacity to carry out social connectivity programmes. Activation of that orbital position was expected to take place by September of 2010. (Since the initial press release in February, there has been no further news on this joint venture).

Argentina

Argentina's first government-private satellite, Arsat 1, which is scheduled to be launched in 2012 and will provide coverage across Latin America, will be supplied by Astrium, a European company. ARSAT-1 is the follow-on satellite to Nahuelsat, launched in the 1990s with the participation of another European consortium. >>

In June 2010, Arianespace announced that it had signed the launch Service and Solutions contract with Argentine operator ARSAT to orbit the Arsat-1 satellite by mid-2012. Honeywell will provide the navigation control equipment for ARSAT in a contract worth $2.4 million. Honeywell's Reaction Wheel Assemblies (RWA) and Miniature Inertial Measurement Units (MIMU) are main parts of the ARSAT-1 satellite's attitude control system. >> Later in the year, Thales Alenia Space announced that it has signed a contract with Empresa Argentina de Soluciones Satelitales SA, ARSAT, to supply the payload for the second Argentine geostationary telecom satellite ARSAT-2, a part of the SSGAT programme. >>

In another development, China was reported to be studying plans to install a satellite dish in Argentina for Beijing's space programme. >>

Bolivia

Bolivian President Evo Morales in February signed a decree establishing a national space agency to oversee the satellite project scheduled to be completed by 2013, according to a press report. The document stipulates that the Bolivian Space Agency will promote technology transfer, human-resource development and the application of satellite-communications programmes to education, defence, medicine and meteorology. The new government agency will also manage the implementation of the Tupac Katari satellite.

The agency will have an initial budget of $1 million and will be financed through government funding, donations and foreign loans. According to a press report, technical experts from China and Bolivia met in January to assess Bolivia's telecommunications capabilities and to start preliminary work on the design of the Tupac Katari, which will be built on the basis of the Chinese DFH-4 satellite. The first Bolivian satellite is expected to be put into orbit in 2013. >>

In December 2010, the Bolivian Space Agency announced that it selected China Great Wall Industry Corp. (CGWIC) to build its Tupac Katari (TK) Sat-1satellite. On 15 December 2010, Bolivia and China have signed a deal to build a 300-million-dollar communications satellite to be launched into space within three years. Construction of the Tupac Katari satellite, named after an 18th century indigenous hero who fought Bolivia's Spanish colonizers, will be financed 85 percent with funds from China. The satellite will be based on the DFH-4 platform, which is manufactured by the China Academy of Space. Bolivia expects the Chinese to construct and launch Tupac Katari, within three years. Bolivia's satellite is intended for domestic security; it would be the country's first telecommunication satellite and cooperative project with China, according to the Bolivian government. The parties

signed the contract in April, making the satellite construction viable in 2010. The $300 million project would be funded by secured credit from a Chinese bank. The satellite, to be dubbed Tupac Katari after an indigenous leader who fought Spanish rule, will be made available for use by neighbouring countries. Bolivian media put the cost of building the satellite at 300 million dollars.

China's development bank will lend Bolivia $251 million to finance the South American country's first communications satellite, China Great Wall Industry Corp. (CGWIC) confirmed in late December 2010. The financing will be used to help pay for Bolivia's $295 million contract with CGWIC to build the satellite. The Bolivian government has agreed to put up the remainder of the funds. The satellite is due to be launched in the next three years, and will be used for communications and broadcasting services as well as for remote education and telemedicine projects. >> >> >>

On 1 April 2010, Chinese and Bolivian officials Thursday signed an agreement to build Bolivia's first communications satellite, intended for domestic security, for launch in 2013.

Brazil

Brazilian Satellite Operator Hispamar teamed up with NewCom International to employ its new satellite, Amazonas 2, for the Latin America market. Amazonas 2, which recently completed orbit testing (IOT), features an advanced intelligent processor, called Amerhis, capable of processing and regenerating signals onboard the satellite without the need for a central ground station (hub). Amerhis allows for real-time directing of signals, while eliminating the costly expenditures associated with facilitating and maintaining a hub. The new satellite, co-located with Amazonas 1 at 61 Degrees west to double capacity at the location, has a broad footprint that stretches from the southern tip of South America to southern Canada. With a lifetime of 15 years, it offers new, cost-efficient opportunities for high power, high quality communications with its 54 Ku band and 10 C band transponders and bandwidth of 36 MHz Ku and 54MHz C.

Brazil and China will postpone their fourth joint satellite launching from 2010 to mid-2011. Brazil and China established in 1988 a joint committee for the construction, launching and operation of satellites under the China-Brazil Earth Resources Satellite (CBERS) Program. The programme allows the two countries to gather information about the Earth's environment, agriculture, urban development planning and water pollution. In 2007, CBERS-2B was launched to maintain the supply of images in the period of time between the end of CBERS-2 operation and the launching of CBERS-3. The first three satellites had 70 percent of their construction under China's responsibility, but the CBERS-3 and CBERS-4 will be equally shared between Brazil and China. Brazil, which started training nationals in 1988, now has enough technical and scientific experts to count on. More than 1 million images provided by CBERS satellites have been distributed and about 40,000 people check these images frequently, since they can be accessed on the Internet for free.

The governments of Brazil and China have agreed to share satellite data with each other and with developing countries including in Africa, a Brazilian official in Beijing announced in March. The two countries were to sign an accord to share data during a Chinese visit to Brazil in April. Details of which African countries would be included in the data sharing would be provided in due time. This agreement is part of

the Chinese-Brazilian Earth observation programme, CBERS.

China and Brazil agreed to share data collected from their satellites with developing countries including in Africa. >> However, Brazil and China postponed their fourth joint satellite launching from 2010 to mid-2011. The two parties held a critical design review meeting and decided to reschedule the date for launching the satellite CBERS-3. >>

Brazil's National Space Research Institute (INPE) will provide technical assistance to help tropical countries improve their forest monitoring capabilities, according to an INPE official. Brazil will share "knowledge and technology" on its leading satellite-based deforestation monitoring system with countries in Africa and Southeast Asia. One goal is to train countries in geospatial information systems (GIS) so they can eventually adapt and benefit from the UN- REDD system that will be defined under the UN Convention on Climate Change.

INPE will also help other countries with climate modelling. INPE's system tracks deforestation, degradation, and associated emissions. INPE's involvement is part of an agreement between Brazil and the UN's Food and Agriculture Organization (FAO).

On 1 January 2010, INPE took over the CEOS presidency which gathers 28 space agencies and 20 national and international organisations, with the purpose of coordinating the Earth observation satellite data global interchange. >>

Brazilian Amazonian Protection System (SIPAM) contracted Gilat to provide its SkyEdge 2 VSAT broadband satellite communications network to more than 1,000 SIPAM sites in the region, it was announced in February. SIPAM will use the VSAT network to disseminate critical information to Amazonian states and cities and to the dozens of institutions and isolated sites. SIPAM can increase the quality of information, including weather bulletins, that it provides to the press, civil defence, educational institutions and researchers nationwide. When completed, SIPAM expects the performance of its broadband communications network to meet or exceed that of commercial broadband services available to Brazil's largest corporations, according to SIPAM Technical Director Cristiano da Cunha Duarte. >>

*Globo***,** one of the leading Brazilian pay-TV providers completed a deal with DirecTV Latin America: a $604.8 million cash for stock transaction which increases DirecTV's ownership of Sky Brasil to about 93 percent, the pay-TV operator announced Dec. 16. DirecTV, which previously held a 74 percent stake in Sky Brasil, acquired 178.8 million shares from Globo and its affiliates with funds from its existing cash balances. Globo will continue to provide its programming to Sky under pre-existing agreements. Globo still owns 7 percent of Sky Brasil and retains the right to exchange all of its remaining equity interests in the company until January 2014.

Brazilian satellite operator *Star One's C1* satellite has seen delays in the launch of its satellite, due to financial reasons (the global economic crisis), resulting in delays of government projects that were based on this satellite.

Canada

At the beginning of 2010, Canada's space programme sought to catch its breath in 2010 after an action-packed year in which the country sent up a record-breaking astronaut and a celebrity clown, who became its first space tourist. Next year might be even more historic, with announcements from the US, Canada, and private

companies that could set the stage for a new era in space flight. Canadian Space Agency (CSA) head Steve MacLean plans to issue a long-term space policy next year, although it is still months away from being public.

At the end of 2010, the head of CSA stated that a Canadian astronaut might end up hitching a ride to the ISS on board a commercial vehicle. CSA President Steve MacLean said he supported the possibility of commercial flights in the future. The world's space agencies are looking at three possible ways to ship their astronauts to the space station after the American shuttles retire. These include commercial companies like SpaceX, the Soyuz spacecraft, and Europe's ATV if it was upgraded to carry passengers. In the meantime, MacLean is still trying to get approval of a long-term space plan, which he first began developing in 2008, but experts state it will be difficult to maintain the space workforce in Canada unless the plan is forthcoming.

CSA will invest more than Cdn $8 million (US $7.6 million) in 26 research and development contracts with Canadian companies, the government announced in November 2009. The projects involve timely development of priority technologies that are required for the implementation of specific potential future missions of interest to Canada. The 26 contracts were awarded through the CSA's Space Technology Development Program, which issues periodic requests for proposals to identify and support the development and demonstration of strategic space technologies. Among the recipients were Advantech Satellite Networks, Com Dev International Ltd., EMS Satcom and MDA. These projects are coming from innovative and skilled Canadians at the leading edge of important developments in science and technology; thus, the Space Technology Development Programme is a critical vehicle which leverages scientific and technological expertise while supporting the priorities of the Government of Canada.

CSA and NASA have been working to bring home the original Canadarm, which first flew into space in 1981. Discussions over the Canadarm, which flew on Columbia, have been ongoing for the past year. CSA declined to comment when asked what it planned to do with the 15-metre, 411-kilogram tool, although the Canadian Air and Space Museum in Downsview, is very interested in acquiring that piece of aerospace history.

Engineering Services Inc. (ESI) announced that it had signed a contract with the Canadian Space Agency worth $3 million (CAD) to develop robotic arm technologies for lunar missions, with an option for a second arm worth $500 thousand (CAD). Along with a micro-rover and a smaller robotic arm, this is the third robot that ESI is developing for the CSA and establishes ESI as a major player in Canada's space industry. >>

CSA announced that it would share leadership for a new science instrument that will probe the atmosphere of Mars in search of biological sources of methane, and consequently, signs of life. The instrument, known as MATMOS (Mars Atmospheric Trace Molecule Occultation Spectrometer), is a partnership between the California Institute of Technology (Caltech), the CSA and NASA's Jet Propulsion Laboratory (JPL). MATMOS has been selected by NASA and ESA for launch on board the ExoMars Trace Gas Orbiter, slated for launch in 2016. MATMOS will help scientists attempt to solve the mystery of methane on Mars by confirming seasonal distribution patterns, and providing new interpretations of the origin of the gas on Mars. Methane was discovered on Mars in 2003 in greater abundance than expected. It is a possible biomarker for signs of life, since the gas is readily produced by

biological activity. >>

On 16 December 2010, Jean-Jacques Dordain, Director General of ESA, and Steve MacLean signed a new Cooperation Agreement between ESA and Canada that will extend their partnership for a further 10 years, until 2020. >>

CSA and *Com Dev* data services subsidiary *exactEarth* signed a $1.4 million contract to provide space-based Automatic Identification System (S-AIS) data collected by its AIS nanosatellite (NTS). Under the contract, exactEarth will provide datasets from its exactAIS service to be captured at times and locations specified by the CSA through March 31. The data will be used by Canadian government departments to supplement other sources of maritime information and be used to develop and evaluate operational plans for the use of S-AIS data. When the exactAIS service becomes operational later in 2010, it will be based on a constellation of larger 100-kilogram-class microsatellites. Its early successes with NTS have demonstrated that even 10-kilogram-class nanosatellites can serve as operational assets that offer utility for certain applications. Launched in April 2008, the NTS nanosatellite gathers data on global maritime traffic.

MacDonald, Dettwiler and Associates (MDA) signed a contract in January 2010 with Boeing Satellite and Intelligence Systems to deliver four network and media services technology solutions for Canadian Defense Forces on Boeing 702B satellites. The contract offers the potential opportunity for MDA to supply 12 additional units, and is a part of Boeing's industrial and regional benefits programme associated with the Canadian government's acquisition of four C-17 airlifters - designated CC-177 for the Canadian Forces. Canadian government policy requires prime contractors such as Boeing to make investments in the Canadian economy as a result of winning defence and security contracts. MDA also signed a contract worth more than $13 million with EADS Astrium for four systems that will be used in its Astra satellites. >> ScanEx of Russia has finalized a distribution agreement with MDA Geospatial Services Inc. to be an official distributor of Canada's RADARSAT-2 satellite. The application of RADARSAT-2 images will expand the possibilities of radar satellite monitoring of natural and man-made objects and phenomena in Russia. >>

OmniGlobe has applied for an orbital slot to launch Canuk-1, a medium-sized spacecraft, in the third quarter of 2013. OmniGlobe said the application kicks off its business plan to procure, launch and operate a Ka-band FSS geostationary communications satellite over Canada. Canuk-1 aims to facilitate the delivery of advanced services including broadband Internet, Voice-over-IP, virtual private networks, videoconferencing, cellular telephony and telemedicine. The current lack of availability of ubiquitous Ka-band capacity over Canada due to the ever-increasing demand for higher bandwidth services led OmniGlobe to seek increased space segment to support its growth strategy as well as deliver enhanced services to its wide customer base.

OmniGlobe subsidiary *RAMTelecom* won a three-year contract from the Canadian Public Works and Government Services for the provision, maintenance and operation of Iridium satellite services and terminal equipment. The contract is valued at $2 million with three additional one-year extension options. Connecting people in remote locations provides a valuable lifeline and peace of mind in emergency situations.

Telesat contracted with Space Systems/Loral (SS/L) to build the Nimiq 6 satellite. The Ku-band satellite will be based on SS/L's 1300 spacecraft bus. Nimiq 6 is fully leased to Bell TV and will aim to provide Direct-to-Home HDTV and advanced video services in Canada from the 91 degrees West orbital slot. In 2009, both Telstar 11N and Nimiq 5 were launched and successfully put into service. Following the success of working with Space Systems/Loral on these two programmes, According to Telesat, SS/L was able to provide the best combination of technology, cost and schedule among several competing manufacturers for the Nimiq 6 contract.

Telesat's Anik F3 satellite provided services to the Canadian government in support of Canada's country's relief efforts to Haiti. Anik F3 provided high-speed communications services over C-band and wireless services via Ku-band to Canadian government agencies in Haiti from Telesat's Ottawa teleport. Additional communications for Haiti relief were being provided on Telesat's Telstar 11N satellite. Telesat has significant satellite capacity in the Caribbean, on both C-band and Ku-band, with excellent coverage of Haiti. As Haiti relief efforts continued to expand, Telesat was providing a range of services to help address one of the most serious natural disasters to occur in this hemisphere.

Telesat reported an 11 percent year-over-year increase in consolidated revenues at $787 million by end 2009. Telesat said the revenue growth was driven by its three new satellites, Nimiq 4, launched in late 2008, and Telstar 11N and Nimiq 5, both launched in 2009. The Canadian operator also said the sale of Telesat's interest in Telstar 10, the removal of Nimiq 3 from service, and lower North American enterprise revenues offset unfavourable foreign exchange rate movements. Net income was $414 million, compared to a loss of $822 million in 2008. Telesat's operating expenses were approximately 14 percent less in 2009, compared to 2008, at $37 million, due to lower compensation and administrative expenses and reduced revenue-related expenses. With the recent entry into service of Telstar 11N and Nimiq 5, the future launch of the Telstar 14R and Nimiq 6 satellites presently under construction, and its continued operating discipline and focused execution, Telesat remains well positioned for 2010 and beyond, according to Telesat's CEO.

FreeHD Canada, a new Satellite TV company, in February won limited approval from the Canadian Radio-television and Telecommunications Commission (CRTC) to operate in Canada. In August 2009, FreeHD Canada applied for a CRTC license to offer a free package of local television channels to customers who agreed to buy the equipment necessary to pick up the company's satellite signal. While CRTC granted FreeHD's license request, the commission mandated that the company operate under the same rules as other Canadian satellite providers. This rule prevents FreeHD from offering only local stations in its basic package and requires the broadcaster to include at least one CBC channel, one Radio-Canada station, the APTN channel and the Weather Network. Larger pay packages also must follow rules requiring certain services and channels to be optional to consumers.

At the Astrodynamics Specialist conference in Toronto, Canada held in July, Kristin Gates of the Global Aerospace Corporation proposed that balloons could be used to drag satellites into an orbit where they would burn up in the atmosphere so they do not add to space debris. Dr. Gates calculates that a balloon 37 metres across would take just one year to drag a 1200-kilogram satellite from an initial orbit of 830 kilometres to an altitude low enough to burn up in the atmosphere; without the

balloon, this would take centuries. The balloon would be stowed in the satellite and inflated when the satellite's mission was over. Global Aerospace admits that the balloon concept would only work below 1500 km or so, but notes that this includes a particularly congested region between 750 and 900 km above sea level.

Veteran Canadian astronaut Bob Thirsk won't be leaving Earth any more as he has decided that his six-month visit to the ISS last year was his last trip into space. Thirsk made his comments when he and Dave Williams, a retired astronaut, dropped in for a visit to McGill, their alma mater.

The Swedish Space Corporation (SSC) and the Canadian company Iunctus Geomatics jointly formed a new company PrioraNet Canada. This will pursue business opportunities related to ground stations in Canada. The initial venture is a station that is being built at Inuvik, north of the Arctic Circle in the Canadian Northwest Territories. >>

Russia and Canada will start negotiations on the integration of their national space systems to monitor the Arctic, a Russian space official said. >>

Colombia

SATCOL, the domestic satellite project came to an end in late November 2009, when the Ministry of Technology, Informatics and Communication (MINTIC) rejected the only bid from a Russian consortium, Information Satellite Systems - Reshetnev Company, to build and operate the satellite. Several companies from Europe and the USA responded to the RFP issued in early 2009, and acquired the bidding papers, but only the Russians presented an offer. This offer was turned down by the Ministry's evaluation committee, which found that it did not meet the qualifications set out in the RFP.

SATCOL bidders had to designate an orbital position at which it would be placed, as well as the launcher and the manufacturer. An outstanding point of this project was that it foresaw using the Ku or Ka band, making it one of the pioneer initiatives in the region in using this band, which was also contemplated by CANTV in Venezuela as part of the previsions for the Venesat 1 Satellite, launched in 2008.

A seminar held in May called attention to progressive steps that are being taken in shaping a Latin American national space policy, one that unifies various space efforts throughout the region, and noted the increasing use of space applications, such as Earth remote sensing, to help mitigate the devastating impacts of natural disasters. The seminar was organized by the School of Law and Astronomical Observatory, and the Research Group CREAR at the Sergio Arboleda University, and the Secure World Foundation. The seminar concluded that space technologies could be utilized more effectively if regional cooperation increased and appropriate policies were put in place.

NewCom International, a global communications provider, has rolled out an iDirect-based DVB-S2 broadband satellite service in Colombia to bring 21st century communications to key government and community facilities in remote locations. The initiative, which is being funded by the COMPARTEL programme through Colombia's Ministry of Communications, provides high-speed Internet access to hospitals, schools, police departments, fire departments, city government offices and cyber cafes. The communications project was launched in partnership with Colombia-based telecom provider Contecol. NewCom is deploying iDirect's DVB-S2 Evolution platform for the Colombia initiative to take advantage of optimized bandwidth and

reduced costs. The network will be managed by NewCom with Contecol providing on-the-ground logistics. Contecol originally tapped NewCom to provide satellite services for 650 locations. Based on NewCom's quality performance over the past six months, Contecol recently awarded NewCom 300 additional sites in 2009, with an additional 1000 sites expected to roll out by mid- 2010.

The Ministry of Technologies, Information and Communications (MINTIC) awarded Gilat Satellite Networks in January a one-year contract to support certain rural communications projects in the country. Under the deal, valued at about $12 million, Gilat will provide services for Rural Communitarian Telephony and Telecentros projects through December.Gilat's previously announced agreement with the Colombian government expired at the end 2009. The current extension for continued service provides for a government subsidy of about $1 million per month, which is dependent upon meeting certain installation schedules, performance indicators and providing similar services to those provided over the past year.

Costa Rica

The Costa Rican national telecommunications operator Instituto Costarricense de Electricidad (ICE), placed new VSAT orders with Gilat Satellite Networks in February, thus building on ICE's initial order with Gilat in September 2008 for SkyEdge VSAT network services. Gilat will deploy its SkyEdge 2 VSAT platforms to provide broadband services to approximately 1,000 new ICE sites and to ICE's corporate sector subsidiary, Radiografica Costarricense, serving 500 enterprise customers. The SkyEdge network aims to deliver interactive data applications and services, such as videoconferencing, virtual private networks, VoIP services, IP multicasting and broadband Internet connectivity, to meet ICE's mission-critical requirements. ICE also plans to expand its existing SkyEdge network to provide satellite backhaul, voice and data services to an additional 500 rural locations, meeting its universal service obligations to the Costa Rican government. The network also will provide satellite backhaul for wireless Internet access to those citizens.

An official timeline for the opening of the cellular phone market in Costa Rica appears to be in place. According to the Superintendence of Telecommunications (SUTEL), three new cell phone companies will be named in the coming months and will get the green light to compete with their service plans and coverage by the first quarter of 2011. The winners were to be determined by auction. New faces and new competitors in the Costa Rican telecommunications market will improve the mobile telephone market in the country. By September SUTEL was to give its approval to the country's new operators. These companies have been waiting for a chance to enter the market since January 2009 when the Central American Free Trade Agreement with the U.S. (CAFTA) went into effect, breaking up the long-standing telecommunications monopoly held by the Costa Rican Electricity Institute (ICE). The process of opening the cell phone market has been a difficult one, with SUTEL and ICE wrangling during most of 2009 over the nature and scope of regulations to govern the opening.

Amino Communications won a contract in February with the Costa Rican government to provide set-top boxes to the *Costa Rican Electricity Institute (ICE),* a state-owned network operator, to support a national IPTV rollout. Amino was to launch the services in the first half of 2010, targeting up to 100,000 homes across Costa Rica. IPTV will provide ICE's customers the better of the three worlds: video, voice and data. Also the opportunity to enter a new world of business.

Cisco Sytems Inc., one of the world' s leading suppliers of Internet networking equipment, communications technology and network management, announced in January that it will establish the Cisco Entrepreneur Institute in San José, to instruct small- to medium-sized businesses and entrepreneurs on how to improve business functions and information technologies.

Haiti

Satellite images and video from on-the-ground showed the impact of the earthquake in Haiti following the magnitude 7 earthquake on Tuesday 12 January. New satellite images released by Google and GeoEye showed the devastation from above, giving a new view of the severity of this disaster.After the earthquake, a group of organizations requested satellite data of the area from the International Charter on Space and Major Disasters, in order to provide this data free to anyone affected by disasters anywhere in the world. With this comparison, officials can pinpoint areas hit the hardest and proceed to identify passable routes for relief and rescue workers, according to the European Space Agency, which also released a space-based photo of Haiti. Two satellite telecommunication companies, Vizada Networks and SES World Skies donated satellite and service capacity to the World Health Organization (WHO) VSAT site in Port au Prince, Haiti, to provide addition communication services. They also donated satellite capacity with the deployed Vizada Companion for three months to allow the WHO to set up and run the emergency communications centre to optimize disaster recovery processes and support local authorities and humanitarian partners in this relief operation. Without effective and reliable communications systems, an already slow process could become even more difficult. Relief efforts in Haiti have been on-going throughout the year, with satellite communications companies providing a considerable of capacity towards these efforts.

Mexico

The Agencia Espacial Mexicana (AEXA), the Mexican Space Agency, was approved by the Mexican Congress Chamber of Deputies on 20 April 2010, after receiving a significant vote of confidence on 26 April 2006. The law creating the agency was published by President Felipe Calderón on 30 July 2010 and is effective as of 31 July 2010. The agency aims to coordinate the space activities that are performed in the country, such as those developed around the Large Millimetre Telescope in the state of Puebla, as well as enlarging the antenna "farm" in Tulancingo. >> >>

Among its objectives, AEXA will implement Mexico's National Space Policy, through the National Programme on Space Activities. It also aims to develop scientific-technical capacity in academia and industry. The President of AEXA is the Secretaria de Comunicaciones y Transportes, (Communications and Transportation Secretariat). As Mexico has had its own satellites in orbit since 1985, having the Communications Secretariat in charge is a good choice. AEXA's initial budget is 10 M Mexican pesos, and it hopes to receive additional funds for services rendered.

Satélites Mexicanos (Satmex) experienced problems with the Satmex 5 satellite's primary Xenon Ion Propulsion System (XIPS) early in the year. Satmex said that it had not been able to restart the XIPS system after an unexpected shutdown and a failure in its secondary system. The satellite, situated at 116.8 degrees West, was operating on its back-up bi-propellant propulsion system. Satmex also confirmed that its Satmex 5 satellite was not insured for a loss due to a XIPS failure and that the

malfunction would likely to lead to a reduced lifetime for the satellite. The back-up system means the satellite will have a remaining life of 2.7 years, as compared to almost four years if the XIPS failure had not occurred. The operator said it does not expect to restart the XIPS system and began plans to obtain financing for a replacement satellite.

Satélites Mexicanos S.A. de C.V. (Satmex) was to be acquired by EchoStar Satellite Services, for about $374 million, the companies announced in February '10. EchoStar and MVS Comunicaciones, EchoStar's partner in DTH provider Dish Mexico, formed a joint venture that would have paid about $267 million in cash for all Satmex outstanding stock and up to $107 million in cash on Satmex's balance sheet at closing, resulting in total cash of up to $374 million available for distribution to Satmex's stakeholders. Satmex owns and operates three satellites and two satellite uplink facilities, which were all included as part of the transaction. In January, The deal was expected to close early in the third quarter, contingent upon other closing conditions, including actions related to the construction of a replacement satellite for Satmex 5. (Satmex disclosed that the Satmex 5 satellite was suffering from propulsion problems that will cut the lifetime of the satellite short by more than a year.) However, in March, EchoStar Satellite announced that it had terminated its stock purchase agreement to acquire Satmex, according to documents EchoStar filed with the U.S. Securities Exchange Commission (SEC). EchoStar told the SEC that it required Satmex to solicit consent to amend its outstanding debt and waive all defaults and to enter into lockup agreements with the holders of at least a majority of its debt within 17 days of the execution of the purchase agreement. Satmex also was asked to redeem or repurchase a sufficient percentage of its existing debt due in 2011 and 2013. EchoStar exercised its right to terminate the agreement after Satmex failed to meet this obligation.

In December 2010, the Mexican Government issued a $1 billion contract to Boeing for the development and delivery of the Mexsat end-to-end communications system. The system will consist of three satellites, two ground sites, and associated network operations. >>

International experts converged on Mexico City in February to discuss the best way to establish a global detection and warning network to monitor potential asteroid threats to all life on Earth. The workshop was organized by the Secure World Foundation (SWF) and by the Association of Space Explorers and the Regional Centre for Space Science and Technology Education in Latin America and the Caribbean (CRECTEALC). Sergio Camacho, former Director of the UN OOSA, and currently Secretary General of CRECTEALC as well as Chairman of the COPUOS Working Group on Near-Earth Objects stated that the workshop's report will be a vital resource to the Scientific and Technical Subcommittee of COPUOS, its Working Group on NEOs. The goal was to use existing capabilities already being provided by states or institutions and adding other necessary capability.

People in central Mexico in February 2010 reported seeing in an explosion in the sky that ended up being a Russian satellite plunging back to earth. The space debris was likely the Cosmos 2421 reconnaissance satellite launched by the Russian Navy in June 2006 that malfunctioned and broke apart into 15 pieces two years later.

Mexico was host to the *"Sexta Conferencia Espacial de las Américas"* (Sixth Space Conference of the Americas), held in Pachuca, Hidalgo, from 15 to 19 November 2010. The conference attracted scientists, political leaders and many

younger generation persons involved in space activities from Latin American countries, Asia, Europe, and the US. The United Nations Regional Centre for Space Science and Technology Education in Latin America and the Caribbean (CRECTEALC) provided support to this important regional forum on regional and international cooperation, whose theme was "Space Development in the Service of Humanity and Latin America." Mexico thus becomes the Secretariat Pro-Tem of CEA, as well as the focus for future aeronautical and Astronautical development in the region.

Paraguay

Paraguay's Ministry of the Economy in December 2009 contracted Telespazio Argentina to develop and implement a cadastral registry information satellite network as well as supply informatics devices for the system. The total contract value is $3 million, which is being financed by a loan from the Inter-American Development Bank to the Republic of Paraguay. The contract called for Telespazio to complete the project within a year of the contract award.

The Paraguayan National Cadastre Service will use the system for state and municipal property administration based upon a geographic information system, which will automate communication between offices. This system aims to promote direct access to all information related to registry and cadastre for the interested government entities, owners and the private sector and reduce the duration and security of cadastral registration activities.

United States

In late December 2010, US President Obama signed H.R.3237 into Law: National and Commercial Space Programs is now Title 51 of the United States Code (USC).

Over the past five decades, a substantial amount of legislation has been enacted relating to national and commercial space programmes. In the United States Code, some of these provisions appear in title 15 (Commerce and Trade), some in title 42 (The Public Health and Welfare), and some in title 49 (Transportation). No distinct title for national and commercial space programmes exists in the United States Code because the organizational scheme for the Code was originally established in 1926, before such programmes were contemplated. The bill gathers provisions relating to national and commercial space programmes, and restates the provisions as title 51, United States Code, "National and Commercial Space Programs". The bill does not provide for any new programmes. Nor does it modify or repeal any existing programmes. Rather, the bill restates existing law in a manner that adheres to the policy, intent, and purpose of the original enactments, while improving the organizational structure of the law and removing ambiguities, contradictions, and other imperfections. The bill was prepared by the Office of the Law Revision Counsel of the House of Representatives, as part of its responsibility under 2 U.S.C. 285b to submit to the Committee on the Judiciary proposed bills to enact titles of the United States Code into positive law. For more information about the process of positive law codification generally, see the brochure Positive Law Codification in the United States Code.

In December, U.S. President Barack Obama unveiled proposals to speed the progress of export control modernization and revise the U.S. Munitions List (USML) and Commerce Control List. The initiatives, revealed at a meeting of the President's

Export Council chaired by Boeing President and CEO will attempt to revise export controls on military vehicles through proposals to eliminate commerce-licensing requirements for low sensitivity, dual-use exports to U.S. allies. The proposals also include the establishment of a consolidated list of entities that require extra scrutiny by U.S. companies before exporting.

The Administration's continued interest and attention on streamlining and strengthening the U.S. export control process will be a welcome change, as the current export control system has not changed to meet the needs of the sector or kept up with the pace of technological change. Rationalizing these technology lists will support US national security interests by bolstering its security partners and strengthening the global competitiveness of the U.S. high technology industrial base.

17 July 2010 marked the 35th anniversary of the historic Apollo-Soyuz meeting in space, marking the first major cooperation between the only two nations then engaged in manned space flight. One author called this meeting the "beginning of the end of the Cold War rivalry in space." Despite lofty promises, there was no repeat of Soviet-American cooperation until the early 1990s, after the collapse of the Soviet Union and the emergence of the Russian Federation. The collaboration led to the ISS, the greatest partnership between the Russians and the USA and that has matured into a robust friendship, a stepping-stone to even greater cooperation in the decades to come.

U.S. President Obama signed a 2011 budget proposal that planned to replace the six-year old Constellation programme with a commercial approach to the current low Earth orbit (LEO) programme that has limited the U.S. space programme since Apollo. While a commercial approach will be good for many newly-founded space companies, America's image and its ability to compete in the international marketplace is at stake. The U.S. space exploration programmes have stimulated jobs, scientific knowledge, development of commercial products, solutions to problems in almost every facet of life. But U.S. space pre-eminence has continually eroded over the last two decades. One impact of this is a loss of interest in science and technology among the best and brightest students. Whether government or commercial programmes, what is needed is a space challenge that captures the imagination of the world. Humankind must explore and must not remain stagnant. One such challenge, advocated by some, is to prepare to send U.S. astronauts to Mars.

The U.S. space and satellite industries enter a completely new political atmosphere in 2011, shaped not only by the elections this past November, but also by substantial policy changes over the past 12 months. U.S. government space policy shifts and the eventual retirement of the space Shuttle, and of key personnel associated with the Shuttle programme and other scientific endeavours. The global economic downturn is another factor affecting the space sector in the US.

The National Science Foundation's Ocean Observatories Initiative (OOI), said that it aims to build a network of ocean sensors to measure the physical, chemical, geological and biological variables in the ocean and sea floor. OOI will integrate into a larger, multi agency, public-private effort called the Integrated Ocean Observing System, or IOOS. IOOS itself will plug into the greater Global Earth Observation System of Systems (GEOSS), in which 80 governments are participating. >>

The United States and China agreed to discuss expanded cooperation in space science and to start a dialogue on human space flight and exploration, according to a

joint statement released in Beijing. The U.S.-China Joint Statement said both nations looked forward to reciprocal visits by the NASA administrator and appropriate Chinese space leaders in 2010. >>

The White House proposed major changes of the U.S. government's troubled next-generation weather satellites, cutting the NPOESS programme in half and directing NOAA and the Air Force to continue developing their own weather observatories. >>

Space Shuttle

After 29 years of space shuttle flights, NASA planned to wrap up the programme with five missions to complete construction of the ISS and retire the fleet before the end of 2010, but this was extended to early 2011. The ISS deputy programme manager called 2010 the last major growth spurt for the station. After detailing what additions and deliveries to be made in 2010, NASA stated that it was going to finish strong with the shuttle and make sure it left the station in the best possible posture. No other vehicle could have been used to construct the station, but now that the station is assembled, smaller vehicles to transport crew back and forth can be used.

In July, the US Senate panel voted to extend the Shuttle's life into 2011, as part of NASA's 2011 budget. The budget plan maintains the White House's $19 billion request for NASA funding and adds another shuttle mission in 2011 to the two already scheduled for November and February. Representatives from Texas and Alabama lobbied strongly for adding shuttle missions. The skirmish between President Barack Obama and Congress over NASA - and the future of the Johnson Space Center - rests largely on one issue: How much money will be handed over to commercial spacecraft companies to carry astronauts into orbit. Both houses of Congress have signalled the historic change that will begin with the amount of money they have put into appropriations bills. This bill awaited final vote of the Congress, in September.

The White House was expected to complete by mid-December 2009 a sweeping review of US national space policy led by the director of space policy for the White House National Security Council. It would address a range of topics, including space protection, cooperation; acquisition reform; US export controls and national space strategy. The deputy director of space policy at the State Department said that a key element of the review involved ways to protect critical government and commercial space infrastructure against orbital debris. After the review, the Obama administration's forthcoming policy would emphasize international cooperation and a consultative approach with allies in addressing space access and other strategic concerns.

The re-establishment of a National Space Council would help in setting a National Space Policy, but seems to be a moot point. This recommendation was made 2 years ago by the US Naval War College, and was an item during President Obama's campaign, but is no longer mentioned. A person at the Naval War College stated that "the ability to stifle such a promised action is a tribute to the power of bureaucratic and organizational politics," adding that without a National Space Council, there will be no progress on important issues.

According to a presidential directive signed on 21 December 2009, President Barack Obama directed his administration to recommend by end January 2010, steps leading to an overhaul of the U.S. export control regime. The directive said these

recommendations would be used to draft a new U.S. export control system. A task force was already established. The directive also instructs the task force to draw upon the expertise of U.S. industry and allies, particularly those from countries with regulatory regimes that could serve as a model. The task force likely will provide a range of recommendations to Cabinet secretaries to include everything from minor system tweaks to the creation of a new export control agency. Current regulations have had a negative economic impact on US space industries.

Nearly a year later to the day, on 9 December 2010, President Obama unveiled proposals to speed the progress of export control modernization and revise the U.S. Munitions List (USML) and Commerce Control List. These initiatives attempt to revise export controls on military vehicles through proposals to eliminate commerce-licensing requirements for low sensitivity, dual-use exports to U.S. allies. The proposals also include the establishment of a consolidated list of entities that require extra scrutiny by U.S. companies before exporting. The Obama administration may remove restrictions on exporting goods with potential military applications, if such technologies area already available elsewhere. Commerce Secretary, in a meeting of the US-China Business council, stated that the US had too many controls on items readily available around the world, and to restrict US companies from sending those around the world, hurts the US. The National Association of Manufacturers estimates the rules may have cut exports by as much as $100 billion, and would include items such as software, machine tools, and basic encryption technology.

Policy analysts wrote that after the Augustine Commission, they were expecting a “rewriting” of the national space policy. However, questions arose whether reviews like this are needed with each administration. An obvious problem with this approach is that the space enterprise has become so large and diverse that no single policy document can be truly comprehensive. Targeted policies have been the ones that have provided the clearest guidance to U.S. agencies, influencing the development and implementation of their space-related programmes. A national space policy review would only lead to increased costs and delays before the more important targeted policies are tackled.

NASA needs to continue to improve astronaut crew safety on its new shuttle-replacing rocket, as well as on promising commercial vehicles that could ferry crews to orbit. Meanwhile, NASA officials told congressional representatives that its new Ares rockets should be 10 times safer than the space shuttle. Jeff Hanley, who leads Constellation, said: “Simply put, safety is a top priority in NASA’s Constellation programme.” As for commercial transportation, NASA’s safety chief said the agency has provided its safety requirements to Space Exploration Technologies (SpaceX) and Orbital Sciences Corp., but formal discussions over human-rating a commercial spacecraft have not yet begun.

HR 3819, the commercial launch indemnification regime extension, was signed into law by the President on 28 December 2009. The law was passed by the Senate the previous week.

The U.S. government intends to terminate Northrop Grumman's contract to manage a troubled weather satellite programme and transition responsibility for all elements of the programme to NASA. Under the 2011 budget, the NPOESS programme was split with NASA and NOAA overseeing two polar-orbiting weather satellites and the Defense Department overseeing another two. NOAA’s Administrator

stated that NASA will build two satellites under the newly created Joint Polar Satellite System that will launch in 2015 and 2017. The satellites will retain all of the instruments that were slated to fly on NPOESS.

Commercial Space Travel Safety

Congress was to hear in December from NASA officials, proponents of commercial crew transportation and independent safety experts. Meanwhile, US President Obama faced decisions that would set safety levels for American astronauts launching on space expeditions for decades to come. One issue to be raised is that the original 2005 study that NASA used to select the Ares I and Orion over other alternatives found that the two systems needed to fly at least seven times before they could be deemed safer than the space shuttle. This was at odds with NASA's current assertion that Ares and Orion would be so safe they could launch humans after just one flight without astronauts on board, which has become critical to NASA's defence of the Ares I.

NASAWatch.com, a respected watchdog website, reported that NASA allegedly withheld information from a White House panel that showed the Ares I rocket did not meet the agency's own safety goals. The website says that the information was contained in a chart prepared by a consultant who has authored several studies for NASA and clearly indicates that Ares I falls short of the safety standards that the Constellation Program set for itself.

According to congressional testimony from U.S. Government Accountability Office (GAO) in December, the lack of a comprehensive U.S. national space launch strategy and unified oversight council is obstructing the domestic commercial launch industry's ability to grow and compete. According to the U.S. National Academy of Sciences, aligning the strategies of the various civil and national security space agencies will address many current issues arising from or exacerbated by the current uncoordinated, overlapping, and unilateral strategies.

Congressional Panel to Examine Commercial Spaceflight

In late 2009 it was reported that the House Transportation and Infrastructure aviation subcommittee was holding a hearing on the safety and regulation of US commercial spaceflight. It was expected to consider regulatory changes during the next three years as NASA gets ready to retire its space shuttle fleet, firms like XCOR plan to launch passengers into suborbital space, and private companies including Space Exploration Technologies (SpaceX) prepare to deliver cargo and eventually people to the international space station. Additionally, the panel planned to examine the effect of space tourism and commercial spaceports on air traffic control and the safe and effective use of the national airspace system, as well as the need to ensure passenger and crew safety.

In October 2010, the American Bar Association (ABA) held a conference on "Commercial Spaceports – the New Frontier". A spokesperson for the Federal Aviation Administration (FAA) stated that "spaceport" does not occur in the statutory language; rather, the laws and regulations use "launch site" and "re-entry site." Historically these sites have been run by the federal government, but with the dawn of commercial spaceflight, the FAA was given competency to regulate such sites. When they were first developed they were intended to govern ELVs, but they have had to be changed in order to adapt to the changing nature of commercial spaceflight. These regulations were intended to protect the civilian population from the high risks

involved with launch activities. It is important to note that the regulations differentiate between the site operator and the launch operator, who have different responsibilities under the FAA regulations. There are several such launch sites: the SeaLaunch platform launches mostly satellites into geosynchronous orbit, while the Mojave space port is intended to service primarily suborbital space tourism activities, and the Kodiak (Alaska) Launch complex launches objects to low earth orbit (LEO).

A December 2010 review of the past year in terms of spaceflight news, highlights a tumultuous year in human spaceflight. This included events like President Obama's trip to the Kennedy Space Center to pitch an unpopular space policy, a new commercial capsule launched toward an Apollo-like splashdown and roughly 1,500 shuttle workers collected severance packages. The article also listed the year's shuttle and International Space Station news, as well as other events important to Florida and Kennedy Space Center. These historic milestones will be followed by thousands of additional local layoffs when the wheels stop on the last shuttle mission, beginning a post-shuttle 'gap' in US human spaceflight of undetermined length.

Commercial Space Transportation Safety

In an op-ed in Space News early in 2010 Patti Grace Smith, an aerospace consultant and former FAA associate administrator for commercial space transportation, wrote: “Several policymakers seem to make the unwarranted leap of logic that if commercial space travel costs less than a government programme, it is inherently less safe.” Smith criticized the Ares programme's safety and design, then adds: “It’s vital to recognize that although commercial human spaceflight will be under a different regulatory framework than past NASA launches, this does not mean that commercial crew systems will be held to a lower standard in regard to safety.” According to Smith, the FAA's Office of Commercial Space Transportation will learn from and work with NASA, the Air Force, and other agencies to create “a regime that will be different from, but in no way inferior to, what NASA would otherwise demand.” Smith concludes that “safety and affordability are not mutually exclusive, and for human spaceflight, it's high time that we demand both.”

Commercial Launch Indemnification Legislation

The Senate Commerce Committee was scheduled to deal with a bill in December to extend the existing launch indemnification regime for thee years. This was passed by the House in October, where it passed on a voice vote with little debate. Timing was critical though, since the current indemnification provision was set to expire at end December 2010, but the U.S. Congress extended government indemnification of U.S. commercial launches for another three year.

In a move essential to Florida’s efforts to develop an expanded commercial launch industry, the US Senate passed legislation in late December that would extend federal liability protection for commercial space launch providers against catastrophic events. The legislation continues indemnification for the next three years. While the measure is vital for commercial aerospace companies, especially publicly traded ones, so far it's never been invoked.

The indemnification regime helps protect U.S. commercial launch services providers against third-party liability claims resulting from launch activities licensed by the U.S. Federal Aviation Administration. As space launch capabilities have been developed by other nations, the United States share of commercial launches has decreased significantly, and elimination of government indemnification would have

driven launch business overseas. In 2008, only six of the 28 worldwide commercial launches were conducted by U.S. companies, and America can't afford to lose more of that business, according to the Aerospace Industries Association (AIA). The indemnification regime provides a level playing field in a very competitive global space launch market, since every other space faring nation provides some form of government indemnification to commercial launchers.

Congress and satellite broadcasting

The U.S. House of Representatives has passed an updated version of HR 3750, commonly known as the Satellite Reauthorization Bill, Congress announced on 4 December 2009.

The bill, which upon signing was renamed the Satellite Home Viewer Reauthorization Act, reauthorizes the license for satellite companies to carry distant network affiliate TV station signals. The bill also requires broadcasters to deliver local broadcasts to all 210 designated markets areas across the United States and imposes harsher penalties for any future problems, and requires pay-TV providers to deliver high-definition station signals by 2011. The new deadline replaces the U.S. Federal Communications Commission's 2013 deadline. Similar legislation must now pass the U.S. Senate, which was expected to review the bill in 2010.

Federal Aviation Administration (FAA)

The FAA in April took a step closer to setting up a central hub for the development of key commercial space transportation technologies such as space launch and traffic management applications and setting orbital safety standards. The FAA is establishing the Center of Excellence for Commercial Space Transportation in 2010 as an offshoot of other FAA Centers for Excellence and will join universities, industry players and the government in various areas, like space launch operations, commercial human space flight, and "Cross-Cutting Research."

In December 2010, the FAA said that as many as 119,000 (one third) of the 357,000 U.S.-registered aircraft have questionable registrations due to missing paperwork, invalid addresses and other paperwork problems. Until now, aircraft owners were only required to register once, when they purchased an aircraft. Errors accumulated over decades as new purchasers forgot to register, owners died, invalid addresses went uncorrected and junked aircraft went unreported, the FAA said. Similar concerns could be raised regarding spacecraft registration, as national registers and the UN Register, mandated by the Registration Convention, also need an update.

The FAA approved a Launch Site Operator´s License for Space Florida to facilitate commercial launches from Space Launch Complex 46 (SLC-46). The license went into effect on 1 July 2010. With the FAA License now approved, Space Florida may actively pursue commercial customers for launch commitments at SLC-46. >>

Federal Communications Commission (FCC)

On 15 July, the Federal Communications Commission (FCC) issued a combined notice of proposed rulemaking (NPRM) and notice of inquiry (NOI) aimed at removing certain regulatory barriers to enable terrestrial use of certain licensed Mobile Satellite Service (MSS) spectrum for wireless broadband services. The NPRM outlines proposals to add flexibility to, and promote additional investments in, the MSS bands. The NOI seeks comments on how to best increase the value, utilization,

innovation and investment in spectrum throughout the 2 GHz, Big LEO and L-bands.

Google, Verizon Communications and AT&T joined forces to challenge the reach of certain FCC regulations involving the mobile satellite industry, which were outlined in the FCC's National Broadband plan released in February. The debate over the FCC's reach and over net neutrality continues as the U.S. Court of Appeals for the District of Columbia ruled against the U.S. Federal Communications Commission's (FCC) Internet regulations and broadband expansion plan.

The U.S. Court of Appeals for the District of Columbia ruled against the U.S. Federal Communications Commission's [FCC] Internet regulations and broadband expansion plan, released in February. In its ruling, issued April 6, the court stated that the FCC lacks the authority to require broadband providers to give equal treatment to all Internet traffic flowing over their networks. The court case is based on a 2008 legal challenge filed by Comcast against the FCC, after the commission banned the company from blocking its broadband subscribers from using file-sharing torrent sites. Comcast claims the FCC order is illegal because the agency doesn't have the ability to create or enforce legal regulations.

The decision puts the FCC's national broadband plan at risk, which includes a proposal to expand broadband by utilizing government subsidized telephone service in rural communities. "[The FCC] is firmly committed to promoting an open Internet and to policies that will bring the enormous benefits of broadband to all Americans," the FCC said in a statement following the ruling. The FCC's broadband plan had already been under attack from telcos Google, Verizon Communications and AT&T, which have joined forces to challenge regulations involving the mobile satellite industry.

In addition to complaining about relaxing requirements on satellite providers to deliver broadband service through consumer market devices, Verizon and AT&T claim that the merger between SkyTerra and Harbinger, which was approved by the FCC, would make it more difficult for AT&T and Verizon to lease spectrum from the satellite company and that the FCC "overstepped its authority to impose that condition," the companies said.

A few days after the court's ruling, however, an FCC spokesperson stated that the court's decision should not affect the FCC's National Broadband Plan, and that the FCC is sticking with its current timetable for that Plan and its allocation of spectrum. In its ruling, the court stated that the FCC lacks the authority to require broadband providers to give equal treatment to all Internet traffic flowing over their networks.

The U.S. satellite industry enters a completely new political atmosphere in 2011, shaped not only by the elections this past November, but also by substantial policy changes over the past 12 months.

NASA

S. Neil Hosenball, 84, General Counsel of the National Aeronautics and Space Administration (NASA) from 1975 until his retirement in 1985, died on 23 December in Arlington County, Virginia. Hosenball was an eminent space lawyer and a major contributor to space law; he served as one of the negotiators on the Moon Treaty for the United States. He also served as the U.S. negotiator for the U.N. The Principles Relating to Remote Sensing of the Earth from Outer Space (resolution 41/65 of 3 December 1986) (Principles). He later published a book including interviews on these negotiations.

Over 80 members of the House of Representatives signed a letter in November 2009, to U.S. President Barack Obama calling for a $3 billion annual funding increase for NASA's human spaceflight programme. The letter asserts that NASA's under-funded budgets over the past several years have slowed the pace of exploration, depleted resources, and frustrated the development of new space systems and tied technological innovations resulting from NASA's manned spaceflight programme to weightier issues of national security and U.S. competitiveness in the global aerospace market.

NASA's budget and policies have been the focus of controversy throughout the year. In July, lawmakers approved 2 separate bills: a Senate panel approved a compromise plan with the White House that kills the Constellation moon-rocket programme and sets NASA on an uncertain path toward building a new rocket, while House science committee agreed to add one more shuttle flight, following the lead of the Senate, making the extra flight look increasingly likely, even though a bitter dispute remains between House and Senate committees regarding how much to invest in commercial rockets. Both bills cut out the Moon as NASA's next major goal and both extend space station operations through 2020 as requested by the President. But both reduce funding for commercial manned space initiatives. Members of Congress from states that have close ties with NASA (Florida, Alabama, Texas, California) lobbied hard to continue programmes beneficial to their states.

On 22 December 2010, US President Barack Obama signed into law a short-term appropriations bill that will keep the federal government, including NASA, funded at 2010 spending levels through 4 March, according to a White House news release. While the continuing resolution provides no relief from a prohibition in last year's appropriation that bars NASA from cancelling Constellation contracts, its lack of specificity for NASA programmes gives the agency authority to continue developing a multi-purpose crew vehicle for deep space missions as called for in the authorization act. However, NASA may have some issues with its commercial crew programme because the programme is new, and was not funded in the 2010 appropriation, so NASA could be left to await new appropriations legislation before it can get started.

NASA wouldn't receive the extra funding anticipated for the first year of its new policy, under a spending bill awaiting approval in Congress. Instead of approving a full year spending bill before the end of the year, lawmakers plan to continue debating spending in the 112th Congress, when Republicans will take control of the House and boost their minority in the Senate by six seats. The new spending bill that extends funding to March 4 did not include any extra funding for NASA. But Sen. Bill Nelson, D-Fla., said the space agency should be able to accomplish its goals of launching a third shuttle mission in 2011 and supporting commercial rocket development, despite losing the extra funding, at least temporarily. The third shuttle flight, funding for commercial cargo and crew development and the remodelled Orion capsule all receive healthy funding.

NASA officials are weighing the impact of appropriations legislation approved by the US House of Representatives on 8 December. NASA reportedly was examining it for potential conflicts with the recently signed authorization bill. If the heavy-lift language in H.R. 3082 is enacted, NASA would have little choice but to pursue a vehicle that relies in part on the giant solid-rocket motors used today on the space shuttle, which was the approach under Constellation, leaving "little wiggle room" for

NASA. The $825 million added in the House bill is almost $200 million more than recommended in the 2010 NASA Authorization Act, and would be enough to cover three shuttle missions next year.

According to an article, NASA is at a turning point after nearly 29 years of shuttle flights, a programme that has had “incredible highs, and terrible lows.’While the shuttle hasn’t achieved all its goals, such as having routine and inexpensive launches, it has accomplished a lot, including the launch and multiple servicing trips of what's probably the world's best-known and loved observatory, the Hubble Space Telescope. The Columbia and Challenger tragedies were also highlighted in the article. While the future is uncertain, the year 2010 was surely be an eventful one for NASA, and could mark the end of the space shuttle era.

Terrestrial events also influenced NASA and the remaining flights of the Space Shuttle. The next to last space shuttle external tank was set to depart NASA's Michoud assembly plant in Alabama, bound for the Kennedy Space Center, but due to the April 2010 oil spill in the Gulf of Mexico, the deep water route typically used by NASA barges and their tugs to haul the 15-storey space shuttle fuel tanks from their manufacturing site could not be used. In addition, the tank, built by Lockheed Martin, was ready at end April but high winds prevented it from being shipped. The last tank was scheduled to be finished by June and scheduled to fly with shuttle Discovery on Sept. 16. In addition, the company was constructing ET-122, a spare launch-on-need tank that was damaged in Hurricane Katrina, but is not scheduled to fly. Later in the year, the launch of Discovery was scrubbed, due to problems with the fuel tanks and other difficulties. The launch is to take place in early 2011.

A former director of public affairs for the Kennedy Space Center wrote that the lack of understanding by the public and many elected officials of the space programme's value to the nation is putting the US at risk of losing its leadership role in space. Since there has been no programme in history that has been more effective in the creation of new knowledge, new products and new jobs, proper funding of NASA, and clear direction based on science, not politics, is vital. Space funding is seen as key for the US to balance its debt. US astronauts and ground crews make space flight look easy and fun. The adventure is not just fun; it is the basis for the well being of the US’s entire population.

NASA says it will buy up to $30.1 million worth of data about robotic lander projects - doubling the potential impact of the $30 million Google Lunar X Prize. This support would come under the Innovative Lunar Demonstrations Data programme. Such data could help NASA design its own landers for robotic as well as human missions to the Moon, Mars, asteroids or elsewhere. The programme also provides an extra financial incentive for the 21 teams chasing the Google Lunar X Prize, which would reward the first team to land a privately developed rover on the moon. X Prize competitor Astrobotic Technology hailed the move.

Governments are also keeping a close watch on the United States - and, in particular, on the White House, as the Obama administration must decide how to respond to the Augustine report.

NASA Administrator Charlie Bolden was to meet in December 2009 with President Barack Obama, to discuss the Augustine report findings. This was taken as an indication that the administration could be close to a decision on how it wants to explore space after NASA retires the space shuttle in 2010. It is unlikely that an

announcement of a new policy would happen immediately, but given the options under consideration, it seemed likely to mean the end of Constellation's Ares I rocket.

The change to NASA's space policy were brought about by U.S. President Obama who essentially challenged the space agency to do something other than put a man back on the moon. Despite the "dramatic change" to NASA, according to an article, its goals remain unclear, and need focus. Now, many of NASA employees are uncertain about their future. The uncertainty is even greater in the private sector, where thousands of NASA contractors are facing the end of the Constellation Program.

In an attack on U.S. Presidents's new space policy, a space group criticized the White House plans for NASA, saying that they should concentrate on developing a new heavy lift rocket to take humans back to the moon by 2025. While the National Space Society (NSS) commended the increases to science and the extension to the International Space Station, it said the policy needed destinations and sustainability goals.

House of Representatives' lawmakers expressed confidence in the safety of NASA's planned Ares 1 rocket and questioned whether alternative launchers and spacecraft could provide the same level of assurance sooner than the systems the agency is developing to replace the space shuttle. One Representative said the predicted safety of alternatives to NASA's Orion Crew Exploration Vehicle and its Ares 1 launcher offered no compelling reason for NASA to change course, adding that the commercial sector should not be in competition with the Constellation programme.

NASA awarded a pair of contracts worth nearly $200,000 to Astrobotic Technology Inc. and Carnegie Mellon University, both in Pittsburgh, to study Moon excavation robots and methods to simulate lunar gravity" as part of NASA's Small Business Innovation Research programme. Both Phase 1 awards total $199,850 and cover six months of work, while the envisioned Phase 2 awards could be worth a combined $1.2 million.

U.S. space exploration will reach beyond the moon and further into the solar system's reaches by 2025, according to a speech by U.S. President Barack Obama at the Kennedy Space Center in Florida in early 2010. Despite criticism from the space industry over cuts to NASA's Orion programme, announced in February, Obama remains 100 percent committed to the mission of NASA and its future, but defended his plans to use federal funding to bring more private companies into space exploration following the retirement of the Space Shuttle programme.

While US President's NASA policy has its share of critics, the plan also has supporters in the U.S. commercial launch industry. SpaceX's CEO Elon Musk said the President reached a "reasonable" conclusion that spending $50 billion to develop a NASA launch vehicle replacement for the Space Shuttle is too expensive. By the time President Obama cancelled Ares I/Orion earlier this year, the schedule had already slipped five years to 2017 and completing development would have required another $50 billion. Moreover, the cost per flight, inclusive of overhead, was estimated to be at least $1.5 billion compared to the $1 billion of Shuttle, despite carrying only four people to Shuttle's seven and almost no cargo, according to Musk.

NASA Administrator Charles Bolden told audience members at the 2010 Space Symposium that U.S. President Barack Obama's new direction for NASA

should be seen as a transformative effort rather than a massive budget cut. According to Bolden, both NASA and the President are absolutely committed to human spaceflight, and will use innovative technologies developed in a step-wise approach. NASA will take small steps along a game-changing path. The re-focus with international and commercial partners is a move that aims to promote competition and allow innovation to thrive.

In its 2010 fiscal year governmental budget, released 1 February, the White House terminated NASA's work on Orion, the follow-up vehicle to the Space Shuttle; ended development on two NASA rockets designed to fly manned missions to the moon; and set aside funding to hand over space transportation and future human exploration mission to private commercial companies.

A NASA Advisory Council (NAC) subcommittee is echoing members of Congress in asking the US space agency to provide more detail and justification for its plan to substitute commercial space taxis for the Orion crew exploration vehicle and its Ares I launcher as a route to the International Space Station for astronauts. The subcommittee expressed dissatisfaction with NASA at a meeting late July. The NAC subcommittee said that further analysis needs to be conducted on the cost, reliability and safety implications of the overall commercial space transportation business, as well as the impact of domestic and foreign competition.

Kennedy Space Center quietly marked a significant shuttle programme at end December 2010, when technicians preparing an orbiter for flight installed a set of main engines for the last time. The engines were installed into Atlantis, which could make the final shuttle mission if funded by Congress. A Kennedy Space Center spokesperson said this was kind of a quiet milestone that pointed in the direction of finality to the shuttle programme. These are the last engines that would take the last space shuttle into space for the last time.

In other developments, NASA awarded Innovative Lunar Demonstrations Data contracts to six companies for the purchase of technical data resulting from industry efforts to develop vehicle capabilities and demonstrate end-to-end robotic lunar landing missions. >>

NASA Administrator Charles Bolden and Chairman of the German Aerospace Center (DLR) Executive Board Johann-Dietrich Worner signed a framework agreement for cooperative activities in aeronautics, exploration and the peaceful use of space. >>

The US and European space agencies signed the "letter of intent" that ties together their Mars programmes. The agreement, between NASA and ESA, which was penned in Washington DC, gave the green light to scientists and engineers to begin the joint planning of Red Planet missions. The union will start with a European-led orbiter in 2016, and continue with surface rovers in 2018, and then perhaps a network of landers in 2018. >>

NASA told the major contractors working on its Constellation moon rocket programme that they were in violation of federal spending rules - and must immediately cut back work by nearly $1 billion. >>

In August 2010, NASA was asked by the Chilean government through the U.S. Department of State to provide technical advice that might assist the trapped miners at the San Jose gold and copper mine near Copiapo, Chile. >>

US Air Force

The US Air Force (USAF) stated in January that, in the face of threats from jamming and attacks on satellites, the United States must lessen its dependence on the Global Positioning System and develop alternatives to GPS. The USAF confirmed that GPS has been jammed or interfered with recently. Already the DoD's Space Posture Review has tentatively recommended that the U.S. scrap building five more GPS satellites.

The U.S. Air Force launched an upgraded Global Positioning System (GPS) satellite aboard a Delta 2 rocket on March 20, from Cape Canaveral Air Force Station. The satellite upgrades include an advanced antenna panel, which aims to deliver greater performance and power for GPS receivers for users to determine precise time and velocity and worldwide latitude, longitude and altitude to within a few metres.

The Air Force's GPS constellation currently comprises 27 satellites, including nine new-generation GPS 2R spacecraft, designed to improve worldwide coverage and increase the overall performance of the global positioning constellation.

The US National Geospatial-Intelligence Agency (NGA) awarded contracts to three companies to provide commercial radar satellite data, each of which will rely on foreign-owned satellites because no U.S. firm operates spacecraft collecting the imagery NGA seeks. Lockheed Martin Space Systems, EADS North America, and MDA Geospatial Services were awarded contracts for synthetic aperture radar (SAR) data over five years. Because of the NGA's broad set of requirements, the NGA had to contract with several providers, as they cannot be satisfied by any single radar satellite constellation currently on orbit.

The US government is embarking on a comprehensive, 20-year programme worth as much as $700 million per year to procure commercial satellite bandwidth and services to support the Defense Dept. and state and local agencies. This is the Future Comsatcom Services Acquisition (FCSA) programme that will merge the needs of these groups for a potential 15-20% in savings. Sources state that the FCSA is not a replacement for the terminated Transformational Satellite (TSAT) system, but the access it will provide to bandwidth will relieve some of the burden left after the programme's termination. A request for proposals was to be issued in February 2010. Defense Information Systems Agency says one goal is to protect the signals travelling to and from the satellite as opposed to physical protection of the satellites.

Space Insurance

Space insurers were expected to generate more than $400 million in profit for 2009, according to a statement released in November 2009 by Aon International Space Brokers, a specialist risk adviser in this sector. Aon said growth would lead to more competitive premiums for satellite operators in the new year as the capacity for space risks continues to increase. However, the $400 million figure is dependent on there being no more claims before the end of the year.

In 2009, more than $800 million of premiums were expected to be paid for all-risks launch and in-orbit insurance. The third quarter of 2009 saw five major insured launches (two Ariane 5s, two Protons and one Long March 3B, of which ISB were involved in four), which generated an estimated $154.6 million of premium income for the space insurance market, according to a Aon's space business unit leader.

Demand for satellite communication capacity continues to grow, from delivering broadband and television to surveying the earth for pollution, resources and disaster monitoring. The recession made it more difficult for some operators and particularly new projects to raise capital, but, nevertheless, there are a number of interesting projects that are progressing well. The health of the insurance industry means it is well positioned to support satellite programmes by providing sufficient capacity to satisfy investor requirements.

Private Sector

Satellite Broadcasting

A Florida federal court issued a $51 million dollar judgement award to Dish Network, EchoStar Technologies and NagraStar in its anti-piracy lawsuit against Robert Ward, who posted software on the Internet that allowed individuals to illegally receive Dish Network programming using free-to-air receivers. In the summary judgement decision, the court held that the posting of pirate software constitutes a violation of the U.S. Federal Communications Act, and that statutory damages should be calculated based on how many individuals downloaded the pirate software. This is a significant victory in the effort to eradicate piracy of the Dish Network system. The court was thanked for its well-reasoned analysis by NagraStar's CEO.

Non-profit /non-governmental /academic

A relatively new organization of space advocates, the Commercial Spaceflight Federation (CSF), is the industry association representing 37 companies, businesses and organizations working to make commercial human spaceflight a reality. The mission of the Commercial Spaceflight Federation is to promote the development of commercial human spaceflight, pursue ever higher levels of safety, and share best practices and expertise throughout the industry. Founded in 2005, its focus has been on personal spaceflight. As the organization has evolved and grown, it also changed its name to CSF in June 2009. Its incoming Chairman of the Board is Eric C. Anderson, who holds the position of chairman of Space Adventures, Ltd.

In December 2010, the CSF criticized a White House deficit reduction commission's recommendation to cut $1.2 billion in proposed NASA spending on the industry, a linchpin of the Obama administration's new space policy which the CSF supported. Commercial Spaceflight Federation's President said this would have disastrous consequences for NASA and would result in total reliance on Russia to get to the space station and result in the loss of thousand of high-tech jobs. Congress' recommendations haven't been voted on, and isn't expected to act on any recommendations that aren't supported by at least 14 of the group's 18 members.

The CSF announced the creation and initial membership of the Spaceports Council, composed of spaceports worldwide who seek to cooperate on issues of common interest such as airspace access, legal and regulatory frameworks, infrastructure, international policy migration, liability, and voluntary common operating standards. >>

Satellite Industry Association (SIA)

The Satellite Industry Association (SIA) elected its new board officers for 2010 in January. CapRock Government Solutions Vice President David Cavossa will serve as SIA chairman, joined by Leslie Blaker of Rockwell Collins as vice chairman and Jennifer Warren of Lockheed Martin's Washington, D.C. operations as treasurer.

Cavossa previously served as SIA vice chairman in 2009 and as executive director of SIA from 2004 through 2007. Blaker and Warren are new additions to the board.

The launch of Kentucky's first satellite, scheduled for November with NASA's Glory climate monitoring spacecraft, will mark an important milestone for Kentucky Space, a non-profit consortium of universities and public and private organizations based in Lexington. The group hopes to be a leader in CubeSat development. Kentucky Space formed a partnership with NanoRacks LLC, a Houston-based startup that is shepherding small experiments to the international space station under a Space Act Agreement with NASA. Kentucky Space's goal is to launch one CubeSat annually.

Washington DC-based Center for Strategic and International Studies (CSIS) Report criticizes US Space Policy for not addressing problems regarding government support for the commercial space launch industry. The problems have not been addressed in the Obama administration's new National Space Policy, and threaten future military operations if they are not resolved. The CSIS analysts found that while there is lip service for US government support of the commercial launch industry, most commercial launches today are conducted by non-US launch vehicles. The CSIS found that the space policy issued in June fails to back up laudable goals with a way to reach them.

The University of Colorado at Boulder received $3.3 million from NASA for a study of a mission to Venus and could land $650 million more to send a spacecraft to the planet. The University of Arizona and Washington University were also given funds for other missions. The Venus mission would land a spacecraft on the planet to study the surface and atmosphere. NASA will chose one of the three proposals for full development after reviewing each university's studies. The finalists for the next New Frontiers Program mission include spacecraft that may land on the surface of Venus or the Moon, or return a chunk of an near-Earth asteroid.

Researchers at Oregon State University (OSU) are using cockroaches as a source of inspiration for the world's first legged robot to be able to run easily over rough terrain. OSU has found that the insects use instinctive muscle action that doesn't require reflex control. It's this ability that, in part, the researchers are trying to put into new robots in order to get them moving faster but without the enormous use of energy and computing power they require. The researchers believe the technology has application for planetary exploration.

After a year of economic uncertainty, the North American satellite broadband industry became the first region to top 1 million subscribers, with Western Europe likely to exceed 100,000 subscribers before the end of 2010, according to an NSR research report released in April. NSR projects that broadband VSAT networking, satellite broadband access and broadband trunking and backhaul services will generate nearly $8.8 billion by 2019, a growth of 135 percent over 2009. The report also claims that global satellite broadband access will add the most new revenues, contributing $4.1 billion between 2009 and 2019 and surpassing traditional broadband VSAT as the leading revenue market by 2013. While the imminent launch of the second generation of high throughput satellites like ViaSat-1, KaSat, Jupiter and Hylas-1 have created options for broadband satellite customers, the industry still faces the challenge of changing the perceptions of its service in government agencies and consumers.

Uruguay

The Centro de Investigación y Difusión Aeronáutico - Espacial (CIDA-E) celebrated its 34th anniversary with a day-long conference, during which the Uruguayan "Cubesat" project was presented. The LAI is an experimental satellite being constructed by the Engineering Faculty of the Universidad de la República. Project LAI builds on previous experiences with high altitude balloon platforms developed and built from scratch. All R&D is the work of undergraduate students.

In November, the First International Congress on Research in Aerospatial and Terrestrial Phenomena took place in Montevideo. The congress's aim was to develop and promote scientific research on the topic of UFOs. CIDA-E's Director presented a paper on "National and International Positions on the Subject", which included an analysis of the possibility of extra-terrestrial intelligence, as has been discussed at COPUOS, in the outer space treaties, the IAA's Committee on SETI, and CIDA-E's position on the subject. The congress was attended by scientists and lawyers from a number of countries.

A group of Uruguayan university students participated in the NASA's National Institute of Aerospace (NIA) forum, RASC-AL (Revolutionary Aerospace Systems Concepts Academic-Linkage). The goal of the Forum is to give university students to the opportunity to design engineering projects, based on some of the engineering challenges faced by NASA, and to provide NASA with new research and projects designed by students. This year, students were to design a Lunar base, taking into account all aspects necessary to sustain human life on the Moon, at an economically viable cost. The Uruguayan Project was called "Bidu Guiday" or "Lovely Moon" in the Charrúa language. This was the first time ever that non-USA students were invited to participate in RASC-Al's forum. The Uruguayan students were among the finalists, together with groups from MIT, Harvard, Princeton and Maryland.

CIDA-E participated in ALADA's IV Colloquium, held in Montevideo. Among topics addressed were the legal gaps in the responsibility regime related to space debris. ALADA is the Spanish acronym for the Asociación Latinoamericana de Derecho Aeronáutico y Espacial, or Latin American Association of Air and Space Law.

Uruguay has joined the Space Generation. Victoria Alonsopérez was named coordinator of projects for the Space Generation Congress, which meets during the annual International Astronautical Congress. She also presented a paper on Uruguay's experiments with balloons and efforts to build a satellite, and spoke on "Enhancing undergraduate studies in Uruguay in aerospace activities" at the IAC in Prague.

Venezuela

For the last two years a China-made-and-launched communications satellite has helped develop education and communications in Venezuela, especially in this nation's remote regions. More than 1,700 education centres, 89 energy resource stations and 214 agricultural infrastructure points have been connected through the Venesat-1 satellite that was launched on 30 October 2008 by China Great Wall Industry Corp. In two years of operation, the satellite has promoted the development of telecommunications, broadcasting, remote education and medical services in Venezuela, according to a statement of the China Aerospace Science and Technology Corporation, which built the satellite that has a designed service period of 15 years.

X. INDUSTRY

X.1 Appointments

Dr K Radhakrishnan, Member of the Space Commission and Director, Vikram Sarabhai Space Centre, assumed the office of Chairman of the Space Commission and Chairman of the Indian Space Research Organisation (ISRO). >>

Bretton Alexander, President of the Commercial Spaceflight Federation, was appointed by NASA Administrator Charles Bolden to the NASA Advisory Council, a federally chartered body of experts that provides advice and counsel directly to the NASA Administrator. Additionally, Alexander was selected to chair the newly formed Commercial Space Committee of the NASA Advisory Council. >>

NASA Administrator Charlie Bolden announced two changes in his leadership team at Headquarters in Washington. David Radzanowski was selected as the agency's new chief of staff, and James Stofan was named as the acting associate administrator for Education. >>

Michel de Rosen took over the role of CEO of Eutelsat Communications from Giuliano Berretta in November 2009. For most of the previous decade, de Rosen had been chairman and CEO of ViroPharma, a U.S. pharmaceutical corporation. De Rosen is well-versed in Eutelsat's operations, having become its deputy CEO and worked with Berretta since July. He is ready to, and will seek to continuously grow the company and not remain complacent about its success.

Eutelsat announced the appointment of Ethan Lavan as director of Eutelsat's In-Orbit Resources division. Prior to joining Eutelsat, Ethan was responsible for regulatory policy and management of service and spectrum licenses at global level for Inmarsat Global Ltd**.** He also held various responsibilities at Alcatel Space Industries**,** including head of regulatory standards coordination for the SkyBridge broadband satellite programme.

Virgin Galactic appointed George T. Whitesides as its first Chief Executive Officer. >>

For the first time in 30 years, the Planetary Society named a new chief - Bill Nye. >>

The Council of the European Space Agency announced that Jean-Jacques Dordain will continue as the Director General of ESA for a further period of four years. Mr Dordain has served as Director General of ESA since 2003. This third mandate extends his term to June 2015. >>

The Commercial Spaceflight Federation selected its next Chairman of the Board, Eric C. Anderson, who holds the position of chairman of Space Adventures Ltd. >>

NASA named Richard Keegan as the agency's associate deputy administrator. He replaces Charles Scales, who has held the position since April 2007 and who is retiring. >>

X.2 Awards

In November 2009, the X PRIZE Foundation along with NASA hosted an awards ceremony to culminate the Northrop Grumman Lunar Lander X PRIZE

Challenge. Masten Space Systems, led by David Masten, was awarded the top $1 million prize, while Armadillo Aerospace, led by id Software founder John Carmack took home the second place prize of $500,000. The Challenge was a partnership with NASA funding the $2 million in prize money as part of their Centennial Challenges programme while the X PRIZE Foundation managed the competition which began in 2006. >>

The Planetary Society awarded the Thomas O. Paine Award for the Advancement of Human Exploration of Mars to Steve Squyres and the Mars Exploration Rover (MER) team. Squyres is the Principal Investigator for the two Mars Exploration Rovers, which have been exploring the surface of the Red Planet for nearly six years. >>

The MESSENGER spacecraft was named one of Time magazine's best 50 inventions of 2009. >>

Sir Martin Sweeting of Surrey Satellite Technology Ltd was awarded the Faraday Medal, the Institution of Engineering and Technology's (IET) most prestigious award, for his outstanding contribution to the advancement of satellite technology. >>

The UK's Royal Aeronautical Society awarded its top Gold Medal Team prize to ESA's Automated Transfer Vehicle operations team, in recognition of their achievement in operating ATV Jules Verne during its 2008 mission to the International Space Station. >>

The Indian Space Research Organisation's commercial arm Antrix Corporation received the Globe Sustainability Research Award 2010, set up by Stockholm-based Global Forum, for fostering sustainable development. >>

The Association Aéronautique et Astronautique de France awarded ESA's Herschel and Planck its Special Grand Prix 2010. >>

The Space Frontier Foundation leaders announced that Masten Space Systems is the recipient of the 2010 "Vision to Reality" Award in recognition of their 2009 Northrop Grumman Lunar Lander Challenge win. >>

Boeing was named the Large Business Prime Contractor of the Year by NASA for outstanding contributions to the agency’s small-business programme on the Checkout, Assembly and Payload Processing Services (CAPPS) contract at Kennedy Space Center. >>

PART TWO

PROGRESS IN SPACE RESEARCH 2009-2010

I. SPACE STUDIES OF THE EARTH'S SURFACE, METEOROLOGY AND CLIMATE

Satellites are an essential and exceptional tool to monitor the current state and evolution of the Earth environment with a synoptic and global coverage. They have provided a vast amount of precious data to feed and correct dynamic models for better forecasts in meteorology and oceanography, and have played significant roles in addressing issues of climate, ecosystems, energy, disasters and health.

This chapter provides an overview of selected Earth Observation (EO) initiatives, new satellite missions, and scientific achievements during 2009-2010, as well as future prospects and challenges of EO in studies of the Earth's surface, meteorology and climate from space.

I.1 EO Initiatives and Development

Virtual Constellation

In support of the Group on Earth Observations (GEO) objectives, and as a space component of the Global Earth Observation System of Systems (GEOSS), CEOS, the Committee on Earth Observation Satellites, has been working on six space-based virtual constellations. A constellation is a coordinated set of space and/or ground segment capabilities from different partners that focuses on observing a particular parameter or set of parameters of the Earth system. It is required to define standards (or guidelines) that describe optimal future constellation capabilities, characteristics and practices.

The Atmospheric Composition Constellation aims to improve monitoring, assessment and predictive capabilities for changes in the ozone layer, air quality and climate forcing associated with changes in the environment through the coordinated collection and delivery of EO data from existing and future international space missions. The Land Surface Imaging Constellation promotes the efficient, effective and comprehensive collection, distribution and application of space-acquired image data of the global land surface, especially to meet societal needs of the global population. The Ocean Surface Topography Constellation aims to build a sustained, systematic capability to observe basin- to meso-scale (~100 km) ocean surface topography of the global oceans. The ocean surface topography from satellite altimeters, when integrated with the upper-ocean density field from Argo profiling floats, can be used to understand the dynamics of the oceans, assess their role in climate, and develop an operational forecast capability. The third workshop of the Precipitation Constellation, the goal of which is to establish an international framework to guide, facilitate and coordinate the continued advancement of multi-satellite global precipitation products, was held in Salt Lake City, United States, from 29 to 30 October 2009. The workshop resulted in the finalization of the 2008 accomplishments document, the 2009-2010 workplan, and the beginning of the new 'Conical Scan Microwave Imager Study' initiative. The Ocean Colour Radiometry Constellation provides long time series of calibrated ocean colour radiance at key

wavelength bands from multiple satellites, with activities including calibration, validation, merging of satellite and *in situ* data, product generation, as well as the development and demonstration of new and improved applications. The Ocean Surface Vector Wind Constellation aims to improve operational marine warnings and forecasts through the use of ocean surface vector winds from satellite scatterometry (together with significant wave height data from the Ocean Surface Topography Constellation). It will also characterize the wind field for use in climate data records and facilitate research related to wind influence on the ocean circulation. For more information, see http://www.ceos.org.

ESA Climate Change Initiative

The European Space Agency (ESA) has initiated a new programme on Global Monitoring of Essential Climate Variables, known for convenience as the ESA Climate Change Initiative, designed to provide an adequate, comprehensive and timely response to the extremely challenging set of requirements for (highly stable) long-term satellite-based products for climate research, that have been addressed to space agencies (e.g., via CEOS). Although the effort will mostly be focused on activities related to historical archives of ESA and the contributions of ESA research missions to essential climate variables (e.g. sea level), a very important component in this initiative is to ensure international collaboration and thereby achieve global consistency in producing essential climate variables products. This initiative will implement a programme of work which ensures that the responsibilities and capabilities of ESA member states, in addressing issues of climate change, can be undertaken on a scale commensurate with the problem. It is based on the delivery of climate variables derived from satellite data sets (not just those of ESA, but from all sources via international collaboration) and includes all aspects of their availability including data acquisition, calibration and validation, long- term algorithm maintenance, data curation, re-processing as necessary, all within the context of an internationally agreed set of priorities.

This ESA programme will bring together European expertise covering the full range of scientific, technical and development specialisations available within the European Earth Observation community, and will establish lasting and transparent access to its results for the global climate scientific and operational communities. The essential feature of the programme will be to implement a coherent and continuous suite of actions that encompass all steps necessary for the systematic generation of relevant essential climate variables, and ensure their regular updating on timescales corresponding to the increasingly urgent needs of the international climate change community. See http://earth.eo.esa.int/workshops/esa_cci/ESA_CCI_Description.pdf for more information.

The International Charter

Following the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space held in Vienna, Austria in July 1999, the European and French space agencies (ESA and CNES), together with the Canadian Space Agency initiated the International Charter ‘Space and Major Disasters’, which was signed on 20 October 2000. Currently, there are about 20 members.

The International Charter aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each member agency has committed resources to support the

provisions of the Charter and thus to help mitigate the effects of disasters on human life and property. For more information, visit http://www.disasterscharter.org/home.

Global Climate Observing System (GCOS)

In 2010, the GCOS Steering Committee published an update of the Implementation Plan for the Global Observing System for Climate in Support of the United Nations Framework Convention on Climate Change (UNFCCC). A detailed global climate record for the future critically depends upon an observing system that includes a major satellite component. However, for satellite observations to contribute fully and effectively to the building of long-term records, the satellite component must be implemented and operated in an appropriate manner to ensure that the observations are sufficiently homogeneous, stable and accurate for climate purposes. The GCOS Climate Monitoring Principles (GCMPs) were extended to address the following satellite-specific key operational issues: (1) Continuity, homogeneity and overlap; (2) Orbit stability; (3) Sensor calibration; and (4) Data interpretation, sustained data products and archiving.

The Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring initiative (SCOPE-CM), which has been established with contributions from various space agencies, focuses on the sustained generation of long-term essential climate variables products including regular reprocessing. Implementation of the GCOS satellite component will also involve collecting and archiving all satellite metadata so that long-term sensor and platform performance is accessible. For more information, visit http://www.wmo.int/pages/prog/gcos/.

I.2 EO Space Missions Launched in 2009-2010

GOCE

GOCE (*Gravity Field and Steady-State Ocean Circulation Explorer*) satellite was launched on 17 March 2009. It carries a gradiometer with three pairs of 3-axis, servo-controlled, capacitive accelerometers, a 12-channel dual-frequency GPS receiver of geodetic quality, and a laser retro-reflector facilitating tracking by ground-based lasers. The mission includes a three-month commissioning and calibration phase, followed by science measurement phases adapted to a long-eclipse hibernation period. *GOCE* is dedicated to measuring the Earth's gravity field and modelling the geoid with unprecedented accuracy and spatial resolution. The mission objectives are to determine gravity-field anomalies with an accuracy of 1 mGal (1mGal = 10^{-5} ms^{-2}) and to determine the geoid with an accuracy of 1-2 cm. Data from this advanced gravity mission will improve our knowledge of ocean circulation, which plays a crucial role in energy exchange around the globe, sea-level change and Earth-interior processes. *GOCE* will also help to make significant advances in geodesy and surveying.

CryoSat-2

ESA's Earth Explorer *CryoSat-2* mission, launched on 8 April 2010, is dedicated to precise monitoring of the changes in the thickness of marine ice floating in the polar oceans and in the vast ice sheets over Greenland and Antarctica. It is increasingly important to understand exactly how the Earth's ice fields, particularly in polar regions, are responding to a changing climate. Diminishing ice cover is often quoted as an early casualty of global warming. In turn, since ice plays an important role in regulating climate and sea level, the consequences of the diminishing ice cover are far reaching.

Satellites such as ESA's *Envisat* have been mapping the extent of ice cover for years. Nevertheless, there is a comparably urgent need to determine exactly how the thickness of the ice, both on land and floating in the sea, is changing. By addressing this challenge, data from the *CryoSat-2* mission will lead to a better understanding of the role ice plays in the Earth system.

TanDEM-X

TanDEM-X (*TerraSAR-X* add-on for Digital Elevation Measurement), the German Aerospace Center (DLR) and EADS Astrium satellite, was launched into orbit on 21 June 2010. Together with its twin, *TerraSAR-X* (launched on 15 June 2007), *TanDEM-X* will survey the entire land surface area of the Earth – a total of 150 million square km – several times over during its three-year mission. The two satellites fly in a closely controlled formation, typically separated by between 250 and 500 m, thereby constituting the first configurable synthetic aperture radar (SAR) interferometer in space. The primary objective of *TanDEM-X* is to generate a consistent global digital elevation model with unprecedented accuracy. It also provides a highly reconfigurable platform for the demonstration of new SAR techniques and applications.

TanDEM-X represents the first step for a constellation of radar satellites. The user community will have access to data, facilitating a broad spectrum of scientific, commercial and security applications. The data can be used for high quality Digital Elevation Models (e.g. hydrology), along-track interferometry (e.g. measurement of ocean currents) and new bi-static applications (e.g. polarimetric SAR interferometry). Commercially, potential applications arise from the increased efficiency of the *TerraSAR-X* data production chain, high quality and efficient cartographic capability, and implementation of experimental modes and services.

COMS

The Korean *COMS* satellite (*Communication, Ocean and Meteorological Satellite*), was successfully launched on 26 June 2010. *COMS*, jointly developed by the Korean Aerospace Research Institute (KARI) and Astrium, France, carries three payloads dedicated respectively to meteorology, ocean observation and telecommunications. It will continuously observe world-scale meteorological phenomena, along with specific local weather events such as hurricanes, monsoons and sandstorms. Its multi-band imager dedicated to ocean observation will be particularly useful for the fishing industry to monitor changes in the marine ecosystem. Its innovative imager offers 400 m resolution, a level of performance unprecedented in geostationary orbit. The commissioning period will last about six months. Normal operations should start at the beginning of 2011 and the satellite is scheduled to operate for a total of 7 years.

Oceansat-2

Oceansat-2 was launched on 23 September 2009. It is an Indian satellite designed to provide service continuity for operational users of the ocean colour monitor instrument on *Oceansat-1*. The main objectives of *Oceansat-2* are to study surface winds and ocean surface strata, to observe chlorophyll concentrations, monitor phytoplankton blooms, and understand atmospheric aerosols and suspended sediments in the water. Data from all instruments are available to the global scientific community.

SMOS

The *SMOS* (*Soil Moisture and Ocean Salinity*) satellite was launched on 2 November 2009 into a nearly circular orbit of 763 km. *SMOS* carries a new type of instrument called the Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) that measures changes in the wetness of the land and in the salinity of seawater by observing variations in the natural microwave emission arising from the surface of the planet. The goal of the *SMOS* mission is to monitor surface soil moisture with an accuracy of 4% (at 35-50 km spatial resolution), and to monitor sea surface salinity with an accuracy of 0.1 psu (10-30 day average and a spatial resolution of 200 km by 200 km).

Soil moisture is an important aspect of climate, and therefore to climate forecasting. Plants transpire water from depths lower than 1 m in many places and satellites like *SMOS* can only determine moisture content down to a few cm, but by using repeated measurements in a day, the satellite can extrapolate soil moisture values. Scientists hope to work with farmers around the world for better determinations of soil moisture, as it may help to secure a better understanding of crop yields over wide regions.

Information from *SMOS* is expected to help improve short- and medium-term weather forecasts, and also to have practical applications in areas such as agriculture and water resource management. In addition, climate models should benefit from having a more precise picture of the scale and speed of movement of water in the different components of the hydrological cycle.

I.3 Prospective EO Space Missions (selected)

Megha-Tropiques

Megha-Tropiques (a French-Indian cooperative mission) for the study of the Monsoon and tropical regions is soon to be launched. Its scientific objectives are to improve knowledge of the water cycle in the inter-tropical region, to evaluate its consequences on the energy budget, and to study the life cycle of tropical convective systems over the ocean and continents, the environmental conditions for their appearance and evolution, their water budget, and associated transports of water vapour. The applied objectives are to provide data about the processes leading to dramatic weather events affecting tropical countries, such as hurricanes, systems producing heavy rainfall, processes governing monsoon variability or droughts. Geophysical parameters to be retrieved are elements of the atmospheric water cycle (water vapour, cloud-condensed water content, ice/water, precipitation) and radiative budget elements (solar reflected and terrestrial emitted fluxes at the top of the atmosphere).

SARAL

SARAL (Satellite with the Argos-3 data collection system and ALtika altimeter), to be launched in 2011, is a cooperative mission between CNES and the Indian Space Research Organization (ISRO). Complementary to *Jason-2*, it will provide observations of ice, rain, coastal zones, and wave heights and facilitate the maximum use of ARgos – a joint NOAA CNES data collection system. The main objectives of *SARAL* are to create precise, repetitive global measurements of sea surface height, wave heights, and wind speed, to ensure continuity of the altimetry service currently available from *Envisat* and *Jason-1*/*-2*, and to contribute to global

ocean and climate studies (e.g. global ocean observing system). These objectives will be accomplished by studying mesoscale ocean variability through observations of coastal areas, inland waters, and the surface of continental ice sheets.

Jason Series

The launch on 20 June 2008 of *Jason-2*, a cooperative enterprise between CNES, NASA, Eumetsat and NOAA, marks the true beginning of operational space altimetry. *Jason-2*, with its improved capabilities compared with its predecessor *Jason-1*, has shown the ability to follow the level of coastal waters, lakes and the biggest rivers with a never-before-achieved precision. *Jason-1* and *Jason-2* are the reference missions for establishing the long-term sea level trend, an important indicator in measuring the climate change. Building on the success of *Jason-1* and *Jason-2*, Eumetsat and NOAA have decided to lead the *Jason-3* mission, which is expected to be launched in 2013.

HaiYang-2 (HY-2)

HaiYang-2, is a dynamic environment satellite mission to be launched in 2010 by the China National Space Administration (CNSA), which will carry microwave sensors to monitor global ocean wind field, ocean surface topography, and sea surface temperature. It will include an altimeter dual-frequency in Ku and C-bands, a scatterometer and a microwave imager. The planned orbit is Sun-synchronous: the first two years with a 14-day cycle, then one year with geodetic orbit (168-day cycle, 5-day approx. subcycle).

CNSA, in cooperation with France (CNES), is developing *CFOSAT* (China-France Oceanography SATellite) designed to measure the size, shape and directions of ocean waves with a novel instrument called SWIM (Surface Wave Investigation and Monitoring). The satellite will also carry a scatterometer to measure ocean winds, the overall mission objective being to monitor the wind and waves at the ocean surface on a global scale.

The Radarsat Constellation

The *Radarsat* Constellation (Canadian Space Agency) is a development of the *Radarsat* Programme with the objective of ensuring data continuity, improved operational use of Synthetic Aperture Radar (SAR) and improved system reliability. The constellation will comprise a three-satellite configuration giving complete coverage of Canada's land and oceans and capable of providing an average daily revisit at 50 m resolution, as well as daily access to 95% of the world to Canadian and international users. For disaster management, the satellites will be capable of high resolution modes at 3 m and 5 m. The mission development began in 2005, with satellite launches planned for 2014 and 2015.

I.4 Examples of Science Advances

Satellite observations have helped improve significantly our understanding of the Earth's environment. Here we provide a few examples related to atmosphere, ocean and land surfaces.

Vertical Structure of Clouds and Aerosols

Knowledge of the vertical structure and properties of clouds and aerosols was poor until recently. Observations from the *CALIPSO* (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) satellite have provided an unprecedented

opportunity for improving existing climatologies, as well as new capabilities to identify boundary-layer clouds and distinguish optically thin ones from aerosols (Winker *at al*. 2010*). The *CALIPSO* mission has made it possible for the first time for aerosol optical depth above clouds to be estimated.

Ammonia Distribution

Ammonia, originating mainly from the agricultural use, is a significant contributor to the development of pollution episodes, but our understanding of ammonia in the atmosphere is very limited, with the emission inventories being neither precise nor comprehensive. The observations provided by IASI (Infrared Atmospheric Sounding Interferometer) onboard the *MetOp* (Meteorological Operational Satellite) satellite (launched at the end of 2006) has enabled the first complete mapping of ammonia sources (Clarisse *et al*. 2009*). The results identified a total of 28 ammonia hotspots, primarily over the agricultural regions of North American, Asia and Europe with some hotspots being linked to biomass burning. The study found that the current inventories for ammonia in the agriculture valleys of the northern hemisphere underestimate ammonia sources, most significantly in Central Asia.

Phytoplankton Abundances and Mechanism

Based on about 20 years of satellite observations of chlorophyll and sea surface temperature, Martinez *et al.* (2009)* have shown that multidecadal changes in global phytoplankton abundances are correlated to those in the physical oceanographic states on basin scale, specifically the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation. One mechanism for the relationship is an interaction between the main pycnocline and the upper ocean seasonal mixed layer. The findings are useful for interpreting contemporary changes in global phytoplankton and could help improve predictions of phytoplankton evolution under a changing climate.

Variability in the North Atlantic Subpolar Gyre

The monitoring and understanding of the interannual and decadal variability in the North Atlantic subpolar gyre is important because it is intimately linked to the global thermohaline circulation. Sarafanov *et al*. (2010)* combined satellite altimetry and hydrography to infer an intensification of the western boundary current at intermediate and deep levels south of Greenland between the mid-1990s (1994-1997) and 2000s (2000-2007). Han *et al*. (2010)* synthesized the satellite altimetry with density profiles and found that the Labrador Current declined significantly in the mid-1900s and partially rebounded in the early 2000s. These studies demonstrate the feasibility of combining satellite altimetry with hydrographic measurements for

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* D.M. Winker, J. Pelon, J.A. Coakley Jr., S.A. Akerman, R.J. Charlson, P.R. Colarco, P. Flamant, Q. Fu, R.M. Hoff, C. Kittaka, T.L. Kubar, H. Letreut, M.P. McCormick, G. Megie, L. Poole, K. Powell, C. Trepte, M.A. Vaughan & B.A. Wielicki, 2010 The CALIPSO mission: a global 3D view of aerosols and clouds. Bull. Amer. Meteoril. Soc. [in press.]

* L. Clarisse, C. Clerbaux, F. Dentener, D. Hurtmans & P.-F. Coheur, 2009 Global ammonia distribution derived from infrared satellite observation.s Nature Geosci., 2, 479-483.

* E. Martinez, D. Antoine, F. D'Ortenzio & B. Gentili, 2009 Climate-Driven Basin-Scale Decadal Oscillations of Oceanic Phytoplankton. Science, 326, 1253-1256.

* A. Sarafanov, A. Falina, P. Lherminier, H. Mercier, A. Sokov, and C. Gourcuff (2010), Assessing decadal changes in the Deep Western Boundary Current absolute transport southeast of Cape Farewell (Greenland) from hydrography and altimetry. J. Geophys. Res. [in press.]

* G. Han, K. Ohashi, N. Chen, P.G. Myers, N. Nunes & J. Fischer, 2010 Decline and partial rebound of the Labrador Current 1993-2004: Monitoring ocean currents from altimetric and CTD data. J. Geophys. Res. [in press.]

assessing the climatic variability of the major boundary currents in the world oceans.

Greenland Ice Sheet Mass Loss and Sea Level Rise

Using mass budget calculations, validated with gravity observations from the Gravity Recovery and Climate Experiment (*GRACE*) satellites, van den Broeke *et al.* (2009)* quantified individual components of recent Greenland ice sheet mass loss. Surface processes (runoff and precipitation) and ice dynamics account equally for the total 2000-2008 mass loss of ~1500 gigatons (equivalent to a global sea level rise of 0.46 mm per year). The moderating effects of increased snowfall and refreezing after 1996 resulted in lower mass losses. In 2006-2008, the Greenland ice sheet mass loss was 273 gigatons per year (equivalent to a sea level rise of 0.75 mm per year) due to high summer melting rates.

Role of Aerosols in Sea Surface Temperature

Northern tropical Atlantic surface temperatures are sensitive to regional changes in stratospheric volcanic and tropospheric mineral aerosols, but the importance of the temporal variability of these aerosols is unknown. Evan *et al.* (2009)* combined a simple physical model with 26 years of satellite data to estimate the response of the ocean mixed layer temperature to changes in aerosol loadings. They found that the response of the mixed layer temperature to regional aerosol variability accounted for 69% of the recent upward trend, and 67% of the detrended and 5-year low-pass-filtered variance, in the northern tropical Atlantic Ocean.

Deforestation and Carbon Emissions

Reducing emissions from deforestation and degradation (REDD) may curb carbon emissions, but the consequences for fire hazard are poorly known. Aragao and Shimabukuro (2010)* analyzed satellite-derived deforestation and fire data from the Brazilian Amazon and found that fire occurrence increased in 59% of the area that experienced reduced deforestation rates. It is shown that fire-free land-management can substantially reduce fire incidence by as much as 69%. If the REDD mechanism does not include a sustainable fire-free land management of deforested areas, the carbon saving effects of avoiding deforestation may be partially reduced by increased emissions from fires.

Impacts of Natural Hazards on Ocean Chlorophyll

Examination of multi-sensor satellite data related to several hurricanes/cyclones, earthquakes and dust events have shown anomalous enhancement of chlorophyll concentrations. The dust in the atmosphere influences the atmospheric parameters that reduce the sea surface temperature while dust contains iron minerals which act as nutrients to fish. Enhanced chlorophyll concentrations are found in the Arabian and Pacific Ocean during the dust seasons almost every year (Singh *et al.* 2008)*. Chlorophyll blooming has been observed a few days after cyclones/ hurricanes/typhoons. The chlorophyll concentrations associated with natural

* M. van den Broeke, J. Bamber, J. Ettema, E. Rignot, E. Schrama, W.J. van de Berg, E. van Meijgaard, I. Velicogna & B. Wouters, 2009 Partitioning Recent Greenland Mass Loss, Science, 326, 984-986.

∗ A.T. Evan, D.J. Vimont, A.K. Heidinger, J.P. Kossin & R. Bennartz, 2009 The Role of Aerosols in the Evolution of Tropical North Atlantic. Ocean Temperature Anomalies. Science, 326, 778-781.

* L.E.O.C. Aragao & Y.E. Shimabukuro, 2010 The Incidence of Fire in Amazonian Forests with Implications for REDD. Science, 328, 1275-1278.

* R.P. Singh, A.K. Prasad, V.K. Kayetha, et al., 2008 Enhancement of oceanic parameters associated with dust storms using satellite data. J. Geophys. Res., 113, C11008.

hazards show a strong coupling between ocean-land-atmosphere that needs to be understood in detail.

Advances from SMOS

The completion of the *SMOS* commissioning phase in May 2010 concluded that *SMOS* was meeting practically all of its science requirements (http://www.esa.int/esaLP/LPsmos.html). *SMOS* was then switched to its normal operation mode. Early in June 2010, the Level 1C data were reprocessed and made available to the scientific community, while the Level 2 data were available to the *SMOS Validation Retrieval Team* for scientific validation from the beginning of July 2010.

SMOS picked up clear differences in soil moisture as heavy rains hit Tennessee and Kentucky, USA, and the subsequent drying period in early May 2010. *SMOS* provided the first ever global map of sea surface salinity from space. The early results are close to the GODAE (Global Ocean Data Assimilation Experiment) requirements in accuracy. The *SMOS* instrument can also detect the evolution of the Amazon and Orinoco freshwater plumes.

I.5 Summary

Satellite observations have made significant contributions to monitoring the state of and changes in the atmosphere, ocean, and land surface, especially in the context of studying climate change.

The on-going and expanding effort to integrate observations from different instruments and platforms in a global system (GEOSS) has significantly enhanced the impacts of Earth observations in today's political, social and economic arena. The EO data have been used by a great variety of agencies such as the IPCC. They will play more significant roles in saving our planet, saving lives, and homes.

Nevertheless, the road ahead for Earth observations remains full of challenges. For example, it cannot be stressed too much that continuous support for Earth observations is required to maintain and improve scientific research and operational monitoring of the Earth's environment. Any gaps between existing and follow-on missions will create great challenges for cross-calibrations and for detecting long-term trends. The quality of operational forecasts is severely reduced by inadequate concurrent missions and thus insufficient temporal and/or spatial resolution. With limited resources, there is a need for enhanced international cooperation and partnership in space programmes. Data policy needs to be improved for mutual sharing among nations and for free and open access by scientists. It is important to attract and train more young scientists in the EO field, for example, through COSPAR's capacity-building courses.

II. SPACE STUDIES OF THE EARTH-MOON SYSTEM, PLANETS AND SMALL BODIES OF THE SOLAR SYSTEM

II.1 Lunar Exploration

Recently Completed Missions

SMART-1, the first ESA Small Mission for Advanced Research in Technology, was launched on 27 September 2003. As its name implies, it was principally a technology mission, and its aim was to demonstrate electric propulsion in deep space.

The spacecraft carried a small scientific payload (AMIE – Advanced Moon micro-Imaging Experiment, D-CIXS – Demonstration of Compact X-ray Spectrometer, SIR – SMART-1 Infrared spectrometer, SPEDE/EPDP – Spacecraft Potential Electron and Dust Experiment/Electric Propulsion Diagnostic Package, KATE/RSIS – Ka-band Telemetry and telecommand Experiment/Radio Science for SMART-1 experiment) in order to study surface composition, formation and evolution of the Moon, and to survey resources for future exploration. The *SMART-1* mission ended with a controlled impact in the Lunar Lake of Excellence on 3 September 2006. A world-wide observing campaign was organized to study the flash and debris created by the impact in real time.

Chang'e 1, the first Chinese lunar mission was launched on 24 October 2007 and relayed the first images of the Moon on 26 November 2007. The spacecraft included a payload comprising a CCD stereo camera, an imaging interferometer, a laser altimeter, a gamma/X-ray spectrometer, a microwave radiometer, a solar high-energy particle detector and a low-energy ion detector. The spacecraft operated until 1 March 2009, when it was de-orbited and crashed onto the far side of the Moon.

Selene (*SELenological and ENgineering Explorer*) also called *Kaguya*, the JAXA Japanese orbiter mission was launched on 14 September 2007 by an H-IIA rocket, and inserted into lunar orbit on 4 October 2007. It carried a comprehensive set of instruments for multi-spectral remote sensing of the lunar surface (X-ray and gamma-ray spectrometers, multi-band imager and spectral profiler, terrain camera, radar sounder), for gravity studies (VLBI and data relay), and for lunar environment studies (magnetometer/plasma imager, charged-particle spectrometer and plasma analyser, radio science). It also released two sub-satellites, *Okina* and *Ouna*, into lunar orbit. In February 2009, the orbit was lowered to 50 km and a planned impact ended the mission on 10 June 2009.

*Chandrayaan-1***,** the first ISRO lunar mission was launched aboard a PSLV launch vehicle on 22 October 2008, with objectives of studying the origin and evolution of the Moon, producing a 3D atlas and chemical mapping of the lunar surface. Its core payload included: a terrain mapping stereo camera, a hyperspectral wedge filter, a laser ranger, a low energy X-ray spectrometer, a solar X-ray monitor, a high energy X-ray instrument, and a descent system 'ranger module'. It carried instruments from other agencies, namely SIR2, CIXS and SARA from ESA, and a Moon mineralogy Mapper, and radar instrument, from the US. It also deployed the Moon Impact Probe to test technologies for landing in the future. The mission was declared over after communications were lost on 29 August 2009 and the vehicle subsequently crashed onto the lunar surface.

Current missions

LRO (*Lunar Reconnaissance Orbiter*), NASA's latest lunar mission, was launched 18 June 2009 and is designed to undertake survey measurements of the lunar surface as a preparation for future exploration. From a 50 km orbit, it is examining the lunar surface environment, producing high resolution maps and geodetic data and surveying lunar resources. Its instruments include a laser altimeter, camera, neutron detector, diviner radiometer, Lyman-alpha mapper and cosmic ray sensor.

LCROSS (*Lunar Crater Observation and Sensing Satellite*) was launched with *LRO* and included an impactor of 2 tons followed by a shepherd spacecraft, both of which impacted a polar crater on 9 October 2009 to characterize the polar ice

deposits, the ensuing data being relayed through the *LRO*.

Chang'e 2, China's second lunar probe, was launched 1 October 2010 and entered lunar orbit on 9 October 2010. The mission uses the *Chang'e 1* spare spacecraft and carries a similar payload. In addition to continuing scientific studies of the Moon, *Chang'e 2* is scheduled to descend to orbits as low as 15 km to survey potential future landing sites at very high resolution.

Planned missions

Selene-B, a potential landing mission, is being discussed in the framework of the Japanese lunar exploration programme.

Chang'e 3, a soft lander and rover, and *Chang'e 4*, a sample return mission, are being planned as the next phases of the Chinese lunar programme. The launch of *Chang'e 3* is being considered for 2013.

Chandrayaan-2/Luna Resource mission is planned by ISRO as an orbiter and soft lander (South pole) with small rover. It is planned as a joint mission with the Russian Federal Space Agency for launch in about 2013. In parallel, Roscosmos has approved the *Luna-Globe* mission as a similar soft lander (North pole) and an orbiter, for launch after *Chandrayaan-2*.

LADEE (*Lunar Atmosphere and Dust Environment Explorer*) is being prepared by NASA for launch in 2012.

GRAIL (*Gravity Recovery and Interior Laboratory*) was selected by NASA as part of its Discovery Programme. *GRAIL's* primary objective is to map the lunar gravity field with unprecedented precision, using the two-spacecraft tracking techniques similar to those of the highly successful Earth-orbiting *GRACE* mission. The data are expected to provide new insights into the structure of the lunar crust and interior as well as of giant impact structures. It is scheduled for launch in 2011.

Moonrise, a mission to return a sample from South Pole Aitken Basin, was selected in 2010 as one of three missions for the second round of NASA's next New Frontiers competition.

Science Highlights

The search for water in possible polar cold-traps on the Moon has been a consistent theme of lunar exploration in the last few years, with most missions performing at least some experiments designed to study this problem. In 2009, the *LRO/LCROSS* impact experiment and lunar spectral data from three spacecraft, *Chandrayaan-1*, *Deep Impact*, and *Cassini* provided some of the strongest evidence yet for some level of volatile enrichment on the lunar surface. The spectral data show evidence for OH/H_2O features in the 3 μm spectral regions, correlated with cold regions in some places, but also occurring at lower latitudes. These observations have been interpreted in terms of surface interactions with solar wind protons and may be an indication of a significant source of water to supply cold traps in permanently shadowed regions. Observations from the *LRO* and *LCROSS* impact experiment as well as Earth-based observations during the event are consistent with cold water reservoirs in shadowed areas, although the data are still being analyzed to constrain processes and quantities of water that might be present.

II.2 Mercury and Venus Exploration

Current missions

Venus Express, a mission to conduct investigations of the Venusian atmosphere and surface, was launched by ESA in November 2005, and utilized hardware developed for the *Mars Express* spacecraft. Instruments developed for other ESA planetary missions were adapted to facilitate a faster and cheaper payload development. The *Venus Express* payload comprises a combination of spectrometers, spectro-imagers and imagers covering a wavelength range from the ultraviolet to thermal infrared, a plasma analyser and a magnetometer. This set of instruments has been able to study the atmosphere, plasma environment and surface of Venus in great detail. The investigation aims to enhance our knowledge of the composition, circulation and evolution of the atmosphere of Venus. The surface properties of Venus and the interaction between the atmosphere and the surface are being examined and evidence of volcanic activity is being sought. *Venus Express* performed its Venus Orbit Insertion on 11 April 2006 and a steady stream of data has been returned ever since. These data have formed the basis of numerous publications (including a special issue of *Nature*). The data are being archived in ESA's Planetary Science Archive. The mission will be competitively reviewed in November 2010 for continued operations.

MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging), NASA's Mercury orbiter mission was launched on 3 August 2004. It is part of NASA's Discovery programme. A significant part of its instrumentation is dedicated to geological studies of this innermost terrestrial planet. *MESSENGER* completed two swing-bys of Venus (on 24 October 2006 and 5 June 2007) to use the pull of the planet's gravity to guide it closer to Mercury's orbit. The encounter offered opportunities for new observations of the Venusian atmosphere and cloud structure and some co-ordination with *Venus Express* was also made.

MESSENGER has made three close flybys of Mercury while setting up the necessary conditions for orbit insertion: The first encounter was at 19:04:39 UTC on 14 January 2008, at an altitude of 200 km above Mercury's surface; the second flyby was at 10:40 UT on 6 October 2008, gaining a gravity assist that tightened its orbit; the third encounter was at 21:55 UTC on 29 September 2009. Arrival at Mercury and orbit insertion is scheduled for 12:48 UTC 18 March 2011.

Planned missions

BepiColombo is an ESA and JAXA mission, consisting of ESA's *Mercury Planetary Orbiter* (for high resolution multi-wavelength geophysical and geochemical observations, together with gravimetry and fundamental physics studies), and JAXA's *Mercury Magnetospheric Orbiter* (dedicated to studying particles and fields). The latter will be provided by JAXA to ESA for integration prior to the launch of *BepiColombo* on an Ariane 5 launcher in August 2014. With the innovative combination of electric propulsion and gravity assists, the planned cruise duration is about six years. Observations from *BepiColombo* in its orbit around Mercury are expected to last for one Earth year.

Venus Climate Orbiter, a Japanese mission designed to focus on plasma and atmospheric studies, is currently scheduled for launch in 2011 and is expected to provide for coordinated observations and cross-calibration with an extended *Venus Express* mission.

SAGE (*Surface and Atmospheric Geochemical Explorer*) was one of three mission selected for the second round in the competition for NASA's next New Frontiers mission. It is designed to descend to the surface of Venus making atmospheric chemical measurements with a mass spectrometer and tunable laser spectrometer during descent. Once on the surface, it will study the surface geochemistry using Neutron-Activated Gamma Ray Spectroscopy and Laser Induced Breakdown Spectroscopy (LIBS) techniques. If selected, launch would be in December 2016, with Venus arrival in May 2017.

Science Highlights

In 2009, the VIRTIS infrared instrument on *Venus Express* mapped the southern hemisphere of Venus. Significant differences in inferred thermal emissivity values between plateau regions and other portions of the surface are interpreted as composition differences consistent with past or present volcanic activity and, possibly, plate tectonics.

MESSENGER has found that the thrust faulting seen in some *Mariner 10* (Mercury) images is common on the surface, indicating a significant degree of planetary contraction during its history.

II.3 Mars Exploration

Recent missions

MGS **(***Mars Global Surveyor*), NASA's mission in Mars orbit since September 1997, continued to operate well until November 2006, and to provide impressive images of the surface of Mars. Clear evidence has been found for a 'sapping' origin of many channels probably from melting of subsurface ice, suggesting the possible existence of liquid water in the recent past of Mars. *MGS* fulfilled all of its science objectives. The mission studied the entire Martian surface, atmosphere, and interior. By studying Mars for several Martian years (a Mars year is about twice as long as an Earth year), *MGS* has observed gully formation, new boulder tracks, recently-formed impact craters, and diminishing amounts of carbon dioxide ice within the south polar cap.

Data from the spacecraft's laser altimeter have provided the first 3-D views of Mars and, along with high precision gravity data, revolutionized studies and understanding of Mars geophysics, the polar ice caps and the planet's interior structure. After studying Mars for four times as long as originally planned, *MGS* last communicated with Earth on 2 November 2006.

Phoenix, a lander mission, was the first chosen for NASA's Scout programme, an initiative for smaller, lower-cost spacecraft. *Phoenix* was launched in August 2007. It uses a lander that was intended for use by 2001's *Mars Surveyor* lander prior to its cancellation. It also carries a complex suite of instruments that are improved variations of those that flew on the lost *Mars Polar Lander*. *Phoenix* landed on the icy northern pole of Mars between 65º and 75º north latitude. During the course of the 150 Martian-day mission, *Phoenix* deployed its robotic arm and dug trenches up to half a metre into the layers of water ice. These layers, thought to be affected by seasonal climate changes, could contain organic compounds that are necessary for life. To analyse soil samples collected by the robotic arm, *Phoenix* carried an 'oven' and a 'portable laboratory'; selected samples were heated to release volatiles that were then examined for their chemical composition and other characteristics. Preliminary

analyses confirm that the samples are alkaline, and composed of salts and other chemicals such as perchlorate, as well as sodium, magnesium, potassium and chloride ions. In November 2008, signals from *Phoenix* ceased, as expected with the declining power levels with the onset of winter in the Martian arctic regions. As repeated attempts to communicate after the Martian winter were unsuccessful, operations were officially ended in May 2010. In the same period, images of the spacecraft from *Mars Reconnaissance Orbiter* showed evidence of severe ice damage to *Phoenix*'s solar panels.

Current missions

Mars Odyssey, the NASA orbiter mainly devoted to the mapping of chemical elements and minerals on the surface, was launched on 7 April 2001, and arrived on 24 October 2001. After a manoeuvre into a 25-hour capture orbit, aerobraking was used to achieve a low Mars orbit. The orbiter carries three science instruments (THEMIS – Thermal Emission Imaging System, GRS – Gamma-Ray Spectrometer, and MARIE – Mars Radiation Environment experiment). THEMIS maps the mineralogy and morphology of the Martian surface using a high-resolution camera and a thermal infrared imaging spectrometer. The GRS, a rebuild of the instrument lost with the *Mars Observer* mission, achieves global mapping of the elemental composition of the surface and determines the abundance of hydrogen in the shallow subsurface. Evidence has been found for the widespread distribution of water ice, buried to a depth of at least 1 m and mixed with rocky material. The MARIE characterizes aspects of the near-space radiation environment as related to the radiation-related risk to human explorers. The primary science mission continued through August 2004 and *Mars Odyssey* is currently in its extended mission, orbiting the red planet, collecting scientific data and relaying communications from NASA's two Mars rovers to Earth. *Mars Odyssey* has made global observations of the Martian climate, geology and mineralogy. The spacecraft's Gamma Ray Spectrometer has made it possible for maps to be made of the elemental distribution of hydrogen, silicon, iron, potassium, thorium and chlorine on the Martian surface. A global map of minerals associated with water, essential to life, as we know it, guided NASA in its selection of Meridiani Planum, the landing site for NASA's *Opportunity* rover, an area rich in haematite.

Mars Odyssey supported landing site selection for the *Phoenix* Scout mission, launched in 2007, using data showing that surface areas near the poles of Mars consist of more than 50% water ice by volume. Other *Odyssey* accomplishments include measurement of radiation, a pre-requisite for future human exploration because of its potential health effects, and a ground-breaking programme in education outreach that has allowed students to take pictures of Mars and conduct scientific investigations with the cameras on the probe. The spacecraft continues to send information to Earth about the Martian geology, climate and mineralogy.

Mars Express, an ESA mission, was launched on 2 June 2003 and entered Mars orbit on 25 December 2003. *Mars Express* consists of an orbiter with eight experiments (HRSC – High Resolution Stereo Camera, OMEGA – IR mineralogical mapping spectrometer, SPICAM UV and IR – atmospheric occultation spectrometer, PFS – Planetary Fourier spectrometer, ASPERA – Analyser of space plasma and energetic atoms, MaRS – Mars Radio Science experiment, MARSIS – Mars Advanced Radar for Subsurface and Ionosphere Sounding), and a lander. The lander, *Beagle 2*, was planned to be a valuable complement to the main mission with *in situ*

analysis of the Martian subsurface chemistry relevant to exobiology, using a suite of cameras, spectrometers, and gas and environment analysis sensors. The *Beagle-2* lander, after a nominal separation from the *Mars Express* orbiter on 19 December and nominal injection, entered the Martian atmosphere on 25 December 2003. However, no contact could be established with the lander.

Since the start of science operations in early 2004, *Mars Express* has delivered a range of new science results including information on the water ice within the polar caps, the presence of sulphates, evidence for recent volcanic and glacial activity, the detection of methane in the atmosphere and signatures of atmospheric escape. *Mars Express* has been mapping water in its various states. In building up a global data set on the composition and characteristics of the surface and atmosphere, *Mars Express* has revealed that volcanic and glacial processes are much more recent than expected. It has confirmed the presence of glacial processes in the equatorial regions, and mapped water and carbon dioxide ice, either mixed or distinct, in the polar regions. Through mineralogical analysis, it has discovered that large bodies of water, such as lakes or seas, might not have existed for a long period of time on the Martian surface.

Analysis of the spectrometer data from *Mars Express* led to the identification of methane in the Martian atmosphere. Spectral observations from Earth have also reported methane detection. This, together with the possible detection of formaldehyde, suggests either that there is current volcanic activity on Mars or, more excitingly, that there are current active 'biological' processes. This hypothesis may be reinforced by the fact that *Mars Express* saw that the distribution of water vapour and methane, both ingredients for life, substantially overlap in some regions of the planet. Furthermore, the mission detected aurorae for the first time on the red planet. *Mars Express* has also acquired data leading to global mapping of the density and pressure of the atmosphere between 10 and 100 km altitude, and to studies of atmospheric escape processes in the upper layers of the atmosphere. These developments are contributing to our understanding of the weather and climate evolution of the planet.

In addition to providing an impressive wealth of scientific results on its own, *Mars Express* has also co-operated successfully with NASA's Mars Exploration rovers, in terms of coordinated scientific observations and to test *Mars Express* in relaying the rover data to Earth. Further scientific collaboration between *Mars Express*, both rovers and *Mars Odyssey* is expected, as well as with NASA's *Mars Reconnaissance Orbiter* mission during its extended mission.

The *Mars Express* mission is continuing in 2010 in its extended phase. The extensions give priority to fulfilling the remaining goals of the nominal mission (including gravity measurements and seasonal coverage), to catch up with the delayed MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) observations, to complete global coverage of high-resolution imaging and spectroscopy, and subsurface sounding with the radar, as well as to observe atmospheric and variable phenomena, and revisit areas of discoveries.

MER (*Mars Exploration rovers*), consisting of two identical lander rover missions were launched by NASA on 10 June and 7 July 2003, and arrived on 4 and 25 January 2004. *Pathfinder*-derived airbag technology was used for landing the rover vehicles *Spirit* and *Opportunity* onto the Martian surface. The rovers are considerably larger and more sophisticated than the *Sojourner*/*Pathfinder* rover, and include multiple camera systems as well as a variety of compositional investigations in an integrated science payload. The primary science instruments carried by the rovers

include:

- Panoramic camera (Pancam) to determine the mineralogy, texture and structure of the local terrain;
- Miniature Thermal Emission Spectrometer (Mini-TES) to identify promising rocks and soils for closer examination and determine the processes that formed Martian rocks. The instrument will also look skyward to provide temperature profiles of the Martian atmosphere;
- Mössbauer Spectrometer (MB) for close-up investigations of the mineralogy of iron-bearing rocks and soils;
- Alpha Particle X-Ray Spectrometer (APXS) for close-up analysis of the abundances of elements that make up the rocks and soils;
- Magnets, for collecting magnetic dust particles. The Mössbauer Spectrometer and the Alpha Particle X-ray Spectrometer will analyse the particles collected and help determine the ratio of magnetic to non-magnetic particles. They will also analyse the composition of magnetic minerals in airborne dust and rocks that have been ground by the Rock Abrasion Tool;
- Microscopic Imager (MI) to obtain close-up, high-resolution images of rocks and soils;
- Rock Abrasion Tool (RAT) for removing dusty and weathered rock surfaces and expose fresh material for examination by onboard instruments.

The findings from the *Mars Exploration rovers* have largely been reported in the refereed literature (*Science* special issues) and in the media. Major results to date include evidence for evaporated minerals in exposed rock layers, and other signs strongly suggesting the presence of standing bodies of water on Mars when the rocks were formed. The project has been extended due to the rovers' survival through the depth of Martian winter. Two and a half years after landing, both rovers are still working and have far exceeded their initial 90-day warranties on Mars.

Opportunity observations have revealed evidence for past inter-dune playa lakes that evaporated to form sulphate-rich sands. The sands were reworked by water and wind, solidified into rock, and soaked by groundwater. During the extended mission, *Opportunity* has detected more sedimentary bedrock exposures where an even broader, deeper section of layered rock is likely exposed that could reveal new aspects of Martian geological history.

While *Spirit*'s initial travels revealed a more basaltic setting, the rover found a variety of rocks indicating that early Mars was characterized by impacts, explosive volcanism, and subsurface water. Unusual-looking bright patches of soil turned out to be extremely salty and affected by past water. *Spirit* discovered finely layered rocks that are as geologically compelling as those found by *Opportunity* and that may hold clues to a history of past water.

Both rovers have found metallic meteorites on Mars. *Opportunity* discovered one rock with a composition similar to a meteorite that reached Earth from Mars.

In May 2009, after driving a total distance of 7.73 km, *Spirit* became embedded in deep soil in an area known as Troy. Various attempts to continue roving were unsuccessful and the *Spirit* effectively became a stationary science station. After the onset of winter conditions in early 2010, *Spirit* went into hibernation mode in March 2010. Communications had not been re-established as of October 2010.

Opportunity continues its extended roving mission. As of October 2010, it has travelled a total distance of approximately 24 km during its Martian journeys.

MRO (*Mars Reconnaissance Orbiter*) was launched by NASA in August 2005 and arrived at Mars on 10 March 2006. Its aim is to characterize the surface, subsurface, and atmosphere of Mars, and to identify potential landing sites for future missions. *MRO* carries six science instruments, three engineering instruments that will assist in spacecraft navigation and communications, and two more science-facility experiments. The science package includes:

- High Resolution Imaging Science Experiment (HiRISE) able to reveal small-scale objects in the debris blankets of mysterious gullies and details of the geological structure of canyons, craters and layered deposits;
- Context Camera (CTX) to provide wide area views to help determine a context for high-resolution analysis of key spots on Mars provided by HiRISE and CRISM;
- Mars Colour Imager (MARCI) to monitor clouds and dust storms.
- Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) to identify minerals, especially those likely to have been formed in the presence of water;
- Mars Climate Sounder (MCS) to detect vertical variations of temperature, dust, and water vapour concentrations in the Martian atmosphere;
- Shallow Radar (SHARAD) for probing beneath the Martian surface to see if water ice is present at depths greater than 1 m.

MRO carries the most powerful camera ever flown on a planetary exploration mission for homing in on details of Martian terrain with extraordinary clarity. This capability has not only provided an astoundingly detailed view of the geology and structure of Mars, but it has also contributed to the identification of obstacles that could jeopardize the safety of future landers and rovers. The SHARAD radar sounder is complementary to the MARSIS radar on *Mars Express* and has provided an unprecedented look at the structure of the polar caps.

MRO will also serve as the first installment of an 'interplanetary Internet', a crucial service for future spacecraft, as the first link in a communications bridge back to Earth. Several international spacecraft will use the *MRO* in coming years. The Orbiter's primary mission is planned to end on 31 December 2010.

Planned missions

Phobos-Grunt is a Roscosmos mission planned for launch in December 2011; its primary objectives are to collect soil samples from Phobos and to return the samples to Earth for comprehensive examination. After reaching Mars orbit, the mission is to study the Martian atmosphere and environment, approach and land on Phobos which would be studied by a number of *in situ* and remote methods. With the help of a small return rocket, a 100 g sample of Phobos regolith would be returned to Earth for laboratory analysis.

MSL (*Mars Science Laboratory*) is NASA's next rover mission planned for launch in the Fall of 2011. Twice as long and three times as heavy as the Mars Exploration Rovers *Spirit* and *Opportunity*, the *Mars Science Laboratory* (to be known as *Curiosity*) would collect Martian soil samples and rock cores for analysis *in situ* for organic compounds and environmental conditions that could have supported microbial life in the past or might even be doing so now. The science payload includes several cameras, a sophisticated suite of instruments for compositional analyses (an

alpha particle/X-ray spectrometer, a laser-induced sample breakdown spectroscopy (LIBS) system, a mass spectrometer and tunable laser spectrometer, and an X-ray diffraction system for chemical and mineralogical analyses), together with atmospheric, radiation and environmental sensors.

The *Mars Science Laboratory* is intended to be the first planetary mission to use precision landing techniques, steering itself towards the Martian surface in a way similar to the technique whereby the Space Shuttle controls its entry through the Earth's upper atmosphere. In this way, the spacecraft will fly to a desired location above the surface of Mars before deploying its parachute for the final landing. As currently envisaged, in the final minutes before touchdown, the spacecraft will activate its parachute and retro rockets before lowering the rover package to the surface on a tether. This landing method should enable the rover to land at a point within an area 20 to 40 km long, about the size of a small crater or wide canyon and three to five times smaller than previous landing zones on Mars.

Like the twin rovers now on the surface of Mars, *MSL* will have six wheels and cameras mounted on a mast. Unlike the twin rovers, it will carry a laser for vaporizing a thin layer from the surface of a rock and analysing the elemental composition of the underlying materials. It will be able to collect rock and soil samples and distribute them to on-board test chambers for chemical analysis. Its design includes a suite of scientific instruments for identifying organic compounds such as proteins, amino acids, and other acids and bases that attach themselves to carbon backbones and are essential to life as we know it. It can also identify features such as atmospheric gases that may be associated with biological activity. Using these tools, *MSL* will examine Martian rocks and soils in greater detail than ever before in a bid to determine the geological processes that formed them, study the Martian atmosphere, and determine the distribution and circulation of water and carbon dioxide, whether frozen, liquid or gaseous.

NASA plans to select a landing site on the basis of highly detailed images sent to Earth by the *Mars Reconnaissance Orbiter*, in addition to data from earlier missions. The rover will carry a radio-isotope power system that generates electricity from the heat of plutonium's radioactive decay. This power source gives the mission an operating lifespan on Mars' surface of at least a full Martian year (687 Earth days), while also providing significantly greater mobility and operational flexibility, enhanced science payload capability, making it possible for the rover to explore a much larger range of latitudes and altitudes than was possible on previous missions to Mars.

As of October 2010, the *MSL* rover was being integrated with its science instruments and readied for testing before launch in 2011.

For the *MEJI* (*Mars Exploration Joint Initiative*), ESA and NASA have agreed to a framework for joint exploration of Mars following the *MSL* mission, including launches in 2016 and 2018, and joint planning for a Mars sample return mission in the 2020s. The first of these missions is the *ExoMars Trace Gas Orbiter* to be launched in 2016 and for which ESA and NASA selected the instruments in August 2010. It is designed to study the atmospheric composition of Mars, including the recently discovered methane gas, in great detail. The mission will also carry a European Entry, Descent and Landing demonstration vehicle with the entire mission to be launched on a NASA launch vehicle. Two rovers (one NASA and one ESA vehicle) are currently being planned for the 2018 window of opportunity.

II.4 Exploration of Dwarf Planets and Small Solar System Bodies

Kuiper Belt Objects and Dwarf Planets (Plutoids)

Following the official IAU definition from 2006, additional dwarf planets have been added to the ranks, joining Pluto, Ceres (the largest member of the asteroid belt) and Eris (discovered in 2003 and thought to be larger than Pluto at about twice the latter's distance from the Sun). These new members include Makemake (discovered in 2005 and about three-quarteres the size of Pluto) and Haumea (originally discovered in 2004 and thought to be distinctly ellipsoidal in shape with its long axis exceeding the diameter of Pluto). The IAU introduced the term, *plutoid*, to describe a trans-Neptunian *dwarf planet* or an object that is likely to be such a body.

Other large bodies in this region (known as the Kuiper Belt) and ranging in size between Makemake and Ceres are Varuna and Quaoar (both classical trans-Neptunian objects), Orcus (a plutino), and Sedna (a distinctly red planetoid). Whether these objects qualify as dwarf planets is not yet clear. During this reporting period, two small moons were reported orbiting Haumea (Hi`iaka and Namaka), but none have been found at Makemake. It is expected that many more plutoids will be discovered in this region of the solar system within the next decade. More than 60 smaller Kuiper Belt Objects (KBOs) have been discovered since the last report, bringing the rapidly growing total to more than 1200. The orbital ensemble of these bodies displays an incredible variation of structure and includes classifications such as Plutinos, Scattered Disk Objects, Resonance Objects, Cubewanos, and other dynamical classes. A new model suggests that the large planets Jupiter and Saturn entered a temporary orbital resonance in the early history of the solar system, pushing the orbits of Uranus and Neptune into the outer protoplanetary disk and gravitationally scattering large icy planetesimals throughout the solar system while at the same time scattering planetesimals from the asteroid belt. This idea accounts for many observations in the inner as well as the outer solar system. The total mass of the Kuiper Belt is currently estimated to be less than one-tenth of the Earth's mass, but is still quite uncertain.

Current missions

New Horizons, NASA's New Frontiers one-way journey to the Pluto system (and then to one or more Kuiper Belt Objects), launched in January 2006, encountered Jupiter in early 2008 for a gravity assist and scientific studies (see Outer Planets section below). *New Horizons* is now well past the orbit of Saturn and is expected to arrive at Pluto in July 2015. Seven scientific instruments onboard the spacecraft include imaging spectrometers (ultraviolet to infrared spectral ranges), energetic particle spectrometers (to study solar wind interactions), a radiometer for radio science investigations, and a dust counter operated by students. *New Horizons*' primary goals are to characterize the geology, morphology and chemical compositions of the surfaces of Pluto and Charon and to characterize Pluto's neutral atmosphere with many lower priority objectives including a search for additional satellites and rings.

Asteroids and the Dwarf Planet Ceres

Recent Missions

Hayabusa ('peregrine falcon', formerly MUSES-C) is a JAXA asteroid mission that was launched in May 2003 to investigate a near-Earth asteroid and to return a sample of its surface to Earth. Using solar electric propulsion, *Hayabusa*

arrived at the asteroid 25143 Itokawa in September 2005 and observed it at an altitude from 20 km to 3 km through November 2005. Many new results using its four science instruments (imagers, X-ray and near infrared spectrometers) were obtained concerning the asteroid's shape, geographical features, surface altitude variation, albedo, spectrum, mineral composition, gravity, and the main chemical composition. A miniature rover (Minerva) failed to reach the asteroid, but the spacecraft successfully landed on its surface and may have collected samples, although the amount of material cannot be estimated until the return capsule is examined in detail. After some technical difficulties with the spacecraft, the sample capsule returned to Earth on14 June 2010 and was successfully recovered from the Australian desert. Initial inspection of the sample chamber found a small number of microscopic particles, some of which might be extraterrestrial in origin. Analysis was still continuing in October 2010 with update expected later in the year.

In addition to the remarkable data returned during it exploration of the small asteroid, results from the *Hayabusa* samples are expected to provide insights into our current understanding of asteroids by returning pristine samples from a well-characterized asteroid, bridging the gap between ground-based observations of asteroids and laboratory analyses of meteorites (thought to originate from asteroids) and cosmic dust collections.

Current missions

Dawn, a mission developed in NASA's Discovery series, was successfully launched on 27 September 2007. *Dawn* is designed to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets remaining intact since their formations: Ceres and Vesta. They are considered two of the most interesting large bodies in the main asteroid belt: Vesta seems to be highly evolved, while Ceres – the newly designated dwarf planet – may be water-rich, in the form of ices and/or hydrated minerals. The payload comprises two framing cameras, a visual and infrared mapping spectrometer, and a gamma-ray and neutron spectrometer. After a successful commissioning phase, a Mars gravity assist was successfully performed in February 2009. Arrival at Vesta is scheduled for August 2011.

Planned missions

OSIRIS-REX (*Origins Spectral Interpretation Resource Identification Security Regolith EXplorer*) was one of three missions selected by NASA in 2010 for the second round of the next New Frontiers mission competition. It is designed to rendezvous and orbit a primitive near-Earth asteroid and return a sample to Earth for study.

Comets

Recent missions

Stardust, NASA's comet sample return mission returned safely to Earth after travelling nearly 5 billion km during its seven-year round-trip odyssey to comet 81P/Wild 2. The capsule, carrying cometary and interstellar particles, became an artificial meteor on 15 January 2006 and successfully touched down in the desert salt flats of Utah. Two days later, the sample return capsule's science canister and its cargo of comet and interstellar dust particles were transferred to the Johnson Space Center (Clear Lake, Texas, USA) where it was opened for scientific investigation and curation. The *Stardust* project has delivered, to the international science community,

material that has been unaltered since the formation of our solar system and which should help provide answers to fundamental questions about comets and the origins of the solar system.

Samples from comet 81P/Wild 2 have surprised scientists, showing a remarkable range of minerals with some of the comet particles containing minerals that only form at extremely high temperatures that could not have existed where the comets formed, indicating the formation of at least some comets may have included materials ejected by the early Sun to the far reaches of the solar system. Many of the comet particles are built like loose dirt-clods composed both of 'large strong rocks' as well as very fine powdery materials. The public has been invited to join in the search for tiny particles of interstellar dust at the interactive, internet-based website, Stardust@home, where the aerogel collector can be examined. During its flyby, *Stardust* returned high-resolution images of the nucleus of comet 81P/Wild 2, expanding our knowledge of these small solid bodies that are the source of cometary activity. In the mean time, the *Stardust* spacecraft has been placed into hibernation mode for possible use in an extended mission to another target.

Deep Impact, NASA's Discovery-class mission, has continued the current renaissance in cometary science. Its goal was to study the pristine material of a cometary nucleus by excavating an artificial crater to release subsurface materials. It was launched on 12 January 2005, and delivered a 370 kg copper projectile travelling at a velocity of 10.2 km s^{-1} into the nucleus of comet 9P/Tempel 1 on 4 July 2005. This spectacular event resulted in the formation of a crater, and ejection that was observed by an extensive network of ground-based and Earth-orbiting telescopes as well as from the *Deep Impact* spacecraft and ESA's *Rosetta* spacecraft (see below). The results seem to indicate that the cratering process was gravity-dominated, lending to the notion that the comet's nucleus consists of porous, pristine, unprocessed material of very low tensile strength. Spectra taken shortly after impact revealed emission lines of water, HCN, carbon monoxide and dioxide, and several organics in the hot volatile-rich vapour plume. The amount of dust released was greater than expected, consisting of very fine particles, and containing crystalline and amorphous (glassy) silicates, amorphous carbon, carbonates, and clay minerals (phyllosilicates). Images of the nucleus of comet 9P/Tempel 1 revealed a rugged surface with relatively flat areas, scarps, and circular features thought to be impact craters. Small patches of water ice were detected for the first time on the surface of a comet. Analysis and interpretation of the results of this mission are ongoing.

Current missions

EPOXI is a combination of proposals to use the re-tasked NASA *Deep Impact* spacecraft together with the *EPOCH* (Extrasolar Planet Observation and Characterization) investigation and *DIXI* (Deep Impact eXtended Investigation of comets). The mission's target is comet 103P/Hartley2 with a close flyby scheduled for November 2010. As of October 2010, the mission was on course for the flyby and was making distant observations of the comet.

STARDUST – NExT, playing turn-about with *EPOXI*, uses the re-tasked NASA *Stardust* spacecraft to visit *Deep Impact*'s target comet 9P/Temple 1, with a flyby on 14 February 2011. This will enable investigators to look for changes in the comet since *Deep Impact*'s visit in 2005 and may enable viewing of the impact crater left by *Deep Impact*'s projectile.

Rosetta, ESA's cornerstone comet rendezvous mission, was launched from Kourou (French Guiana) on 2 March 2004 using an Ariane-5 rocket. It is scheduled to rendezvous with comet 67P/Churyumov-Gerasimenko in 2014. The *Rosetta* project consists of an orbiter with eleven experiments and a lander with nine further experiments. The spacecraft and instruments have successfully undergone initial testing and evaluation. One of the major objectives of the orbiter is to study the development of cometary activity and the processes in the surface layer of the nucleus as the solar distance of the nucleus decreases. The near-nucleus phase will start at a heliocentric distance of about 3.25 AU and continue until perihelion passage at about 1 AU. To gain enough orbital energy to reach the cometary target, gravity assists (and accompanying science studies) with Mars and Earth were successfully executed in late 2005. A third Earth-gravity assist occurred in November 2009 leading to the second asteroid fly-by in July 2010 when *Rosetta* encountered 21 Lutetia, the largest asteroid (with a diameter of about 100 km) yet to be studied by a spacecraft. Initial analyses indicated that Lutetia may be a very complex body, with a seemingly primitive surface but a relatively high bulk density ($>\sim$ 3 gm cm^{-3}), suggesting a possibly altered or differentiated interior.

After its first year of operation, at 67P/Churyumov-Gerasimenko, the orbiter will deploy the lander which will focus on determining the elemental and molecular nature of gases given off from the comet's surface. In addition, the properties of the near surface will be studied and the coarse internal structure will be investigated. Various onboard instruments to examine the comet's structure and composition, have already acquired scientific data on the Earth and many comets. In particular, *Rosetta* participated in the observation campaign that accompanied the *Deep Impact* event on July 2005, obtaining many useful data.

On 5 September 2008, the first of two asteroid fly-bys was performed. Asteroid 2867 Steins was selected as a scientific target to be observed because it is a rare, E-type, asteroid of which little is known. The *Rosetta* fly-by provided a unique opportunity to perform the first *in situ* exploration and characterize the surface and environment of this member of the E-type asteroid class.

Rosetta is now on course to rendezvous with its principal target, comet 67P/Churyumov-Gerasimenko, in May 2014.

Space-based Observatories and Small Bodies Research

The JAXA *Akari* ('Light', formerly ASTRO-F) mission aimed at producing a second-generation survey of the entire infrared sky was launched on 22 February 2006. It improves upon its predecessor *IRAS* by virtue of its better sensitivity, spatial resolution, and wider spectral coverage ranging from 1.7 to 180 μm. *Akari* has a 68.5-cm IR telescope cooled to 6K. After achieving a Sun-synchronous polar orbit of about 700 km, it returned its first images in April 2006 and completed its major observational programmes, including its all-sky survey by August 2007. *Akari* has conducted a post-helium mission with near-infrared observations, some part of which have been devoted to solar system studies, including small bodies.

The *Hubble Space Telescope* (*HST*) is continuing to participate actively in small body research. *HST* was used to image Ceres, to search for possible impact features on its surface, the Kuiper Belt Object Sedna, and the dwarf planet Eris with its moon Dysnomia. Extraordinary views were also provided of the fragments of the comet 73P/Schwassmann-Wachmann 3 and of the effect of the collision between the

projectile released by the *Deep Impact* spacecraft and comet 9P/Tempel 1. Recently *HST* images were used to update the rotation pole position of 4 Vesta in support of the upcoming *Dawn* encounter.

The *Spitzer* Space Telescope joined observers around the world in the *Deep Impact* campaign, observing, with its infrared spectrograph, the cloud of material that was ejected when the impactor struck the surface of 9P/Tempel 1.

NASA's *WISE* (*Wide-field Infrared Survey Explorer*), although designed primarily for astrophysics science objectives, is providing a treasure-trove of small body data. Using four infrared bands (3.4, 4.6, 12 and 22 μm), *WISE*'s all sky survey is also detecting most of the known main belt asteroids, providing accurate radii and albedo data for over 100 000 objects, as well as detecting many new objects. A supplementary programme of analysis, the *NEOWISE* programme is also discovering and characterizing many new near-Earth objects every day. After *WISE*'s primary mission, the spectral range has been limited to the two short wavelength bands due the depletion of both the primary and secondary cryogenic cooling systems, but as of October 2010 was continuing to provide valuable asteroid and cometary data.

Through various automated, ground-based observational programmes, asteroids are being discovered at a rate of about 5,000 per month. A total exceeding 500,000 are registered as minor planets at the time of this report, more than 251,650 of these having well-determined orbits and given permanent official numbers, almost 16,000 of which bearing official names, with almost 250,000 un-numbered as yet. Currently, roughly 7,384 Near-Earth asteroids with orbits close to Earth orbit are known, with some 1,148 currently classified as Potentially Hazardous Asteroids (PHAs).

An astronomical survey called Pan-STARRS (Panoramic Survey Telescope And Rapid Response System), a wide-field imaging facility developed at the University of Hawaii's Institute for Astronomy, is designed to discover and characterize Earth-approaching objects, both asteroids and comets, that might pose a danger to our planet. Ten research organizations in four countries are collaborating in the programme that involves continuous astrometry and photometry of much of the sky. The Survey is expected to discover many new asteroids, comets, variable stars and other celestial objects visible from its location in Hawaii (about three-quarters of the entire sky).

II.5 Outer Solar System Space Probes

Jupiter

Recent missions

New Horizons conducted a highly successful flyby of the Jupiter system in early 2008. The new data returned included spectacular time-lapse images of volcanic eruptions on Io, some at locations which have been active since the *Voyager* and *Galileo* missions. Observations of Jupiter also identified lightning in shear zones in the atmosphere.

Current missions

Juno is NASA's second New Frontiers mission – the first being the *New Horizons* mission on its way to Pluto and the Kuiper Belt. *Juno* is a Jupiter orbital mission, scheduled for launch in November 2011. The mission will utilize a highly

elliptical, near polar orbit to permit very low altitude observations whilst minimizing exposure to Jupiter's radiation belts. The primary objectives of *Juno* are to determine the internal structure of the giant planet through detailed study of the magnetic and gravity fields with unprecedented precision, and to determine the abundance of water and, therefore, oxygen, deep in the Jovian atmosphere – a key measurement not accomplished by the *Galileo* atmospheric Probe, which descended in a dry portion of the atmosphere where water was highly depleted.

Saturn

Current missions

Cassini-Huygens, a joint programme between NASA and ESA, was launched in October 1997. It was designed to provide an intensive investigation of the Saturn system including Titan, the chemical environment of which may resemble that of the primordial Earth and thus provide valuable clues as to the chemistry of the early Earth. The *Cassini* spacecraft with the *Huygens* probe attached went into orbit around Saturn on 1 July 2004. A major goal of the mission was achieved when ESA's *Huygens* probe successfully completed its mission, becoming the first spacecraft to land on Titan. The only anomaly in the technical performance of the probe was the loss of one of the two redundant radio channels to the Orbiter due to a commanding error. One of the main science experiments on the lost channel was the Doppler-Wind radio experiment, but fortunately the objectives of this experiment were achieved using an experimental direct-to-Earth tracking channel and an extensive international effort by radio astronomers to detect and measure the probe's radio signal from Earth-based radio telescopes.

During its approximately three-hour descent through Titan's cold, thick nitrogen atmosphere, the *Huygens* probe sent back data on the composition and structure of the moon's atmosphere and took panoramic images of its dimly lit surface. Images taken below about 12 km altitude show the surface of Titan in unprecedented detail, including hills over 100 m in height, with channel and valley networks apparently carved by flowing liquid – probably liquid methane.

Huygens landed on a solid, icy pebble-strewn plain, possibly the outflow deposits from the channels seen in the nearby hills. Although no liquid was detected on the surface in the vicinity of the landing site, data from the mass spectrometer experiment on board showed a sharp increase in methane gas following the landing and heating of the surface by the probe, indicating that the soils may contain liquid methane below the surface. Another major discovery from the chemical analysis of the atmosphere was the lack of primordial noble gases (Kr, ^{36}Ar and Xe), a finding that strongly suggests that the origin of Titan's nitrogen atmosphere is the breakdown of ammonia rather than delivery of nitrogen trapped in very cold icy planetesimals during formation of the moon.

The *Cassini* Orbiter has also made extensive studies of Titan, performing close flybys, typically within a few thousand km altitude. As of October 2006, nineteen targeted flybys had been successfully achieved. The Orbiter carries out remote visual, infrared and radar observations of the atmosphere and surface, and can also perform *in situ* analyses of Titan's atmosphere during close encounters. Synthethic aperture radar (SAR) images of Titan's surface have revealed a geologically young surface, with only a few large impact craters detected. In addition to channel systems similar to those seen in the *Huygens* descent images, the radar has also mapped extensive

dune fields in the equatorial regions, likely composed of solid hydrocarbon particles. Observations near Titan's north pole show extensive dark lake-like features, interpreted as liquid methane/ethane lakes which may be part of a seasonal exchange of methane from the south to the north poles as well as supplying methane to the atmosphere to create the rainstorms recorded in the erosion channels seen by *Huygens*. These conclusions have been strengthened by recent observations by the Visual and Near Infrared Mapping Spectrometer (VIMS) of specular reflection from one of these features at 5 μm (where the atmosphere is relatively transparent) and an absorption feature identified as ethane in another.

Observations of Titan's gravity field and spin state are consistent with a moment of inertia suggesting the possibility of a partially differentiated interior structure, similar to that proposed for Callisto. In addition, radio frequency observations from the *Huygens* probe have recently been interpreted as suggesting a conducting layer lying ~50-100 km below Titan's surface, possible evidence for a liquid water or water/ammonia ocean.

In addition to observing Titan, the *Cassini* Orbiter is making extensive measurements of Saturn's ring system, the smaller icy satellites and Saturn's magnetic and plasma environment. One of the major discoveries of the mission to date has been the detection of huge geyser-like eruptions from cracks in the south polar region of Enceladus, a tiny icy moon close to Saturn which is only ~500 km in diameter. These plumes are composed primarily of water vapour and tiny ice particles and appear to be responsible for creating the huge, extended E-ring around Saturn. The source of the heat to produce these eruptions is still unknown, probably a combination of radioactive heating from the rocky portion of the satellite and tidal heating. The preliminary interpretation of the data on the plumes strongly suggests that there may be liquid water at shallow depths beneath at least the south polar region on Enceladus, and simple hydrocarbons have been detected on the surface and in the plume gas. In addition, recent data from the Cosmic Dust Analyser have shown that the most massive of the ice particles ejected in the plumes have a high sodium content, while the plume gas has been shown, from Earth-based spectral data, to have essentially no atomic sodium. This is most consistent with models of the plume origins in a subsurface liquid ocean or reservoir. Enceladus is thus of major interest to astrobiologists, as yet another planetary environment (along with Mars, Jupiter's moon Europa, and Titan) where the basic requirements for terrestrial life (water, organic material and energy) may be present currently or have been in the past.

Cassini's nominal mission ended in July 2008. NASA approved a three-year extended mission phase (the 'Equinox" mission for the Saturn season covered) ending in 2011. As of October 2010, *Cassini* had completed over 70 flybys of Titan and 11 flybys of Enceladus as well as having had targeted encounters with Phoebe, Iapetus, Rhea and Dione with frequent observations of the rings and smaller satellites. The spacecraft is still fully operational, and a further extension, possibly through 2017 (the 'Solstice' mission), was approved by NASA in 2010.

Future Missions to the Jupiter and Saturn Systems

As a result of *Galileo* and *Cassini*/*Huygens* discoveries, several studies of future missions to Jupiter and Saturn have been conducted by NASA and ESA (as part of the Cosmic Vision solicitation). From these, two specific mission proposals were selected by NASA and ESA in 2008 for future study for a possible NASA-ESA joint mission. These included a Jupiter system exploration mission involving a Europa

orbiter and a Jupiter system exploration ending with a Ganymede orbiter, and a Saturn system mission including a Titan orbiter and descent and *in situ* exploration, as well as future study of the Saturn system. A further down-select of mission concept has resulted in a focus on the Europa Jupiter System Mission (EJSM) for pre-phase A study, with two spacecraft – a NASA Jupiter Europa Orbiter and the ESA Jupiter Ganymede Orbiter, currently in competition for the Cosmic Vision Large mission class selection. Target launch date for EJSM is 2020. Possible additional contributions from JAXA and other national space agencies are also being considered as part of the effort. In the US, a National Research Council survey of priorities for future solar system exploration is currently under way with results expected to be announced in early 2011. This is expected to set the priority for EJSM and identify the future targets for outer solar system exploration.

Other Studies, including Remote Space Studies of Exo-Planets

The solar system observations with the NASA-ESA *Hubble Space Telescope* (*HST*) have continued to be very productive with, for example, the observation that several Kuiper Belt Objects are actually binary systems, most likely the result of mutual encounters and collisions.

The ESA-NASA *Solar and Heliospheric Observatory* (*SOHO*) has completed half a solar cycle of observations during which period it discovered more than 800 comets.

The *Odin* sub-mm satellite, led by Sweden and involving Canada, Finland and France, was launched in February 2001, and is contributing to the study of water vapour in weakly active comets.

The current generation of X-ray space telescopes like *Chandra* have continued to provide important information for the study of solar wind-comet interaction and X-ray spectroscopy of cometary comas. Key measurements of the auroral X-ray emissions of Jupiter and of Saturn have also been made by *Chandra* and *XMM-Newton*. The XMM observations have shown that the Jovian aurora is likely to be produced by the precipitation of captured solar wind ions.

Ground-based activities (observations, laboratory measurements, modelling studies), of major interest for the preparation of future space missions, have been and are being performed in various parts of the world. A new trend has appeared with the development of 'laboratory' experiments under microgravity conditions on-board rockets, spacecraft and the *International Space Station* (e.g., the International Microgravity Plasma Facility and the facility for Interactions in Cosmic and Atmospheric Particle Systems), to study dusty plasmas, dust aggregation, planetesimal formation and the light scattering properties of dust particles.

Several Earth-orbiting satellites are expected to provide results on exo-planets and exo-planetary systems. The NASA *SIRTF* (*Space Infra-Red Telescope Facility*) now called the *Spitzer* Space Telescope, was launched in August 2003, and facilitates the study of Kuiper-belt dust out to 50-100 AU around nearby stars. It has been used to study the details of spectra of some of the recently transiting 'hot Jupiters' and other planets, bringing the study of exoplanets from simple detection to atmospheric and physical characterization as planetary bodies.

The French-European *COROT* mission, launched in December 2006, is being used to search for signatures of the transits of telluric-type and giant planets passing in front of stars. In extended observation periods of 150 days, some 30,000 stars are

observed continuously. As of October 2010, at least 15 transiting planets had been confirmed from *COROT* observations.

NASA's *Kepler* Discovery class mission is also designed to detect transiting planets, some possibly as small as the Earth. *Kepler* was launched on 6 March 2009. It consists of a space telescope that uses photometric transit measurements to search for Earth-like planets. Soon after launch, *Kepler* used observations of a known transiting planet secondary transit (eclipse) and demonstrated the required stability and sensitivity to detect Earth-scale transit signals. To date, as of October 2010, *Kepler* has found seven confirmed transiting planets and 700 candidate planets. The candidate list needs extensive analysis and follow up studies to confirm each valid transiting planet signal and periodic releases of information on new transiting planets will be made.

The NASA *SIM* (*Space Interferometer Mission*) is being studied as a 5-year operational mission to complete a census of nearby stellar systems, using ultra-high precision, micro-arcsec interferometry to detect several Earth-mass planets around nearby stars (and larger planets around more distant stars). Finally, the ESA Cornerstone Gaia astrometric observatory mission, to be launched before 2012, is expected to detect the astrometric signatures of tens of thousands of Jupiter-type planets around stars in our galactic neighbourhood. In addition, it should provide a large, uniform census of minor planet kinematics, Near Earth Objects, trojans, trans-Neptunians, and provide information on galactic perturbations to the Oort cloud.

III. SPACE STUDIES OF THE UPPER ATMOSPHERES OF THE EARTH AND PLANETS, INCLUDING REFERENCE ATMOSPHERES

III.1 The Earth's Middle Atmosphere and Lower Ionosphere

The Earth's middle atmosphere and lower ionosphere are active and diverse regions that couple the lower terrestrial atmosphere with the near Earth space environment. This region of the atmosphere is driven by waves and tides propagating upward from the lower atmosphere, and can be significantly perturbed by solar particle and radiative inputs from above. These external forcing mechanisms are of similar magnitude and importance in driving the global structure of the middle atmosphere and lower ionosphere.

The mesopause is the coldest place in the terrestrial environment and the turbopause, where the atmosphere makes the transition from well mixed to diffusive equilibrium, is located in this region. While dynamics play a major role in forcing the summer mesopause out of radiative equilibrium, chemistry also plays a significant role in this region. The constant ablation of meteors creates metallic layers.

The scientific community is working to understand the processes present in the middle atmosphere and lower ionosphere along with their impact on the region and coupling to other regions above and below. Topics relevant to understanding the region have grown out of recent symposia, including meetings organized by COSPAR. These topics include: understanding the processes that couple the lower atmosphere to the middle atmosphere and then into the lower ionosphere; the global distribution of waves from small-scale gravity waves to large-scale planetary waves and their influence on the system; coordinated ground- and space-based observations; meteoric input and its influence on the region; understanding the impact of geomagnetic storms on the region; understanding the processes that control the polar

regions; layered phenomena such as noctilucent clouds; climatic impact of changes in trace constituents and solar input; impact of cosmic forcing; and the global electric circuit.

Progress on Selected Scientific Topics

While it is not possible to cover all of the topics of interest to this scientific area, we highlight activities from 2009 and 2010.

US CubeSat Programme

Lack of essential observations from space is currently a major limiting factor in space weather research. Recent advances in sensor and spacecraft technologies make it feasible to obtain key measurements from low-cost, small satellite missions. A particularly promising aspect of this development is the prospect for obtaining multi-point observations in space that are critical for addressing many outstanding problems in space science. Space-based measurements from small satellites also have great potential to advance discovery and understanding in other areas of atmospheric sciences. To take full advantage of these developments the US National Science Foundation has developed a CubeSat programme. The overarching goal of the programme is to support the development, construction, launch, operation, and data analysis of small satellite science missions to advance space weather and atmospheric research. Equally important, it will provide essential opportunities to train the next generation of experimental space scientists and aerospace engineers. Currently, six CubeSats are under development with the first being the *Radio Aurora Explorer* (*RAX*) which is scheduled for launch on 19 November 2010 from Kodiak, Alaska. Its primary mission is to study how plasma instabilities in the highest layers of the atmosphere disrupt communication and navigation signals between the Earth and orbiting satellites. Other projects include the *DICE* mission to study the physical processes responsible for formation of the mid-latitude ionospheric Storm Enhanced Density (SED) bulge in the noon to post-noon sector during magnetic storms, the *Firebird* mission to resolve the spatial scale size and energy dependence of electron microbursts in the Van Allen radiation belts and the *FireFly* mission designed to explore the relationship between lightning and those sudden bursts called Terrestrial Gamma Ray Flashes. All of these projects began in 2008 or 2009 and are expected to fly within the next two years.

The Advanced Modular Incoherent Scatter Radar

The *Advanced Modular Incoherent Scatter Radar* (*AMISR*) is a modular, mobile radar facility that is being used by scientists and students from around the world to conduct studies of the upper atmosphere and to observe space weather events. The Poker Flat *AMISR*, also known as *PFISR*, consists of three separate radar faces, with each face comprised of 128 building block-like panels over a 30 m x 30 m roughly square surface. *PFISR* was completed and became operational in early 2007. In February 2008, the *PFISR* completed a year-long International Polar Year (IPY) run. When not running for other experiments, *PFISR* has operated almost continuously in a low-duty cycle mode. The resulting large data set, combined with that from the year-long full-power *EISCAT* Svalbard radar and the biweekly 30 hr runs of the *EISCAT* Tromsø, Sondrestrom and Millstone Hill radars, provided an unprecedentedly large volume of high-latitude measurements during the IPY. From January through March 2009, *PFISR* supported the *ACES-2* and *CASCADES-2* rocket campaigns as well as numerous optical campaigns. Specifically, the *ACES-2*

campaign will help refine current models of aurora structure and provide insights into the high frequency waves and turbulence generated by aurora, while the *CASCADES-2* campaign focuses on motions and structure of electron precipitation in pre-midnight poleward-edge discrete aurora.

In August 2009, the north-looking face of the Resolute Bay Canada *AMISR* known as *RISR-N* completed engineering testing and calibration, and is now fully operational with 128 panels. A second south face *RISR-S* is now under construction with support from Canada and the US. Plans are being developed to consider La Plata in Argentina as a future location for *AMISR*, thus enabling conjugate measurements from the Arecibo *ISR*.

CAWSES

The *Climate and Weather in the Sun Earth System* (*CAWSES*) is an international programme sponsored by SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) and established with the aim of significantly enhancing our understanding of the space environment and its impacts on life and society. The main functions of *CAWSES* are to help coordinate international activities in observations, modelling, and applications crucial to achieving this understanding, to involve scientists in both developed and developing countries, and to provide educational opportunities for students of all levels. Theme three of *CAWSES* specifically focuses on solar and magnetospheric inputs which propagate downward through the atmosphere, and tropospheric effects which propagate upward into the thermosphere-ionosphere system and is of interest to the COSPAR Commission C2 community as illustrated by the C2 supported sessions at the most recent 2010 scientific assembly in Bremen, Germany.

A variety of new evidence suggests that tropospheric weather is an important ingredient in geospace variability. Gravity waves generated by hurricanes or typhoons may propagate into the thermosphere and seed ionospheric instabilities, i.e. plasma bubbles, sporadic-E patches and travelling ionospheric disturbances. Atmospheric tides due to persistent tropical rainstorms produce large longitudinal and local time variations in bulk ionosphere-thermosphere-mesosphere (ITM) properties, i.e. temperature, wind, composition, airglow and plasma density, to name a few.

Oscillations of F-region plasma density and other ITM properties at planetary wave periods at least partly reflect the planetary wave activity and variability in the stratosphere. Thermospheric waves generated by high-latitude auroral energy input change the ionospheric and thermospheric environments even at low latitudes. All these waves may further interact with each other and the background atmosphere, i.e. when propagating upward through the stratosphere to the ionosphere, thereby producing additional variability and/or secondary waves.

Studying the geospace response to variable inputs and waves from the lower atmosphere is particularly important since the induced variability competes with the solar and magnetic driving from above. Consequences for telecommunications, re-entry and satellite operations still need to be explored. The extent to which the effects of this quiescent atmospheric variability are transmitted to the magnetosphere is yet to be resolved.

Thus, we stand now at an exciting research frontier: understanding the cause-and-effect chain that connects tropospheric (weather) and strato-/meso-spheric variability with geospace processes. *CAWSES* Task Group 4 will therefore endeavour

to elucidate the dynamical coupling from the low and middle atmosphere to geospace including the upper atmosphere, ionosphere, and magnetosphere, for various frequencies and scales, such as gravity waves, tides, and planetary waves, and for equatorial, middle, and high latitudes. Attacking the problem clearly requires a systems approach involving experimentalists, data analysts and modellers from different communities. For that purpose, the most essential part of Task Group 4 is to encourage interactions between atmospheric scientists and plasma scientists on all occasions.

PANSY Radar

Global environmental change revealed by observing the Antarctic middle and upper atmosphere is one of the core projects in the new six-year term of *JARE* (*Japanese Antarctic Research Expedition*) which started in 2010. As a part of this project, the *PANSY* (*Programme of the Antarctic Syowa MST/IS radar*) (47 MHz, 500 kW) has been funded and is being manufactured. This radar will be one of the largest atmospheric radars in the world and the first one to be installed in the Antarctic. It will be installed at Syowa, Antarctica (69ºS, 39ºE) in early 2011, and will start operations by the end of the 2010/11 austral summer. A Rayleigh lidar, mm-wave spectrometer will also join the instruments at Syowa Station, such as MF, HF radars, ionosondes and airglow/aurora imagers/ cameras.

Interhemispheric Wave Coupling

Recent analyses [1] have shown the existence of a coupling between the temperature of the high-latitude summer mesosphere and the planetary wave-induced drag in the winter stratosphere. Noctilucent cloud radii are seen to be (anti) correlated with winter hemisphere zonal-mean temperatures. Studies using the Canadian Middle Atmosphere Model have reproduced these results[2]. A mechanism to explain this coupling has been proposed and tested with a simple model[3]. This mechanism relates a planetary wave-induced modulation of the gravity-wave flux into the winter stratosphere to changes in the strength of the meridional circulation. These changes can create a warming in the upper stratosphere which, through its effect on the gravity wave field around it, propagates to the winter mesosphere. The proposed mechanism is currently being tested using observational data.

III.2 The Earth's Ionosphere, Thermosphere and Mesosphere

The Earth's upper atmosphere at altitudes from 70 to above 1500 km is called the Ionosphere, Thermosphere, and Mesosphere (ITM) region and continues to be the focus of active research by international space-based and ground-based teams and facilities. The ITM region has become critically important to the human presence in space and is the area in which dynamical processes dramatically affect communication, navigation, power, aviation, defence, and space transportation systems.

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[1] Karlsson, B., Kornich, H. & Gumbel, J. 2007 Evidence for interhemispheric stratosphere-mesosphere coupling derived from noctilucent cloud properties. *Geophys. Res. Lett.*, **34**, L16806, doi:10.1029/2007GL030282.

[2] Karlsson, B., McLandress, M. & Shepherd, T. G. 2009 Inter-hemispheric mesospheric coupling in a comprehensive middle atmosphere model. *J. Atmos, Sol-Terr Phys.*, **71**, 518-530.

[3] Koernich, H. & Becker, E. 2010 A simple model for the interhemispheric coupling of the middle atmosphere circulation, *Adv. Spac. Res.* , **45** (No, 5), 661-668.

The density, composition, and dynamics of this region are highly responsive to variable energy inputs from above (the Sun and magnetosphere) and from below (the low and middle atmosphere). The ionosphere is generally coincident with the mesosphere, thermosphere and exosphere and is created by two overall processes. These include 1) the direct absorption of solar extreme ultraviolet (EUV) radiation by neutral atoms and molecules and 2) the impact ionization of neutral species by the precipitation of energetic electrons at high latitudes into the thermosphere. Both the ionized and neutral gases are closely linked through collisions and dynamics. They respond to energy and momentum forcing from both the magnetosphere above and the low and middle atmosphere below.

The ITM is studied using a variety of techniques ranging from ground optical and radio instruments to sounding rockets and satellite platforms. Research activity has expanded beyond individual or national investigations to include large, international, focused study projects and campaigns. The Scientific Committee for Solar Terrestrial Physics (SCOSTEP) under ICSU has coordinated international research projects related to the solar-terrestrial physics including the ITM research. In the 1990s, the major project was the *STEP* (*Solar Terrestrial Energy Programme*, 1990-1997). From 1998 through 2002, SCOSTEP coordinated the *SRAMP* (*STEP Results, Applications and Modelling Phase*), *PSMOS* (*Planetary-scale Mesopause Observing System*), *EPIC* (*Equatorial Processes Including Coupling*), and *ISCS* (*International Solar Cycle Study*) programmes. These programmes were then combined into *CAWSES* (*Climate and Weather of the Sun-Earth System*, 2004-2008) and *CAWSES-II* toward the solar maximum (2009-2013). These programmes provide a global network of observing systems and study projects designed to understand the Sun's effects on the Earth's ITM and to determine the global-scale solar, chemical, and dynamical influences on the ITM region. The large number of individual and national projects that study and characterize the processes and variability of the ITM are now too numerous to list in a single article. However, some important highlights can be described.

Ground-Based Observation Programmes

Ground-based observation programmes include optical and radio techniques to measure the ITM region. For optical techniques, Fabry-Perot interferometers have been installed in recent years in several places in the north and south American continents, northern Europe, and Asia to monitor thermospheric winds and temperatures on a global scale. Night airglow imaging observations keep producing new findings in the thermospheric and mesospheric small-scale structures. The *NDMC* (*Network for the Detection of Mesopause Change*) programme promotes an international network of rotational temperature measurements through airglow interferometry to investigate possible long-term cooling of the mesopause region associated with global warming of the troposphere. Sodium lidars (laser radars) measure long- and short-term variations of the mesopause temperatures in the USA, Japan, and Norway.

For radio techniques, ionosonde programmes continue to provide raw ionograms and summary reports at more than 50 positions in the world. Coherent HF radars (*SuperDARN* radar network) for studying the auroral zone electrodynamics including plasma convection is expanding from the auroral zone to subauroral latitudes in the coming few years to investigate storm-time plasma convection. New incoherent scatter radar programmes to measure dynamics from the troposphere to the

ITM region have been fully or partially funded, i.e. *PANSY* at the Antarctic Syowa station, *AMISR* at Resolute Bay, Canada, and *EISCAT-3D* in northern Scandinavia. MLT radars (MF radars and meteor radars) also form a network for mesospheric wind measurements in the American and Asian longitudinal sectors and in northern Europe. GPS radio receivers are compact instruments to monitor and understand ionospheric variations. New GPS receivers are being installed in Africa and now all the continents are covered by a GPS network.

Rocket Systems, Results and Campaigns

These include rockets programmes providing data on thermospheric and ionospheric parameters, high-resolution EUV irradiances, atmospheric density, temperature and winds, electric and magnetic fields, as well as chemical composition, including minor constituents. Many rocket campaigns are coordinated with co-located facilities such as lidars and radars, so that information on the background atmospheric and ionospheric conditions can be determined during the period surrounding the time of specific rocket flights. Examples include polar atmosphere-ionosphere studies by the 2nd *Dynamics and Energetics of the Lower Thermosphere in Aurora* (*DELTA-2*) rocket campaign carried out at the Andøya Rocket Range, Norway.

Satellite Systems

Satellite systems in this field include major spacecraft that continue to make ITM-related measurements. For low-latitude satellites, *Formosat-2*/*COSMIC* makes GPS occultation measurements of the total electron content for 3-D ionospheric tomography; *C/NOFS* was launched in 2008 to make observations of equatorial scintillation; the *DMSP* series keep monitoring the ionospheric density and ion drift at ~800-km altitudes; *CHAMP* and *GRACE* provide accelerometer and GPS data for neutral density specification; *TIMED* continues to study the energy balance (solar heating, IR cooling, transport) and basic state (density, composition, temperature, wind) of the Earth's atmosphere between 60 and 180 km; *Demeter* studies the ionospheric disturbances related to seismic activity; *ROCSAT-1* continues to study ionosphere phenomena, including field-aligned irregularities; *Polar* has completed its observing of both high- and low-altitude perspectives of the polar region of Geospace while *Akebono* is still in operation after more than 21 years measuring plasma density and temperature in the ionosphere/plasmasphere.

For satellites in and above geosynchronous orbit, the *GOES* satellites at geosynchronous orbit monitor solar X-rays and solar particles; *ACE* continues to measure the composition of the solar wind at the Sun-Earth L1 position; *SDO* was launched in February 2010 to understand and, ideally, predict the solar variations that influence life on Earth and humanity’s technological systems; *SOHO* continues to provide information on the structure of the solar interior, surface magnetic fields, inner corona, coronal mass ejections, and the solar wind; *SORCE* provides measurements of the 0.1-34 nm and 115-2000 nm solar irradiances with four instruments; *STEREO* provides 3-D views of solar phenomena and disturbances travelling in the inner heliosphere. In addition, the Solar Platform has been attached to the *International Space Station* to make complementary solar irradiance measurements.

Models and Modelling Activities

There have been substantial advances in both empirical and first principles models that describe the Earth’s upper atmosphere, ionosphere, magnetosphere, and

solar radiative and particle inputs. Models are now being included in systems-level characterizations of the Sun-Earth environment. These coupled models are the basis for climatological research as well as space weather operations and we outline them here:

Physics-based Thermospheric Models: The *CISM* (*Center for Integrated Space Weather Modelling*) is a consortium of ten US institutions whose vision is to understand the Sun's effects on the solar system, life, and society by developing the first comprehensive community model for space weather. NCAR's *thermosphere-ionosphere-electrodynamic general circulation model* (*TIEGCM*) continues to be updated and used for comparative studies with measurements and other models. The *CTIP, CTIM* and *SUPIM* models are global, three-dimensional, time-dependent, non-linear models for the neutral thermosphere and for the mid- as well as high-latitude ionosphere. The Global Numerical Model describes the mesosphere, thermosphere, ionosphere and inner part of the magnetosphere of the Earth as a single system by means of numerical integration of the time-dependent three-dimensional continuity, momentum and heat balance equations for neutral, ion and electron gases as well as the equation for the electric field potential. The *Global Ionosphere Thermosphere Model* (*GITM*) removes the assumptions of hydrostatic equilibrium, which is present in the other models, and solves on an altitude grid, as opposed to pressure levels. A new initiative to develop a data-assimilative, physics-based neutral atmosphere model (known as *NADIR*) for use by operational communities has been started.

Empirical Thermospheric Models: *NRLMSISE-00* incorporates new *AFCRL* accelerometer data sets and the *CEDAR* Database (Millstone Hill incoherent scatter radar and Arecibo) data sets. *NRLMSIS* will be part of the new COSPAR International Reference Atmosphere (CIRA); JB2006 and JB2008 are modified Jacchia-type models, with improved description of the semi-annual variation and using new solar and geomagnetic activity indices that reduce the uncertainties of previous MSIS and Jacchia-type models by almost 50%. JB2008 will be part of the new COSPAR International Reference Atmosphere (CIRA), which is also the basis for ISO's New Work Item for 'Air Density Models' of the Earth's thermosphere.

Physics-based Ionospheric Models: *GAIM* (one version each by USU and USC/JPL) continues to extend the capabilities of first principles/data assimilation for the ionosphere by assimilating a variety of data types including total electron content (TEC) from ground and space-based GPS receivers, and data from orbiting ultraviolet imagers. The USU *GAIM* model has been implemented operationally by the US.

Empirical Ionospheric Models: The newest version of the International Reference Ionosphere model, IRI-2010, includes auroral boundaries and E-region storm effects based on *TIMED* data from the *Global UltraViolet Imager* (*GUVI*) and the *Sounding of the Atmosphere using Broadband Emission Radiometry* (*SABER*) experiment as well as a new global mapping of F-peak parameters that relies on an ionosonde database that is almost 10 times larger than the one used for its predecessor models.

Plasmasphere Models: These are becoming increasingly important in order to specify the electron densities in the higher altitudes of the ionosphere. They include: *FLIP* that describes the seasonal and solar cycle behaviour of the mid-latitude ionosphere during most quiet periods; La Trobe plasmasphere global electron density model for analysing TEC measurement variability based on GPS data; Sheffield model that provides an understanding, through physics-based modelling, of the complex physical processes of the plasma flows along the magnetic field lines; *GCPM* includes the IRI

electron density below 500-600 km and demonstrates sophisticated dependencies of the plasmasphere on the solar and magnetic indices; *GPID* includes IRI below 500-600 km extended with a theoretical plasmasphere electron density description along the field lines; the *IZMIRAN* empirical plasmasphere model, based on whistler and satellite observations, is smoothly fitted to IRI electron density profile at 1000 km altitude and extends towards the plasmapause (up to 36 000 km); the *IMAGE* plasmaspheric model is based on Radio Plasma Imager (RPI) measurements of the electron density distribution along magnetic field lines.

Solar Irradiance Models: *Solar Irradiance Platform* (*SIP*) has evolved from the *SOLAR2000*, *VUV2002* and *SOLARFLARES* models into a hybrid (empirical, physics-based, and data assimilative) system producing research and operational full solar spectrum irradiances between X-ray and radio wavelengths (1-1 000 000 nm) with up to 1 minute time resolution and 0.1 nm spectral resolution; the *Flare Irradiance Spectral Model* (*FISM*) empirical model estimates 0.1 to 190 nm solar irradiances at 1 nm resolution with a time cadence of 60 s to model irradiance variations due to solar flares; the *Solar Radiation Physical Model* (*SRPM*) has evolved from the *SunRISE* solar synthesis model to create a physics-based solar atmospheric spectral model at high spectral resolution to compute the emergent intensity and irradiance spectrum of IR, VIS, UV and EUV wavelengths; the *HEUVAC* solar EUV flux proxy model is used for calculating upper atmosphere densities and temperatures; *NRLEUV* utilizes differential emission measure distributions derived from spatially- and spectrally-resolved solar observations, full-disk solar images, and a database of atomic physics parameters to calculate the solar EUV irradiance.

3D-MHD Models: Thermosphere/ionosphere disturbances can be generated by solar wind shock waves and coronal mass ejections as a result of dynamic pressure pulses and interplanetary magnetic field polarity and magnitude changes. An ensemble of four physics-based Sun-to-magnetosphere models is being extended to include a three-dimensional MHD model. Complementary to these are the statistical solar wind models developed for precipitating electrons and based on 10 years' worth of NOAA-12 *Space Environment Monitor* (*SEM*) data.

International Programmes

ISWI: The *International Space Weather Initiative* (*ISWI*) is a programme of international cooperation to advance space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, having the intention of communicating the results to the public and students. *ISWI* is a follow-up activity to the successful *IHY* 2007, but focusing exclusively on space weather. The goal of the *ISWI* is to develop the scientific insight necessary to understand the science, and to reconstruct and forecast near-Earth space weather. This includes instrumentation, data analysis, modelling, education, training, and public outreach. The *ISWI* programme is sponsored by NASA, the UN Office for Outer Space Affairs, JAXA, the Bulgarian Academy of Sciences (providing the *ISWI* website), and Kyushu University (providing the *ISWI* newsletter).

CAWSES-II (*Climate and Weather of the Sun-Earth System* – II: 2009-2013) - toward solar maximum: This is an international programme sponsored by SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) established with the aim of significantly enhancing our understanding of the space environment and its impacts on life and society. The main functions of *CAWSES-II* are to help coordinate

international activities in observations, modelling, and applications crucial to achieving this understanding, to involve scientists in both developed and developing countries, and to provide educational opportunities for students of all levels. The CAWSES-II is organized around the following task groups:

1. Task 1: What are the solar influences on the Earth's climate?
2. Task 2: How will geospace respond to an altered climate?
3. Task 3: How does short-term solar variability affect the geospace environment?
4. Task 4: What is the geospace response to variable inputs from the lower atmosphere?
5. Capacity Building
6. Informatics and e-Science

TIGER: The primary objectives of the TIGER Programme are to determine the variable solar EUV/UV and X-ray fluxes, to improve the existing and future thermospheric/ionospheric models and to derive EUV/UV indices or proxies for various applications in space research and space-related fields such as navigation and communication. In 2004, 2006, 2008 and 2010, TIGER symposia were held as sessions of the biennial COSPAR Assemblies to emphasize the unique, but interrelated contributions of solar irradiance effects on the terrestrial thermosphere and ionosphere (T/I). Specific presentations and publications included reports on solar irradiance measurements, reference spectra, models, and proxy developments for thermosphere/ionosphere uses, particularly emphasizing solar products that are compliant with ISO 21348 (Solar Irradiance Standard). Airglow emissions correlate well with T/I parameters such as densities or temperatures, and reports of airglow modelling results, especially from the *TIMED* mission, were included.

ISO TC20/SC14/WG 4 (Space Environment – Natural and Artificial) and ECSS: Space environment standards continue to be produced by *ISO TC20/SC14 Working Group 4*. There are several draft standards or technical specifications currently being processed or recently published and these are: ISO 15390:2004 (Galactic cosmic rays), ISO 21348:2007 (Determining solar irradiances), ISO 15856 (Ionizing radiation tests of materials), TS 16457 (Earth's ionosphere/plasmasphere), and ISO 22009 (Earth's magnetosphere). In addition, new work items are being considered for the orbital debris environment, guidelines and standards for Earth atmosphere densities, geomagnetic and solar activity prediction, radiation belt characteristics, charging of GEO solar array panels, and lunar dust simulants, creation, and transport. Working Group 4 held special sessions at the 2002, 2004, 2006, 2008 and 2010 COSPAR Scientific Assemblies to review standards activities related to the space environment. The ECSS European standards community made a major upgrade to the ECSS 10-04E document on the space environment.

III.3 Planetary Atmospheres and Aeronomy

Venus

In October 2007, ESA's *Venus Express* completed its nominal mission, but continued observations in an extended mission now approved till the end of 2012. *Venus Express* continues and extends the investigations of earlier missions by providing detailed monitoring of processes and phenomena in the atmosphere and near-space environment of Venus. Many observational techniques have been used for the first time at Venus. The data volume returned by *Venus Express* has reached

2 Terabits which exceeds the total data amount delivered by the earlier missions excluding NASA's *Magellan*. Four years of *Venus Express* success has triggered a significant increase of interest and science activity within the planetary community. Coordinated campaigns of ground-based observations to support observations by *Venus Express* have become a regular feature. New experimental data have encouraged the growth of modelling efforts especially in the field of atmospheric dynamics, chemistry and airglow emissions. The *International Space Science Institute* (*ISSI*) initiated a workshop focused on modelling of Venus climate and dynamics with a goal of coordinating modelling efforts and building a bridge to the Earth atmospheric community. The *Venus Express* mission, ground-based campaigns and new modelling efforts have resulted in a rich harvest of scientific publications. Special sections of *Planetary and Space Science* (2006), *Nature* (2007), *Journal Geophysical Research* (2008, 2009), and many stand-alone papers in various journals were published during this reporting period.

In addition to standard observations, *Venus Express* began an atmospheric drag experiment. A gradual and controlled decrease of pericentre altitude permitted the spacecraft to enter denser atmospheric layers. The measurement of dynamical effects enabled the structure of the Venus upper atmosphere in polar regions, never investigated before, to be derived. This experiment can be considered as preparatory to a possible aerobraking campaign with the goal of changing the *Venus Express* orbit.

On 28 June 2010, *Akatsuki* – the first Japanese spacecraft to Venus – was successfully launched. A coordinated campaign of observations with *Venus Express* is planned after the JAXA orbiter arrives at Venus in December 2010.

Mars

A flotilla of spacecraft continues detailed investigations of the red planet. NASA's *Mars Reconnaisance Orbiter* (*MRO*) will soon complete its five-and-a-half year primary mission. The *MRO* payload has returned the richest database thus far of Martian climatological parameters such as temperature, dust and atmospheric water. Together with general circulation modeling, these observations are leading to significant progress in our understanding of the current Martian climate. Surface and sub-surface investigations by *MRO* provide unique data unveiling the geological and climate history of Mars. ESA's *Mars Express* orbiter continues its extended mission. Martian dayglow measurements from *Mars Express* are being used to examine the changing structure of the neutral upper atmosphere. Both *Mars Express* and *MRO* found hydrated silicate minerals indicating that liquid water was ubiquitously present on the Martian surface about four billion years ago thus indicating conditions favourable for life.

In May 2010, the NASA Mars Exploration Rovers *Spirit* and *Opportunity* surpassed the *Viking-1* duration record of operations on the Martian surface. In 2008-2009, the *Phoenix* lander successfully studied the northern polar region, weather and atmospheric dynamics in the Martian Arctic. Future missions to Mars which are being prepared by NASA and ESA (*MSL, EXO-MARS, Mars Trace Gas Orbiter*) will focus on a search for signs of present and palaeo-life on the planet.

Jupiter and its Moons

The planetary community is preparing for the next steps in the exploration of the Jupiter system. The NASA *Juno* spacecraft is scheduled for launch in August 2011. It will perform detailed investigations of the interior and magnetosphere of

Jupiter to unveil the origin and evolution of the giant planet. More ambitious plans for the exploration of the Jupiter system are being developed in the framework of the joint NASA-ESA *Europa Jupiter System Mission* (*EJSM*)/*Laplace* mission. If selected by the agencies, the dual-spacecraft mission will study, in unprecedented detail, the full spectrum of planetary environments, from the giant atmosphere of Jupiter to the tenuous exospheres of its moons.

Saturn and its System

In June 2008, the NASA-ESA *Cassini* mission completed its four-year primary mission and began its Equinox mission running through to September 2010. The spacecraft continues its remote sensing observations of the Titan hydrocarbon world, witnessing seasonal changes such as storms, flooding, changes in the coast lines of lakes, and volcanic activity. The debate continues with regard to the controversial issue of CH_4 escaping from Titan's upper atmosphere: new magnetosphere measurements and upper atmosphere modelling simulations are being examined to constrain the escape rate. The other moon of Saturn, Enceladus, surprised many scientists with its geyser activity that results in shooting plumes of organic material from its interior. The observations at the equinox season, when sunlight shifts from south to north on Saturn, have revealed seasonal changes in temperature, winds and cloud patterns.

III.4 Task Groups for Reference Models of the Atmosphere and Ionosphere

COSPAR Commission C is charged with the responsibility of developing Reference Models of the Atmospheres and Ionospheres of the Earth, planets and their satellites. In order to undertake these activities, Task Groups have been set up that report directly to Commission C. Currently, there are three Task Groups – the International Reference Ionosphere (IRI), COSPAR International Reference Atmosphere (CIRA) and Reference Atmospheres for the Planetary System (RAPS). The COSPAR International Reference Atmosphere (CIRA) and the International Reference Ionosphere (IRI) are joint projects of COSPAR and URSI.

International Reference Ionosphere (Joint COSPAR/ URSI Task Group)

The 2010 version of the International Reference Ionosphere will include a number of significant improvements including new models for the electron and ion densities in the lower ionosphere, auroral boundaries varying with magnetic activity, solar cycle variations of electron temperature, and the impact of precipitating electrons on the auroral E-region densities. Progress towards this goal was made during the COSPAR-2008 IRI sessions in Montréal, the 2009 IRI Workshop in Kagoshima, Japan, and the COSPAR-2010 IRI sessions in Bremen. A special task force activity was started in 2009 that focuses on the production of a Real-Time IRI model through data assimilation and model updating; the first meeting of the task force was held at the US Air Force Academy in Colorado Springs in April 2009. The IRI model is the widely-used standard for ionospheric densities and temperatures and is now also recognized by the International Standardization Organization in its Technical Specification TS 16457. Comparison with IRI is often one of the first tasks of a satellite or rocket science team and helps to identify critical times and regions for follow-on studies and for data evaluation efforts. IRI is the benchmark against which other models are compared, for example in community model evaluations like the recent Electrodynamics Thermosphere Ionosphere (ETI) challenge of the CEDAR community.

COSPAR International Reference Atmospheres (CIRA) Task Group

During the COSPAR Assembly at Warsaw in July 2000, Commission C re-organized the Task Groups concerned with development of future Reference Atmosphere models. Subsequent scientific meetings held during the COSPAR Assemblies in Houston (October 2002), Paris (July 2004), Beijing (2006), Montréal (2008) and Bremen (2010) have been used to present and review the very wide range of new data on minor constituent densities in the middle and upper atmosphere, as well as new empirical models describing atmospheric density, temperature and constituent densities of the atmosphere from ground level to well above the exobase. A further CIRA scientific meeting is planned for the 2012 COSPAR Assembly to be held in India.

During the past four years, significant steps have been made in terms of the preparations for the publication of the new CIRA.

In late 2008, the ECSS-10-04 was published, containing sections describing new recommended standards for the Near-Earth Regions to be used in European aerospace activities. This included a section describing new Standards for the Atmosphere to be used from ground level upward. The CIRA Task Group was instrumental in providing the recommendations incorporated within the new ECSS-10-04 Standards.

Task Group members have also been working actively within the ISO TC20 / SC 14 Working Group 4. A Committee Draft (ISO_WD_14222) for the new ISO Standard for Atmosphere Density above 120 km was submitted for consideration within the ISO Committee Structure in June 2010.

During the 2010 COSPAR Assembly in Bremen, the components of the CIRA-2008 Model were presented and given further consideration during a very successful dedicated scientific meeting. The considerable progress with semi-empirical models for atmospheric density was noted.

The new J-B-2008 model demonstrates that, for the first time in some 30 years, there has been a real improvement in the prediction of thermospheric density, so essential for the understanding of satellite orbit lifetime, decay and the prediction of satellite re-entry. The J-B 2008 model also aids preparation for safe manned flight re-entry manoeuvres. There has been further significant progress with regard to the development of improved indices for solar and geomagnetic parameters as used within the Reference Models. These new indices are far more representative of the real physics associated with heating and energization of the upper atmosphere and ionosphere.

For the period up to 2006-2008, it had been considered that it was perhaps finally becoming possible to consider the prediction of thermospheric density, with moderate accuracy, for epochs in the future. However, the relatively unusual (at least for the space era) behaviour of solar activity during the recent solar minimum has led to new questions about the input of solar and geomagnetic energy to the Earth's atmosphere during periods of very low solar activity. The CIRA Working Group is following closely these and many other relevant issues.

Reference Atmospheres for the Planetary System (RAPS) Task Group

The main aim of the task group is the development of the reference atmospheres of the planets and the satellites. Two planets – Mars and Venus – deserve

special attention.

A model of the Venus Atmosphere (VIRA), published in 1985, includes all data obtained up to this time and encompasses models of the structure of the lower, middle and neutral upper atmosphere, ionosphere, atmospheric composition, circulation, particle matter, solar and thermal radiation in the atmosphere. The updated version of VIRA embracing the thermal structure of the atmosphere and its composition was published in 2006. Now new information, which has appeared in the last few years due to *Venus Express*, necessitates a significant update of VIRA. This stresses that it is essential to plan new missions to Venus, including landers and atmospheric probes, so that significant improvements in models of atmospheric structure and its dynamics can be made. A review of different approaches towards a VIRA update was presented in Bremen in 2010.

The Martian International Reference Atmosphere (MIRA), based mainly on *Viking* data, was published in 1982. Since that time, a series of missions to the surface and in the orbit around Mars gave and continue to give an enormous volume of information on the atmosphere, which may be used to improve the reference atmospheres: seasonal cycles of temperature, clouds, dust, CO_2 and H_2O, and as well as a model of the atmosphere over specially interesting extreme places (over polar regions, volcanoes and low lands). At the 2010 COSPAR Bremen Scientific Assembly, the different sources which have to be used to create a new MIRA model were presented. At COSPAR 2012 in India, it is planned to start the necessary activity for the creation of the new VIRA and MIRA models.

III.5 Theory and Applications of Active Space Experiments

There have been substantial new developments in active space experiments and applications of dusty space plasmas which formed the two primary scientific agenda items of COSPAR Sub-Commission C5/D4 during 2009 and 2010. The wide range of contributions have spanned space and laboratory experiments, advanced computational modelling, and theoretical work.

Significant new experimental discoveries have been made in the area of Stimulated Electromagnetic Emissions (SEEs) from high power high frequency (HF) excitation of the ionosphere. Ground-based experiments in which major advances have been made have been performed at facilities in the US (*HAARP*), Norway (*EISCAT*), and Russia (*SURA*). Several of the key discoveries include the first observations of stimulated Brillouin scatter (involving both ion acoustic and electrostatic ion cyclotron decay) and also ion gyro-harmonic structuring of the SEE spectrum. Also, new experimental techniques have been developed using the variation in decay rates of SEE spectral components to access characteristics of the turbulence generation mechanisms. Important new behaviour in previously investigated frequency-downshifted spectral features has been observed. Progress has also been made in laboratory plasma investigations of SEEs. These new advances in SEE investigations are expected to lead to important new diagnostic methods for space plasmas in the near future as well as expansion of the possibilities for using the ionosphere as a laboratory for non-linear space plasma physics.

There have also been several important advances in the basic understanding of processes associated with heating the ionospheric plasma with high power radio waves. These advances include furthering understanding of the electron heating processes in the D region, new diagnostic techniques using artificial periodic

irregularities (API), creation of striations and trapping of low frequency ion waves during the heating process, ion upwelling, and techniques for estimating electron cooling rates subsequent to heating.

Another major advance in active space experiments is the creation of artificial ionospheric layers using high power HF heating. The first observations of this process were made in the US at the HF Active Auroral Programme (*HAARP*) facility in Gakona, Alaska. The HF-driven ionization process is initiated near the 2nd electron gyroharmonic at 220 km altitude in the ionospheric F region. This new ability to produce significant artificial plasma in the upper atmosphere opens the door to a new regime in ionospheric radiowave propagation where transmitter-produced plasmas dominate over the natural ionospheric plasma and may eventually be employed as active components of communications, radar and other systems.

There have been substantial advances in the applications of dusty space plasmas. Active modification of mesospheric radar echoes with high power HF radio waves is expected to provide a powerful diagnostic for mesospheric dusty plasmas which are believed to have links to global change. Advances have been made in understanding modification of these echoes in a wide range of frequencies from UHF through VHF to HF for the first time. Since the physics of the modification is predicted to change drastically in the frequency ranges, this is ultimately expected to lead to important diagnostic information. The importance of variation in the mesospheric radar echoes between summer and winter months is also becoming a more important topic of investigation as the variation is believed to provide important characterization of the mesospheric dust layer. Further progress has also been made in using incoherent scatter radar spectrum measurements to obtain properties of charged dust particles in the D region.

Several important sounding rocket experiment results have been presented to investigate dusty plasmas in the Earth's ionosphere. The *Charged Aerosol Release Experiment* (*CARE*) launched from the USA created an artificial dusty plasma in the Earth's F region to investigate various turbulence generation mechanisms associated with artificially-charged dust clouds. The *Existence and Charge state Of Meteoric smoke in the middle Atmosphere* (*ECOMA*) project, launched from Norway, provided verification of the existence of meteor smoke throughout the entire mesosphere, the first direct *in situ* measurement of mesospheric ice volume, and new insights into the charging properties of meteoric smoke under the conditions of polar summer. The conclusion of the *ECOMA* campaign, scheduled for December 2010, will focus on the effect of the Geminid meteor shower on the properties of meteor smoke particles in the middle atmosphere.

There has been considerable work investigating the lunar environment, in general, and lunar dust charging, levitation, and transport in the laboratory, in particular, and with computational models. There has also been progress in the development of scientific instruments to analyse properties of lunar dust. The importance of furthering knowledge of the lunar environment will have significant consequences for future exploration activities that utilize radio waves and plasma diagnostics. Modelling of dust levitation and transport on asteroids is becoming a more important area of investigation, and progress is being made. Finally, progress in computational modelling of the formation of planets from charged dust clouds continues to be made.

In summary, the exciting and productive projects reported in the last two years clearly demonstrate that the field of active space experiments is a thriving area of research. There are also ample examples where the field of basic dusty plasma physics are being applied to space research. There will be major upcoming space experiments over the next few years that guarantee these fields will continue to produce important results that impact the space science community. These include upcoming sounding rocket experiments focused on dusty space plasmas which include *CARE II, ECOMA, CHAMPS* (*Charge and Mass of meteoric smoke ParticleS*), and *WADIS* (*Wave Dissipation in the Middle Atmosphere*). There will also continue to be ground-based experimental campaigns at the major ionospheric high power HF facilities – *HAARP, EISCAT* and *SURA*. There is a new high power HF facility that will be opening in Arecibo, Puerto Rico, in late 2010 or early 2011. Its unique mid-latitude location guarantees that it can be expected to make new scientific discoveries in the near future. In general, COSPAR Sub-Commission C5/D4 umbrellas a very healthy research agenda that will continue to provide important advances to the space science community for years to come.

IV. SPACE PLASMAS IN THE SOLAR SYSTEM, INCLUDING PLANETARY MAGNETOSPHERES

This section is devoted to the study of plasmas in the solar system, from the Sun's corona to the outermost regions of the heliosphere where the solar wind meets the local interstellar medium. It also includes the magnetosphere and ionized atmosphere of each of the planets as well as the extended plasma environments of comets. Our knowledge of the physics of plasmas in space comes mainly from *in situ* and remote-sensing measurements made on space probes, but important information has also been obtained from sample return missions, sounding rockets, balloons, and ground-based facilities.

The past couple of years were marked by the late onset of solar activity cycle 24. Although the cycle officially began on 4 January 2008, with the appearance of the first sunspot with reversed magnetic polarity at high latitudes, it was very slow in coming. Solar cycle 24 was a late starter, about three and a half years later than the average of the strong cycles in the late 20th century and almost three years later than the weak cycles of the late 19th century. It was almost as late as solar cycle 5, the first half of the Dalton Minimum. The last few months have seen it ramp up relatively rapidly, but even so it is expected to remain a relatively weak, or mild, cycle. It will reach a peak sunspot number of around 64 in about mid-2013, which is just about half of the average of the previous cycles.

We are fortunate that this unusual solar minimum could be observed with a 'Great Heliospheric Observatory', a fleet of spacecraft designed and operated by the international community to observe comprehensively the entire heliosphere in this unusual state, from the solar corona to the outermost realms where the solar wind plasma meets the interstellar medium, and including the reactions of such obstacles as planetary magnetospheres, asteroids and cometary bodies.

IV.1 Sun's Corona and Heliosphere

Launched on 11 February 2010, NASA's *Solar Dynamics Observatory (SDO)* is the most advanced spacecraft ever designed to study the Sun. During its five-year mission, it will examine the Sun's magnetic field and also provide a better understanding of the role the Sun plays in the Earth's atmospheric chemistry and

climate. Since its launch, engineers have been conducting testing and verification of the spacecraft's components. Now fully operational, *SDO* will provide images with a clarity 10 times better than high-definition television and will return more comprehensive science data faster than any other solar observing spacecraft.

SDO will determine how the Sun's magnetic field is generated, structured and converted into violent solar events such as the turbulent solar wind, solar flares and coronal mass ejections (CMEs). The immense CME clouds, when directed toward Earth, can cause large magnetic storms in our planet's magnetosphere and upper atmosphere. *SDO* will provide critical data that will improve the ability to predict these space weather events that may affect us here on Earth by damaging communication satellites and temporarily knocking out power grids. Space weather has been recognized as a cause of technological problems since the invention of the telegraph in the 19th century. These events produce disturbances in electromagnetic fields on Earth that can induce extreme currents in electrical cables, disrupting power lines and causing widespread blackouts. These solar storms can interfere with communications between ground controllers, satellites and aircraft pilots flying near Earth's poles. Radio noise from storms can also disrupt cell phone service.

SDO is now returning early images that confirm an unprecedented new capability for seeking a better understanding of our Sun's dynamic processes. These solar activities affect everything on Earth. Some of the images from the spacecraft show never-before-seen detail of material streaming outward and away from sunspots. Others show extreme close-ups of activity on the Sun's surface. The spacecraft has also made the first high-resolution measurements of solar flares in a broad range of extreme ultraviolet wavelengths. These initial images show a dynamic Sun at a level which has never been seen in more than 40 years of space-borne solar research. Thus *SDO* will change our understanding of the Sun and its processes that affect our lives and our society. This mission will have a huge impact on science, similar to that of the *Hubble Space Telescope* on modern astrophysics.

Recently, *SDO* has observed a massive eruption on the Sun, one of the biggest in years. A billion tons of magnetized plasma was seen blasting into space while debris from the explosion fell back onto the Sun's surface. Astronomers have seen eruptions like this before, but rarely so large and never in such fluid detail. Blobs of plasma falling back onto the surface of the Sun made bright splashes where they hit. Coronal rain has long been a mystery. It's not surprising that plasma should fall back to the Sun as the Sun's gravitational pull is so powerful. The puzzle of coronal rain is how slowly it seems to fall; the Sun's gravity should be pulling the material down much faster than it actually moves. For the first time, *SDO* provides an answer. What's slowing the descent is that the coronal rain appears to be buoyed by a 'cushion' of hot gas. Previous observatories have been unable to see this cushion, but *SDO* has shown that it is there. One of *SDO*'s game-changing capabilities is temperature sensing. Using an array of ultraviolet telescopes, called the Atmospheric Imaging Assembly (AIA), the observatory is able to remotely measure the temperature of gas in the Sun's atmosphere. Coronal rain turns out to be relatively cool – 'only' 60 000 K. When the rain falls, it is supported, in part, by an underlying cushion of much hotter material, between 1,000,000 and 2,200,000 K.

NASA's *Solar TErrestrial RElations Observatory (STEREO)* is the third mission in its Solar Terrestrial Probes programme (STP). The mission employs two nearly identical space-based observatories – one ahead of Earth in its orbit, the other

trailing behind – to provide the first-ever stereoscopic measurements to study the Sun and the nature of its coronal mass ejections (CMEs). *STEREO*'s scientific objectives are to understand the causes and mechanisms of CME initiation, to characterize the propagation of CMEs through the heliosphere, to discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium, and to improve the determination of the structure of the ambient solar wind.

When a CME erupts from the Sun, movies in extreme ultraviolet light often show enormous waves, spreading over a large area of the solar surface, just as tsunamis travel far from the original seismic event on Earth. *STEREO* data have now been used to show that these waves are the footprints of giant domes that spread upward into the corona as well as outward across the surface. This dome is part of a coronal shock wave, separate from the CME itself, travelling at 280 km s^{-1} along the solar surface, but heading upwards at 650 km s^{-1} (almost 1.5 million miles per hour). This is the first time the full wave front has been seen moving through the corona as well as across the solar surface.

STEREO is also providing information about a controversial phenomenon on the Sun known as the 'solar tsunami'. Years ago, when solar physicists first witnessed a towering wave of hot plasma racing across the Sun's surface, they doubted their senses. The scale of the wave was staggering: it rose up to altitudes greater than the Earth's diameter and rippled out from a central point in a circular pattern millions of km in circumference. Sceptical observers suggested it might be a shadow of some kind – a trick of the satellite's eye – but surely not a real wave. But the twin *STEREO* spacecraft have now confirmed the reality of the 'solar tsunami'. When sunspot region 11012 unexpectedly erupted in February 2009, the blast hurled a billion-tonne CME into space and sent a tsunami racing across the Sun's surface. *STEREO* recorded the wave from two positions separated by 90º, giving researchers an unprecedented view of the event. It was definitely a wave, a giant wave of hot magnetically laced plasma. The technical name is 'fast-mode magnetohydrodynamical wave' (MHD wave). The one *STEREO* observed reared up to a height of about 100,000 km high, raced outward at 250 km s^{-1}, and packed as much energy as 2.4 million megatons of TNT. Solar tsunamis were discovered in 1997 by the *Solar and Heliospheric Observatory* (*SOHO*, see below). In May of that year, a CME erupted from an active region on the Sun's surface, and *SOHO* recorded a tsunami rippling away from the blast site. But *SOHO*'s single point of view was not enough to determine the nature of the event that it had witnessed, neither for that first wave nor for many similar events *SOHO* recorded in years that followed. The question remained open until after the launch of *STEREO*. At the time of the February 2009 eruption, *STEREO-B* was directly over the blast site, while *STEREO-A* was stationed at a right angle: perfect geometry for cracking the mystery. The physical reality of the waves has been further confirmed by movies of the waves crashing into features such as sunspots, and being reflected by them. Solar tsunamis pose no direct threat to the Earth, but they are important to study since they can be used to diagnose conditions on the Sun. By observing how the waves propagate and bounce off things, we can gather information about the Sun's lower atmosphere available in no other way. Solar tsunami can also improve our forecasting of space weather. Like a bull's-eye, they 'mark the spot' where an eruption takes place. Pinpointing the blast site can help us anticipate when a CME or radiation storm will reach Earth.

The Japanese *Hinode* (formerly Solar-B), launched on 22 September 2006, is a highly sophisticated observational satellite equipped with three advanced solar

telescopes. Its solar optical telescope (SOT) has an unprecedented 0.2 arcsec resolution for the observation of plasmas confined to fine-scale solar magnetic fields. It can resolve a feature no bigger than 50 cm if it was trained on the Earth. The X-ray telescope (XRT) has a resolution three times as high as *Yohkoh*, and the extreme-UV imaging spectrometer (EIS) has a sensitivity ten times as high as the equivalent instrument onboard ESA's *SOHO*. These X-ray and EUV telescopes are designed to reveal the heating mechanism and dynamics of the active solar corona. With this suite of telescopes, we can address the following key questions in solar physics: Why does a hot corona exist above the cool atmosphere? What drives explosive events such as solar flares? What creates the Sun's magnetic fields?

Images from *Hinode* have already shed new light about the Sun's magnetic field and the origins of the solar wind. The solar wind is a stream of electrically charged gas that is propelled away from the Sun in all directions at speeds of over 1 million km per hour. The data from *Hinode* show that magnetic waves play a critical role in driving the solar wind into space. Better understanding of the solar wind may lead to more accurate prediction of damaging radiation waves before they reach satellites. How the solar wind is formed and powered has been the subject of debate for decades. Powerful magnetic Alfvén waves in the electrically charged gas near the Sun have always been a leading candidate as a force in the formation of solar wind since Alfvén waves can, in principle, transfer energy from the Sun's surface up through its atmosphere, or corona, into the solar wind. In the solar atmosphere, Alfvén waves are created when convective motions and sound waves push magnetic fields around, or when dynamic processes create electrical currents that allow the magnetic fields to change shape or reconnect. Until now, Alfvén waves have been impossible to observe because of limited resolution of available instruments. Using *Hinode*'s high resolution X-ray telescope, it is now possible to peer low into the corona at the Sun's poles and observe record numbers of X-ray jets. These observations show a clear relationship between magnetic reconnection and Alfvén wave formation in the X-ray jets. The large number of jets, coupled with the high speeds of the outflowing plasma, lends further credence to the idea that X-ray jets are a driving force in the creation of the fast solar wind.

Since its launch in December 1995, the *Solar and Heliospheric Observatory (SOHO)* has been stationed near the first Lagrange point 1.5 million km away from the Earth. The *SOHO* mission, a joint ESA/NASA project, is a space-based observatory, viewing and investigating the Sun from its deep core, through its outer atmosphere – the corona – and the domain of the solar wind, out to a distance ten times beyond the Earth's orbit. Discoveries from *SOHO* include complex currents of gas flowing beneath the visible surface of the Sun, and rapid changes in the pattern of magnetic fields. *SOHO* has produced the largest and most detailed database of solar surface features, as well as becoming, serendipitiously, the most prolific discoverer of comets in the history of astronomy.

After the most profound lull in solar activity for nearly a century, the Sun is finally coming back to life. But will the solar activity return to previous levels? ESA and NASA's venerable solar watchdog *SOHO* is there, watching and measuring, providing unique information about our nearest star. Then, in mid-December 2009, came the perfect Christmas present for solar physicists when the largest group of sunspots to emerge for several years manifested itself on the solar surface. It occurred just as some solar physicists were beginning to wonder if large sunspots would ever return. This last minimum was much deeper and longer than anyone predicted, and

some were even beginning to joke that we had entered another Maunder minimum. The Maunder minimum occurred between 1645 and 1715, when sunspots, the visible markers of solar activity, were largely absent from the Sun. The last two years have been the same, with the Sun presenting a spotless face for more than 70% of the time.

Astronomers are used to seeing the Sun sweep through a cycle of activity that lasts approximately 11 years. But until December 2009, the Sun had seemed reluctant to start up again. However, in mid-January 2010, an even larger sunspot group emerged and, most recently, several big, active areas have been crossing the face of the Sun. Even so it is premature to believe that the Sun is ramping up for another energetic cycle of activity. The strength of the upcoming solar cycle is determined by the strength of magnetism at the poles of the Sun, and this is currently very weak. The polar field provides the magnetic 'seeds' for the next cycle's sunspots by being swallowed down inside the Sun, somehow being rejuvenated and then returned to the surface to appear as the dark blemishes. So, although the Sun is coming back to life, we should not expect that much activity in the new cycle. Historical records show that, until the last few years, the solar cycle has been unusually active. So, rather than a sudden drop in activity, this is more like a return to normality. When *SOHO* was launched almost 15 years ago, understanding the solar cycle was not one of its scientific objectives, but now it is one of the key questions.

As newer spacecraft, such as NASA's *Solar Dynamics Observatory* are launched, *SOHO*'s continued observations will provide essential calibration data for the newer instruments, ensuring that astronomers can compare datasets accurately and with confidence. *SOHO* still has one unique capability: it remains the only spacecraft in line with the Sun that can watch for CMEs heading straight for the Earth, events that can disrupt telecommunications, GPS and power lines.

The *Reuven Ramaty High Energy Solar Spectroscopic Imager* (*RHESSI*) is a NASA Small Explorer that was launched on 5 February 2002. Its primary mission is to explore the basic physics of particle acceleration and explosive energy release in solar flares. *RHESSI*'s views of solar X-ray and gamma-ray emissions are nicely complemented by the tools of radio astronomy. This is because radio waves are emitted by energetic electrons of comparable energies, and because radio telescopes can be extremely sensitive. The radio spectrum is in fact vast – the accessible wavelength range being something like 1 mm to 10 km – and each different band tells us something about a different part of the solar atmosphere. Both hard X-ray and decimetric radiation are emitted during flares, and both are widely believed to originate from non-thermal electrons. One would expect that the two emissions would correlate well with each other, bur they do not in general do so. Contrary to the case of solar cm emissions, caused by incoherent gyro-synchrotron emission, the decimetre waves are emitted by coherent processes. Here 'coherent' means that the emitting electrons have correlated motions, which can make their emissivity much larger than that of that of the same number of independently moving ('incoherent') electrons. Only occasionally do some of these coherent decimetric emissions coincide with the hard X-rays. It appears that the radio emissions and hard X-rays often originate from different populations of accelerated electrons.

RHESSI's spectral resolution allows the separation of thermal and non-thermal emissions. Thus the maximum number of photons originating from non-thermal electrons can be extracted. The distribution of radio delays is relatively symmetric around zero, indicating that the radio emission may either be advanced or delayed

relative to the hard X-rays. In both types of radio emission, the average is about -1 s, but is statistically not different from zero delay. There is a kernel in both radio emissions around zero, and broad wings. This distribution can be interpreted as originating from two populations, i.e, (i) the kernel: radio bursts that originated from the same acceleration process as the hard X-ray emitting electrons; and (ii) the wings: chance coincidences of radio events that occurred during the same flare, but involve electrons accelerated by different processes.

It is concluded that the 'bad guys' in the wings contribute strongly to mean values depending on the cut-off used. This seems to be the reason for discrepant reports in the past about average delays. The population of decimetric pulsations and spikes in the kernels, that are not generally delayed relative to hard X-rays, may yield additional information on the main flare energy release. We cannot go much further in identifying these important electron populations in solar flares without an imaging radio instrument in the pertinent wavelength range. Several new facilities that can contribute in this manner are now in the planning stages.

After 18.6 years in space and defying several earlier expectations of its demise, the joint ESA/NASA solar orbiter *Ulysses* reached its 'end of mission' on 30 June 2009. The final communication pass with a ground station started at 17:35 CEST and ran until the final command was issued to switch the satellite's radio communications into 'monitor only' mode. No further contact with *Ulysses* is planned. The shut-down of the satellite was a joint decision of the two agencies and came a year after the mission was expected to end. A year ago, the satellite's power supply had weakened to the point that it was thought the low temperatures would cause the fuel lines to freeze up, rendering *Ulysses* uncontrollable. This didn't happen immediately and spacecraft controllers realized that they could keep the fuel warm and circulating by performing a short thruster burn every two hours, an ingenious solution that has enabled *Ulysses*' science mission to continue. It was decided to maintain the spacecraft in operation using NASA's 70 m ground station network allocated on a 'spare-capacity' basis. However, as *Ulysses* moved further from the Earth, the communications bit-rate went down while other demands for the 70 m Deep Space Network stations increased. Most importantly, the overall return of scientific data has decreased to a level where it is hard to justify the cost of keeping *Ulysses* in operation.

Ulysses was the first spacecraft to survey the environment in space above and below the poles of the Sun in the four dimensions of space and time. Among many other ground-breaking results, the hugely successful mission showed that the Sun's magnetic field is carried into the solar system in a more complicated manner than previously believed. Particles expelled by the Sun from low latitudes can climb up to high latitudes and *vice versa*, with some high latitude particles even unexpectedly finding their way 'down' to the planets. This is a very important discovery as regions of the Sun not previously considered as possible sources of hazardous particles for astronauts and satellites must now be taken into account and carefully monitored. *Ulysses* has taught us far more than we ever expected about the Sun and the way it interacts with the space surrounding it.

On 28 June 2010, *Voyager 2* completed 12,000 days of continuous operations since its launch on 20 August 1977. For nearly 33 years, the venerable spacecraft has been returning unprecedented data about the giant outer planets, the properties of the solar wind between and beyond the planets and the interaction of the solar wind with

interstellar winds in the heliosheath. Having travelled more than 21 billion km on its winding path through the planets toward interstellar space, the spacecraft is now nearly 14 billion km from the Sun. Travelling at the speed of light, a signal from the ground takes about 12.8 hours to reach the spacecraft. *Voyager 1* reached this milestone on 13 July after having travelled more than 22 billion km and is now more than 17 billion km from the Sun.

Recently, the *Voyager*s even made an interstellar discovery: The solar system is passing through an interstellar cloud that physics says should not exist. Using data from *Voyager*, researchers have discovered a strong magnetic field just outside the solar system. This magnetic field holds the interstellar cloud together and solves the long-standing puzzle of how it can exist at all. The discovery has implications for the future when the solar system will eventually bump into other, similar clouds in our arm of the Milky Way galaxy. Astronomers call the cloud we're running into now the Local Interstellar Cloud ('Local Fluff'). It's about 30 light years wide and contains a wispy mixture of hydrogen and helium atoms at a temperature of 6000º C. The existential mystery of the Local Fluff has to do with its surroundings. About 10 million years ago, a cluster of supernovae exploded nearby, creating a giant bubble of million-degree gas. The Fluff is completely surrounded by this high-pressure supernova exhaust and should be crushed or dispersed by it. The *Voyager*s have now found an answer as to how the Fluff can survive: *Voyager* data show that the Fluff is much more strongly magnetized than anyone had previously suspected – at between 4 and 5 microgauss – and this magnetic field can provide the extra pressure required to resist destruction.

The *Voyager*s are not actually inside the Local Fluff, but they are getting close and can sense what the cloud is like as they approach it. The Fluff is held at bay just beyond the edge of the solar system by the Sun's magnetic field, which is inflated by the solar wind into a magnetic bubble more than 10 billion km wide. This bubble, which is known as the heliosphere, acts as a shield that helps protect the inner solar system from galactic cosmic rays and interstellar clouds. The two *Voyager*s are located in the outermost layer of the heliosphere, or 'heliosheath', where the solar wind is slowed by the pressure of interstellar gas. *Voyager 1* entered the heliosheath in December 2004, and *Voyager 2* followed almost 3 years later in August 2007. The size of the heliosphere is determined by a balance of forces: the solar wind inflates the bubble from the inside while the Local Fluff compresses it from the outside. *Voyager*'s crossings into the heliosheath revealed the approximate size of the heliosphere and, thus, how much pressure the Local Fluff exerts. A portion of that pressure is magnetic and corresponds to the ~5 microgauss mentioned above. The fact that the Fluff is strongly magnetized means that other clouds in the galactic neighborhood could be, too. Eventually, the solar system will run into some of them, and their strong magnetic fields could compress the heliosphere even more than it is compressed now. Additional compression could allow more cosmic rays to reach the inner solar system, possibly affecting the terrestrial climate and the ability of astronauts to travel safely through space. On the other hand, astronauts wouldn't have to travel so far because interstellar space would be closer than ever. These events would play out on time scales of tens to hundreds of thousands of years, which is how long it takes for the solar system to move from one cloud to the next.

One consequence of the deep and prolonged lull in solar activity is an unprecedented bounty of high-energy cosmic rays that stream in from the violent astrophysical events outside the solar system. Data collected by NASA's *Advanced*

Composition Explorer (ACE) spacecraft show that cosmic rays are now as intense as they have ever been since the space age began. When the Sun's activity is at a low ebb, the solar shielding that usually deflects cosmic rays from our neighbourhood recedes, and a long dormancy such as the one at present is accompanied by a large enhancement in radiation. That surge serves as a reminder that the solar system is a dynamic place in constant flux, and raises questions about the amount of shielding necessary to protect astronauts on future missions to the Moon or Mars.

ACE has been in orbit since 1997, near the tail end of the last solar minimum (solar activity waxes and wanes in a cycle that repeats about every 11 years). Most previous solar minima during the space age have looked the same, to within a few percent, as far as cosmic rays go, but in this one they have reached roughly 20% higher than previously recorded levels. Cosmic rays, often made of atomic nuclei that have been stripped of their electrons, zoom across the galaxy at nearly the speed of light. They are thought to originate in bulk from supernovae – stellar explosions. Rarer species of cosmic ray particles include electrons and their antimatter counterparts, positrons. For the most part, life on Earth is shielded from harm by the planet's atmosphere and magnetosphere, but even so, cosmic rays pack such a punch that they have been implicated in introducing errors in computer memories. Some researchers have even proposed that the energetic particles striking the atmosphere are responsible for initiating lightning.

Outside Earth's protective shielding, space travellers would be seriously threatened by cosmic rays, without proper safeguards, the development of which has been deemed by some as a possibly insurmountable obstacle to interplanetary travel. The recent enhanced cosmic-ray bombardment coincides with a number of solar-minimum phenomena. Among them: the weakening of the Sun's magnetic field as well as the diminished pressure and speed of the solar wind. The solar wind is 'what blows the bubble in the heliosphere that protects us from the interstellar medium'. As the pressure from the solar wind has been low for the last few years, the bubble is accordingly becoming smaller. The bad news for future space travellers is that the recent peak in the intensity of cosmic rays may not even be that unique. On longer timescales, measurements in the polar ice of a heavy ion of beryllium, produced in the atmosphere when cosmic rays strike, show that the space age may have simply begun during an anomalous span for solar activity and cosmic radiation. The record over the last 1,000 years shows that cosmic rays were actually on average much higher than they have been during the 50 years for which we have direct measurements. Perhaps what we are observing now is something that's more normal, and the space era has occurred when there was more solar activity and, consequently, a lower influx of cosmic rays.

The objective of the *Interstellar Boundary Explorer (IBEX)* mission is to discover the nature of the interactions between the solar wind and the interstellar medium at the edge of the solar system. Roughly the size of a card table, the *Interstellar Boundary Explorer* is the latest in NASA's series of low-cost, rapidly-developed small Explorer spacecraft. *IBEX* was launched on 19 October 2008. The *IBEX* spacecraft has made it possible to construct the first comprehensive sky map of our solar system and its location within the Milky Way galaxy. The new view will change the way researchers view and study the interaction between our galaxy and the Sun. The sky map was produced with data that two detectors on the spacecraft collected during six months of observations. These detectors measured and counted energetic neutral atoms which are created in an area of our solar system known as the

interstellar boundary region, a region that emits no light that can be collected by conventional telescopes. This region is where charged particles from the Sun, the solar wind, flow outward far beyond the orbits of the planets and collide with material between stars. The energetic neutral atoms travel inward toward the Sun from interstellar space at velocities ranging from 160,000 km per hr to more than 6.6 million km per hr. The new map reveals the region that separates the nearest reaches of our galaxy, called the local interstellar medium, from our heliosphere – a protective bubble that shields and protects our solar system from most of the dangerous cosmic radiation travelling through space. The *IBEX* results are truly remarkable, with a narrow ribbon of bright details or emissions not resembling any of the current theoretical models of this region.

First, researchers were mystified by the giant ribbon at the edge of the solar system, called it a 'shocking result' and puzzled over its origin. Now the mystery may have been solved; it may be the result of a reflection process. It is where solar wind particles heading out into interstellar space are reflected back into the solar system by a galactic magnetic field. This is an important finding because interstellar space just beyond the edge of the solar system is mostly unexplored territory. We now know there could be a strong, well-organized magnetic field sitting right on our doorstep.

The *IBEX* data fit in nicely with recent results from *Voyager* that also have sensed strong magnetism nearby, as mentioned above. While *Voyager* measurements are relatively local to the spacecraft, the data from *IBEX* fill in the 'big picture'. The ribbon that *IBEX* has perceived is vast and stretches almost all the way across the sky, suggesting that the magnetic field behind it must be equally vast. To be sure, the postulated reflection process is a bit complicated, involving multiple 'charge exchange' reactions between protons and hydrogen atoms. The upshot, however, is simple. Particles from the solar wind that escape the solar system are met at a distance of ~100 astronomical units (~15 billion km) by an interstellar magnetic field. Magnetic forces intercept the escaping particles and reflect them back. If this mechanism is correct – and not everyone agrees – the shape of the ribbon is telling us a lot about the orientation of the magnetic field in our corner of the Milky Way galaxy.

IV.2 Solar-Terrestrial Connection and Earth Magnetosphere

Since the 1980s, the collaborative efforts by NASA, ESA, and the Institute of Space and Astronautical Science (ISAS) of Japan have led to the conception of the International Solar-Terrestrial Physics Science Initiative consisting of a set of solar-terrestrial missions to be carried out during the 1990s and into the 21st century. The primary science objectives of the ISTP Science Initiative are: to determine the structure and dynamics of the solar interior and their role in driving solar activity; to identify the processes responsible for heating the solar corona and its acceleration outward as the solar wind; to determine the flow of mass, momentum and energy through geospace; to gain a better understanding of the turbulent plasma phenomena that mediate the flow of energy through geospace; to implement a systematic approach to the development of the first global solar-terrestrial model, which will lead to a better understanding of the chain of cause-effect relationships that begins with solar activity and ends with the deposition of energy in the upper atmosphere. The ISTP Science Initiative uses simultaneous and closely coordinated measurements from *GEOTAIL*, *WIND*, *Polar*, *SOHO* and *Cluster*. These measurements of the key regions of geospace are supplemented by data from equatorial missions such as the

Geosynchronous Operational Environmental Spacecraft (*GOES*), and ground-based investigations.

Cluster is a constellation of four spacecraft flying in formation around Earth. They relay the most detailed information ever about how the solar wind affects our planet in three dimensions. The solar wind can damage communications satellites and power stations on Earth. The original operational life-time of the *Cluster* mission ran from February 2001 to December 2005. However, in February 2005, ESA approved a mission extension from December 2005 to December 2009, and recently yet another extension to 2012. The four *Cluster* spacecraft have now spent more than a decade passing in and out of the Earth's magnetic field. Their mission will be to complete the most detailed investigation ever made into the ways in which the Sun and Earth interact.

One of the best-known phenomena studied by *Cluster* is the aurora: red and green curtains of light that illuminate the upper atmosphere during long polar nights. Less well known is the 'black aurora', dark regions that punctuate the colourful northern and southern lights. *Cluster* discovered that the dark patches correspond to 'holes' in the ionosphere that grow in size as more and more electrons shoot upwards into space. This is the opposite to the process during a normal aurora, where electrons spiral down into the atmosphere and collide with ionospheric particles. *Cluster* found that all available electrons are 'sucked' out of the ionosphere within a few minutes. After that the black aurora disappears.

Cluster was also able to make a key discovery about 'killer electrons', high-energy particles trapped in the outer Van Allen radiation belt. These particles move close to the speed of light and carry enough energy to penetrate satellite shielding and cause electrical shorts that can seriously damage vital components. The breakthrough came when a particularly strong solar shock wave hit the magnetosphere in 2004. Over a period of 15 minutes, the *Cluster* spacecraft detected the transition from normal electron intensities to 'killer electrons' levels. In the first stage of the process, electrons were accelerated by the shock wave compressing the Earth's magnetic field. Then the magnetic lines wobbled, creating something like a very large-scale, low frequency laser, which further accelerated the electrons until they reached 'killer' energies.

One of *Cluster*'s main tasks has been to monitor closely the conditions within Earth's magnetosphere, the invisible magnetic bubble, which usually protects the planet from the particles arriving in the solar wind. A key process that takes place in the magnetosphere is 'magnetic reconnection', which occurs when the energy stored in magnetic fields is released explosively. Understanding magnetic reconnection is a major quest in physics, since it plays a key role in numerous phenomena, such as star formation and solar flares, as well as in experimental fusion reactors for electricity generation. *Cluster* data led to the first 3-D picture of what happens at the heart of the process – the magnetic 'null' point. The new insights showed that the magnetic field can be twisted into 500 km-wide tubes.

Another breakthrough came when the *Cluster* quartet and the Chinese/ESA *Double Star* spacecraft were flying inside the magnetosphere at a time when its long, tapering tail was quivering. Detailed measurements by the satellites revealed that huge waves, more than 30,000 km across, were moving outward f*rom* the centre of the magnetotail, rather like the wake created by a boat sailing across a lake. This suggested that the oscillations are generated within the tail, rather than imposed on it

from outside by a gusty solar wind. Because of the geometrical arrangement of the satellites at the time, the oscillations were detected closer to Earth than ever before – only 70,000 km away. At such proximity, the oscillations probably sent particles into the atmosphere, sparking colourful aurorae.

NASA's *Time History of Events and Macroscale Interactions during Substorms (THEMIS)* was successfully launched on 17 February 2007. The mission aims to resolve one of the oldest mysteries in space physics, namely to determine what physical process in near-Earth space initiates the violent eruptions of the aurora that occur during substorms in the Earth's magnetosphere. THEMIS is a two-year mission consisting of five identical probes that will study the violent, colourful eruptions of auroras.

The spacecraft has made three important discoveries about spectacular eruptions of the Northern Lights called 'substorms' and the source of their power. The mission has observed the dynamics of a rapidly developing substorm, confirmed the existence of giant magnetic ropes and witnessed small explosions in the outskirts of the Earth's magnetic field. The discoveries began when a substorm erupted over Alaska and Canada, producing vivid aurorae for more than two hours. A network of ground cameras organized to support *THEMIS* photographed the display from below while the satellites measured particles and fields from above. The substorm behaved quite unexpectedly; the aurorae surged westward twice as fast as anyone thought possible, crossing 15º of longitude in less than one minute. The storm traversed an entire polar time zone (400 miles) in 60 seconds flat. Photographs taken by ground cameras and NASA's *Polar* satellite (also supporting the *THEMIS* mission) revealed a series of staccato outbursts each lasting about 10 minutes. Some of the bursts died out while others reinforced each other and went on to become major onsets. The substorm's total energy over the two-hour event was estimated at five hundred thousand billion Joules: that's equivalent to the energy of one magnitude 5.5 earthquake.

THEMIS may have found an answer to the question - where does all that energy come from? The satellites found evidence of magnetic ropes connecting the Earth's upper atmosphere directly to the Sun, with solar wind particles flowing in along these ropes, providing energy for geomagnetic storms and aurorae. A magnetic rope is a twisted bundle of magnetic fields organized much like the twisted hemp of a mariner's rope. Spacecraft have detected hints of these ropes before, but a single spacecraft was insufficient to map their 3D structure. However, the five identical micro-satellites making up the *THEMIS* constellation made this possible. *THEMIS* encountered its first magnetic rope about 70,000 km above the Earth's surface in a region called the magnetopause; it was very large – about as wide as Earth. There, the rope formed and unraveled in just a few minutes, providing a brief but significant conduit for solar wind energy.

IV.3 Space Plasma Missions under Development

A candidate for a new NASA mission is *Solar Probe Plus*, an extraordinary and historic mission, intended to explore what is arguably the last region of the solar system to be visited by a spacecraft: the Sun's outer atmosphere or corona as it extends out into space. *Solar Probe Plus* will repeatedly sample the near-Sun environment, revolutionizing our knowledge and understanding of coronal heating and of the origin and evolution of the solar wind and answering critical questions in

heliophysics that have been ranked as top priorities for decades. Moreover, by making direct, *in situ* measurements of the region where some of the most hazardous solar energetic particles are energized, *Solar Probe Plus* will make a fundamental contribution to our ability to characterize and forecast the radiation environment in which future space explorers will work and live.

We now know more about the corona and the solar wind than ever before. And yet there remain two fundamental unanswered questions, raised in the 1940s by the discovery of the corona's million-degree temperature and in the early 1960s by the proof of the supersonic solar wind's existence: Why is the solar corona so much hotter than the photosphere, and, how is the solar wind accelerated? The answers to these questions can be obtained only through *in situ* measurements of the solar wind down in the corona. A mission to provide these measurements, to probe the near-Sun particles-and-fields environment, was first recommended in 1958, at the dawn of the space age, and might now become reality.

Quite complementary to *Solar Probe Plus* is an ESA mission candidate called *Solar Orbiter* which is intended to brave the fierce heat radiated by the Sun and carry its telescopes to just one-fifth of the Earth's distance from the Sun, where sunlight will be twenty-five times more intense than we feel it. The spacecraft must also endure powerful bursts of atomic particles from explosions in the solar atmosphere. But the reward will be images significantly sharper than the best available today. The pictures of the weird solar landscapes, where glowing gas dances and forms loops in the strong magnetic field, will be stunning. They will show details down to 100 km wide, which can be compared with the width of the Sun's visible disc, 1.4 million km. After launch, *Solar Orbiter* will manoeuvre into an orbit around the Sun, and perform a close approach every five months. Around closest approach, when travelling at its fastest, *Solar Orbiter* will remain roughly positioned over the same region of the solar atmosphere as the Sun rotates on its axis. Just as geostationary weather and telecommunications satellites are stationed over particular spots on the Earth's surface, so the spacecraft will seem to 'hover' for a while over the Sun. *Solar Orbiter* will therefore be able to watch storms building up in the atmosphere over several days. *Solar Orbiter* will exploit new technologies being developed by ESA for the BepiColombo mission to Mercury, the closest planet to the Sun. These include heat-proofing for all the equipment and instruments and the communications system. Over extended periods *Solar Orbiter* will deliver images and data of the polar regions and the side of the Sun not visible from Earth.

V. RESEARCH IN ASTROPHYSICS FROM SPACE

V.1 Astronomy

The use of space techniques continues to play a key role in the advance of astrophysics by providing access to the entire electromagnetic spectrum from the radio to gamma rays. The increasing size and complexity of large space-based observatory missions places a growing emphasis on international collaboration. This is particularly marked by the increasing range of joint missions involving the large space agencies in Europe (ESA), Japan (JAXA), the Russian Federation (RKA) and the United States (NASA). A major future contribution is foreseen for the Chinese and Indian space agencies.

It is important that the world's space agencies coordinate their mission plans for both large and smaller scale enterprises. The coordination of existing and future

datasets from space-based and ground-based observatories is an emerging mode of powerful and relatively inexpensive collaboration to address problems that can only be tackled by the application of large multi-wavelength datasets.

As in previous reports, an updated overview of world-wide space programmes in astronomy and astrophysics is summarized in Tables 1 and 2. The tables list the missions which are operating in space or have continuing data analysis efforts, and those which are approved and either awaiting a start or already under construction. Tables 1 and 2 include:

- The main responsible agency or nation;
- Launch dates (actual or scheduled)
- A brief description of the main characteristics of the mission

Comments on the content of the tables and on the situation in each of the principal spectral regions are given below.

X-rays and Gamma rays

The NASA *Rossi-XTE* mission (high resolution timing studies of X-ray sources over the 1-200 keV range) continues to operate successfully producing key findings on variable, pulsed and quasi-periodic sources. The world-wide gamma-ray burst and transient monitoring capability is in excellent shape with the continued operation of the *Swift* mission. Bursts have been detected from the early universe at redshifts in the range of the most distant objects known.

NASA's *Chandra* observatory and ESA's *X-ray Multi-mirror Mission (XMM/Newton)* have been operating successfully in space since 1999. With their complementary emphasis on high angular resolution and high throughput spectroscopy, these observatory missions continue to generate major advances in astrophysics. The two missions have been particularly effective in studying distant galaxies, including galactic mergers, the massive black holes at their centres, and the billion-degree gas that permeates the medium in clusters of galaxies. Japan's *Suzaku* X-ray mission, launched in 2005, has X-ray and hard X-ray telescopes that are producing high-quality broad-band observations of accreting and jetted sources. Japan's *MAXI* experiment was installed on the *ISS* in 2009 and is successfully performing full-sky monitoring of the X-ray sky

At the relatively low gamma-ray energies associated with nuclear spectral lines, ESA's *Integral* (*International Gamma Ray Astrophysics Laboratory*) observatory, launched in 2002, is now supplying the world gamma-ray astronomy community with an important imaging and spectroscopic capability. At the higher energies that will facilitate investigation of the highest energy processes in the universe, Italy's *AGILE* (*Astro-rivelatore Gamma a Immagini Leggero*) was launched in 2007 and the major *Fermi Gamma-ray Space Telescope* developed by NASA and the US Department of Energy together with universities and agencies in France, Germany, Italy, Japan and Sweden, was launched in 2008. Both spacecraft are generating discoveries every month.

The Indian *ASTROSAT* mission is an X-ray and multiwavelength satellite in development for launch in 2011. The *Nuclear Spectroscopic Telescope Array* (*NuSTAR*) is a hard X-ray mission with a focusing capability. It is a NASA *SMEX* in development for a launch in 2012. The *Space-based multi-band astronomical Variable Objects Monitor* (*SVOM*) mission is a gamma-ray bursts mission in development in

China and France for a launch in 2015. *ASTRO-H* is a joint JAXA/NASA mission designed to perform high-resolution spectroscopy of X-ray sources that is in development for launch in 2013. Last year, the *Gravity and Extreme Magnetism SMEX* (*GEMS)* was selected in NASA Explorer programme for X-ray polarization measurements and is in development for launch in 2014. *Spectrum RG* is a RKA X-ray observatory with Russian and German X-ray instruments for launch in 2014. The large *International X-ray Observatory* (*IXO)*, involving NASA, ESA and JAXA, is currently being studied, as being the large X-ray facility to follow *XMM-Newton*, *Chandra* and *Suzaku*.

UV/Extreme UV and Visible

The *Hubble Space Telescope* (*HST*) continues to operate successfully producing spectacular images. In 2009, the fourth servicing mission replaced key sub-systems. In addition, two new instruments were installed (*COS* and *WFC3*) and two instruments were repaired (*STIS* and *ACS*). NASA's *GALEX* (*Galaxy Evolution Explorer*), is conducting the first deep all-sky survey in the ultraviolet, and has detected more than one million hot stars and galactic cores since being launched in 2003.

Infrared

NASA's *Spitzer* Observatory has ended its cryogenic phase, and is currently still operational at short infrared wavelengths. With its high sensitivity, *Spitzer* has detected tens of millions of infrared sources, and its data for many years to come will serve as the reference for statistical studies on topics ranging from newly formed stars, debris disks around mature stars, the interstellar medium of our galaxy to star-forming galaxies in the deepest reaches of the universe. An unanticipated highlight has been the characterization of the atmospheres of exoplanets.

ESA's *Herschel* mission was successfully launched (with *Planck*) in 2009. With a primary mirror diameter of 3.5 m, it has opened up, for the first time, the far-IR and sub-mm windows of the electromagnetic spectrum to astronomical observations with high sensitivity and angular resolution. Deep surveys have yielded a quantum jump in the detection of high-redshift galaxies. Galactic surveys have revealed the filamentary nature of the cold interstellar medium and now enable statistically relevant studies of the first phases leading to star formation. Spectroscopic surveys have disclosed the richness of the molecular spectra of interstellar and circumstellar media.

JAXA's *AKARI* satellite has finalized its all-sky IR survey in six bands from 9 to 160 μm and performed pointed observations of a wide variety of astronomical sources. A more sensitive all-sky IR survey in the 3-25 μm range is being performed by the *WISE* NASA *SMEX* mission launched in 2009. First scientific light was achieved with the NASA-DLR *SOFIA* stratospheric observatory for far-IR astronomy in 2010. NASA and ESA are developing the *HST* successor mission with extended near-IR capability, called the *James Webb Space Telescope* (*JWST)*. The expected launch date is in 2014 or 2015.

Sub-Millimetre

NASA's *Wilkinson Microwave Anisotropy Probe* (*WMAP*) Explorer mission has reported the spectacular results of its sky survey. While pinning down the age of the universe to approximately 1%, these results also offer powerful confirmation of all the measurable predictions of the 'hot big bang with inflation' history of the early

universe. An added surprise of these first *WMAP* results is the apparent evidence for the appearance of the first stars earlier than was expected from the standard model of galaxy formation.

ESA *Planck* mission is a precision cosmology satellite launch (with *Herschel*) in 2009. It follows on *WMAP* to make comprehensive observations of the cosmic microwave background.

Sweden's *Odin* mission, launched in February 2001 into a Sun-synchronous 600 km orbit, was designed to study the interstellar medium and the Earth's atmosphere at mm and sub-mm wavelengths. The mission continues to operate successfully.

Radio

Halca (formerly *VSOP*), launched by Japan's ISAS in 1997, has produced maps with a resolution of 0.3 milli-arc seconds at an operating frequency of 5 GHz. The mission ended in 2005.

Complementary Research

Gravitational wave astronomy continues to grow in importance. The *LISA* mission is being studied by ESA and NASA. Both agencies are working on technology development, and ESA currently plans to launch its *LISA Pathfinder* technology demonstration mission in 2012.

Table 1. Missions in Operation/Data Analysis Phase

Year	Radio	sub-	*IR*	visible/U	EUV/X-ray	hard X-ray/gamma
1990				*HST*		
1996						*Rossi-XTE*
1997	*Halca*					
1999					*Chandra*	
					XMM-Newton	
2000						
2001		*Odin*				
		WMAP				
2002						*Intearal*
2003			*Spitzer*	*GALEX*		
2004				←	*Swift*	→
2005					*Suzaku*	→
2006			*Akari*			
2007						*AGILE*
2008						*Fermi (GLAST)*
2009		*Planck*	*WISE*	*HST-SM4*		*MAXI*
			Herschel			
2010						

HST	(NASA/ESA) Observatory mission with 2.4 m telescope for imaging and spectroscopy of galactic and extragalactic sources.
FUSE	(NASA) Deuterium abundance studies. PI mission with GI (guest observer) programme.
XMM/Newton	(ESA) Observatory mission. High throughput spectroscopy and imaging in the soft X-ray
Rossi XTE	range.
200	(NASA) Temporal studies and broadband spectroscopy of compact X-ray sources (1- keV). PI mission with GI programme.
Halca	(Japan) Observatory mission with 10 m antenna for orbiting VLBI imaging 1.3, 6, 18 cm.
Odin	(Sweden/Finland/Canada/France) 1.1 m telescope for mm (119 GHz) and sub-mm

(420-580 GHz). Interstellar chemistry and atmospheric ozone.
WMAP (NASA) Explorer to study anisotropy in the cosmic microwave background radiation.
Integral (ESA) Imaging and spectroscopy from 20 keV to 10 MeV.
GALEX (NASA) Galactic Evolution Explorer. UV all-sky survey mission.
Spitzer (NASA) Observatory mission. Space Infrared Telescope Facility. IR telescope of 0.85 m aperture.
Swift (NASA/UK/Italy) Medium Explorer. Gamma-ray burst detection with X-ray and optical telescopes for rapid follow-up.
Suzaku (Japan/NASA) X-ray and hard X-ray telescopes.
Akari (ISAS) Second generation IR all-sky survey with 0.7 m cooled telescope. Previously called Astro-F.
AGILE (ASI) high energy gamma-ray mission.
Fermi (NASA/DOE/France/Germany/Italy/Japan/Sweden) Gamma-ray space telescope with γ-ray burst monitor. Formerly called GLAST.
Planck (ESA) Medium-size mission to study the spectrum and anisotropy of the diffuse cosmic microwave background radiation relic of the 'Big Bang'. Launched on 14 May 2009 together with Herschel to L2.
Herschel (ESA) Observatory mission, launched with Planck with 3 m warm Cassegrain telescope for high throughput heterodyne and far IR spectroscopy and imaging.
MAXI JAXA experiment on ISS for X-ray sky monitoring and survey.

Table 2. Approved Projects

gravity waves	sub-mm	IR	visible/UV	EUV/X-ray	hard X-ray/gamma ray
LISA Pathfinder		*JWST* *SOFIA*		*Spectrum RG*	*NuSTAR,* *ASTROSAT* *SVOM* *ASTRO-H* *GEMS*

ASTROSAT (India) X-ray observatory.
LISA Pathfinder (ESA) Technology test mission for future Laser Interferometer Space Antenna mission.
JWST (ESA/NASA/CSA) Major international IR telescope.
SOFIA (NASA/DLR) IR telescope flown in a modified Boeing 747 airplane.
SVOM (China/France) Gamma-ray bursts mission.
NuSTAR (NASA) SMEX mission for hard X-rays with a focusing telescope.
GEMS (NASA) SMEX X-ray polarization mission.
Astro-H (JAXA/NASA) X-ray mission for high resolution spectroscopy and hard X-rays.
ASTROSAT Indian mission for X-ray astronomy.
Spectrum RG (RKA) Mission for X-ray astronomy with Russian and German telescopes.

Conclusions

Astronomy from space is a model for international scientific cooperation. Most missions have some international hardware collaboration, and virtually all feature extensive data sharing. International astronomical databases now include ground-based as well as space-based archival data in standard formats, so that astronomers anywhere in the world can access all results after brief proprietorial periods, and can perform extensive multi-wavelength investigations of large data samples from their desktops.

V.2 Solar and Heliospheric Physics

The Sun is a relatively ordinary star by cosmic standards, but its proximity offers us a unique astronomical laboratory. Because of the high temperatures reached in the upper chromosphere and corona, the solar atmosphere is best observed at shorter wavelengths: ultraviolet (UV), extreme ultraviolet (EUV), X-ray and gamma ray. Work at these wavelengths must be undertaken from space since the radiation cannot penetrate the atmosphere of the Earth. Even at visible and infrared wavelengths, observations from space eliminate the distorting effects of the Earth's atmosphere. This allows imaging of fine structures on the Sun's surface (photosphere) at size scales of approximately 100 km and, possibly, below this eventually. Also visible-light observations of the outer corona, say several solar radii above the Sun's surface, are only made possible with spacecraft-borne coronagraphs thanks to the absence of scattered light from the Earth's atmosphere.

At the present time, we are enjoying a 'golden age' in solar physics from space; a fleet of advanced solar observatories, namely the *Solar and Heliospheric Observatory* (*SOHO*), the *Reuven Ramaty High Energy Solar Spectroscopic Imager* (*RHESSI*), *Hinode* ('Sunrise'; formerly Solar-B), the *Solar TErrestrial RElations Observatory (STEREO*), *Sun Watcher with APS Detector and Processing (SWAP),* and the *Solar Dynamics Observatory (SDO)* are all currently in space, observing the behaviour of the Sun in unprecedented detail.

The 'Living With a Star (LWS)' project was initiated by NASA in 2001 and has evolved into the 'International Living With a Star (ILWS) programme. This includes *SDO* launched on 11 February 2010. A set of four *Solar Sentinel* spacecraft are being studied to be placed on the far side of the Sun and in the inner heliosphere to work with *SDO* on studies of CMEs and other disturbances passing through the interplanetary medium with special reference to those that are directed towards the Earth.

Understanding the outer layers of the solar atmosphere and the transfer of energy to these regions from the interior represents a major intellectual challenge that is of substantial cultural significance. It also has a huge potential impact both on our economies and, through the Sun's influence on climate, our quality of life on Earth. Thus, work in solar physics needs to be undertaken on a world-wide basis. The requirement for simultaneous ground-based observations at optical, infrared and radio wavelengths must also be fulfilled and can be achieved gradually by the construction and commissioning of several facilities in countries that do not possess directly the appropriate infrastructure for implementing space-based observations. However, many nations do work with space data and make an immensely valuable contribution to the subject given the increasingly open access to these datasets that is currently possible. This emphasis on coordination is one of the key elements in most of the major programmes for solar physics. Furthermore, from lengthy experience in solar observing and the need for collaboration with colleagues in many countries, the solar physics community has a long and successful history of international collaboration, which is fully exploited in planning space missions.

Currently Operating Solar Programmes

Current solar programmes are directed at three broad areas of solar-terrestrial science:

(1) The solar interior;
(2) The solar atmosphere;
(3) The influence of the solar wind and of large solar events such as CMEs and solar flares on the Earth and the interplanetary medium.

Work continues using the imaging telescopes, spectrometers, and coronagraphs on *SOHO*, *TRACE*, and other spacecraft. These instruments address a broad range of scientific questions concerning the Sun's magnetic activity cycle, solar flares, the nature of the inner and extended corona, CMEs, and the acceleration of the solar wind.

SOHO, a joint ESA-NASA mission, is one of the most ambitious solar physics missions so far deployed. The spacecraft was launched in December 1995 and has been observing the Sun and the heliosphere for fifteen years from the Lagrangian point, L1, between the Earth and the Sun. From this vantage point, 1.5 million km in front of the Earth, *SOHO* observes the Sun continuously without day/night cycles and without serious effects from the orbital motion inevitably experienced in low Earth orbiting missions. L1 also lies outside range of the geocorona's ultraviolet emission. Consequently, *SOHO* has an unprecedentedly clear view of solar phenomena and is able to detect solar oscillations and solar UV emission with minimum noise. *SOHO*'s scientific payload consists of 12 instruments, including six built by ESA member countries in collaboration with groups in the USA. These instruments study the Sun, from the solar interior using helioseismology, to the outer atmosphere by remote sensing in the visible and the ultraviolet. The solar wind is simultaneously probed by *in situ* measurements. One instrument also observes hydrogen Lyman-α emissions from the interplanetary medium to monitor the mass flow of the solar wind. The ESA-NASA cooperation on *SOHO* includes the staffing of a common operations centre at the NASA/Goddard Space Flight Center for day-to-day operational decisions and collaborative research.

SOHO is successfully probing the interior of the Sun. It does so with several instruments observing the solar surface oscillations that can be detected almost completely free of orbital noise. The measurements are of small periodic variations in emission intensity or in surface velocity. The detection of short-range oscillations due to sound waves has already revealed gas motions occurring just below the solar surface as well as solar rotation in and below the convection zone to be traced. Rotation has been found to be less dependent on latitude than on the solar surface.

The surface of the Sun turns out to be highly dynamic even in periods of low solar activity, with the continuous emergence and cancellation of magnetic fields, as shown by the high-resolution telescopes observing the solar disk and the inner corona. A new class of phenomena ('blinkers') has been identified, which along with other new variable phenomena, may provide an important input to the problem of heating the solar atmosphere. These telescopes can locate the onset of CMEs near the solar surface, and identify the large global disturbances caused by flare. The disturbances are in the form of waves propagating from the site where the flare occurs throughout the entire solar atmosphere.

The white light and UV coronagraphs on *SOHO* are continuing to provide dramatic images of CMEs, during the course of which the Sun releases large amounts of hot material into the heliosphere. It has been found that the mass input in the solar wind during mass ejections is much greater than expected as is the frequency of these phenomena. CMEs disturb the entire solar system, can affect the Earth's own space environment, and can have devastating effects on telecommunication satellites.

The fast and slow solar wind flows in the outer solar atmosphere have been mapped by *SOHO* for the first time thereby making it possible to relate the flows to the topology of the solar magnetic fields. The solar wind acceleration has now been traced back to a few solar radii from the solar surface and has been shown to be much more effective at the solar poles and in other regions where magnetic fields are open. Here the solar wind speed reaches 800 km s^{-1} at about three solar radii out from the solar surface. Acceleration is less effective near the solar equator where closed magnetic field lines underlie the streamers, which are probably the source of the slow solar wind.

The *Transition Region and Coronal Explorer* (*TRACE*), a NASA Small Explorer mission, was launched in April 1998 into a Sun-synchronous polar orbit to allow eight months of continuous solar observation without satellite nights. It has been a very successful mission. Its operations were terminated in June 2010 following the successful launch and commissioning of *SDO*.

The *Reuven Ramaty High Energy Solar Spectroscopic Imager* (*RHESSI*) mission, one of NASA's Programme for Small Explorers, is an advanced hard X-ray imager of the rotating modulation collimator type for flare observations. Equipped with cooled germanium detectors, *RHESSI* provides hard X- and gamma-ray images of solar flares with unprecedentedly high spatial and non-dispersive energy resolution over the energy range from 3 keV to 10 MeV. From just after its successful launch on 5 February 2002, the *RHESSI* satellite has provided and continues to provide numerous new results on electron and ion acceleration in solar flares. *RHESSI*, like most solar missions, is an open mission; all data and related analysis software are freely available to the entire solar physics community.

As a successor to the highly successful *Yohkoh* mission, JAXA launched the *Hinode* spacecraft on 22 September 2006. The mission involves collaboration with solar groups in the USA and UK, supported, respectively, by NASA and PPARC (now the UK Space Agency). The payload includes an optical telescope capable of producing photospheric images with a spatial resolution of 150 km on the solar surface and of measuring vector magnetic and velocity fields in the photosphere. An X-ray imager for the diagnosis of plasmas having temperatures of 0.5 to 10 million K is also included in *Hinode*'s payload. Line broadening in the transition region and coronal emission lines, which may be manifestations of energy input into the corona, are being observed with an EUV imaging spectrometer. With the coordinated set of these instruments, *Hinode* aims to unveil the coupling of coronal activity with the underlying photospheric magnetic and velocity fields and, furthermore, reveal more about the mechanism of coronal heating – one of the largest puzzles in solar physics. A Sun-synchronous, polar orbit was chosen to avoid the orbital temperature variation due to day/night cycles and to minimize the effects of observing time gaps and of line shifts due to the orbital motion. First light for the instruments, the Solar Optical Telescope, the EUV Imagine Telescope and the X-Ray Telescope, was October 2006.

STEREO is the third mission in NASA's Solar Terrestrial Probes programme (STP). This mission employs two nearly identical space-based observatories – one ahead of Earth in its orbit, the other trailing behind – to provide the first-ever stereoscopic measurements to study the Sun and the nature of its coronal mass ejections (CMEs). The twin spacecraft were launched on 25 October 2006 from Cape Canaveral and took first light images on 15 December 2006. *STEREO*'s scientific objectives are to: understand the causes and mechanisms of CME initiation, to characterize the propagation of CMEs through the heliosphere, to discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium, and to improve the determination of the structure of the ambient solar wind. Both *STEREO* spacecraft are currently performing as expected and delivering valuable scientific data.

Koronas is a series of Russian satellites designed to observe the solar atmosphere from Earth orbit, and to observe solar activity and magnetospheric solar effects. They carry instruments developed by groups from Russia, in collaboration with researchers from the Ukraine, Georgia, Poland, Germany, France, the UK and USA. The instruments include X-ray spectrometers, multi-layer imaging telescopes and coronagraphs, as well as detectors for helioseismology. The first of the series, *Koronas-I*, was launched in March 1994 with a scientific payload of eleven instruments designed to cover a wide region of the electromagnetic spectrum and to measure particles; this mission operated until 2001. The second, *Koronas-F,* was launched on 31 July 2001 and was operated successfully until December 2005. The twelve instruments on board have observed solar radiation from radio waves to gamma rays, facilitating studies of solar oscillations, the properties of the *in situ* particle flux, and energy deposition and transport processes in quiet and active conditions. The mission had broad scientific objectives associated with observational solar physics, much like *SOHO*. The next mission of the series was *Koronas-Photon* launched on 30 January 2009. This spacecraft (a part of the International Living With a Star programme) carries the *TESIS* complex of solar imaging instruments, developed by the Lebedev Physical Institute of the Russian Academy of Science, designed to obtain high spectral, temporal and spatial resolution solar corona images in the soft X-ray to far UV spectral range, thereby providing a suite of observations of solar active phenomena from the transition region to the inner and outer solar corona in the EUV and Soft X-ray spectral bands. The *TESIS* includes five unique space instruments to observe the inner and outer solar corona from 0.2 to 4 solar radii in the 290-320 Å spectral band. With the advanced capabilities of its instruments, the *TESIS* was expected to lead to a better understanding of the physics of solar flares and high-energy phenomena and provide new data on parameters of solar plasma in the temperature range 10^5 - 10^7K. The *TESIS* experiment started operations in the deep solar minimum between the 23rd and the 24th cycles of solar activity, made some significant observations of solar X-ray outbursts, but unfortunately operations ceased in December 2009 due to power supply problems.

The two main telescopes on board *PROBA 2* (PRoject for OnBoard Autonomy) launched in January 2010, *SWAP* (*Sun Watcher with APS Detector and Processing*) and *LYRA* (*Large Yield Radiometer*) were designed to monitor the Sun's output, eruptive events and atmospheric response on a 24/7 basis. Together they are capable of capturing all solar events important for space weather. *SWAP* images the complete solar disc in EUV (17.4 nm) and is similar to SOHO/EIT but capable of taking images at an higher time-rate.

Daily movies can be found on: http://proba2.sidc.be/swap/data/mpg/movies. *LYRA* is a Lyman Alpha Radiometer (UV), similar to the solar X-ray flux meter on board the US *GOES* satellite, but with a special detector which is 'blind for optical light' and radiation hard. The first images were made public by the end of January 2010. As *PROBA 2* is a mainly Belgian mission, all important responsibilities are taken by Belgian institutes. *PROBA 2* is part of ESA's In-orbit Technology Demonstration Programme.

The *Solar Dynamics Observatory* (*SDO*), the first mission for NASA's Living With a Star (LWS) Programme, was launched on 11 February 2010, has been designed to understand the causes of solar variability and its impacts on the Earth and near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously (see the website http://sdo. gsfc.nasa.gov/). *SDO*'s goal is to understand, with a view to acquiring a predictive capability, the solar variations that influence life on Earth and humanity's technological systems by determining: how the Sun's magnetic field is generated and structured, how this stored magnetic energy is converted and released into the heliosphere and geospace in the form of the solar wind, energetic particles, and variations in the solar irradiance. *SDO*'s operations are being coordinated with those of *SOHO* and *RHESSI*. The objective of the *SDO* mission is to observe directly the connections between the small-scale features that characterize the photospheric magnetic field and the larger-scale structures that are seen in the solar corona, thereby following up on the discovery by *Yohkoh* that the corona is a continuously dynamic atmosphere which responds to impulses from the photosphere. *SDO*, which observes the full disk, has been surveying this connection from the photosphere into the corona with unsurpassed temporal and spatial resolution.

SDO contains a suite of instruments that provide observations that will lead to a more complete understanding of the solar dynamics that drive variability in the Earth's environment. These instruments are the *HMI* (*Helioseismic and Magnetic Imager*), *AIA* (*Atmospheric Imaging Assembly*), *EVE* (*Extreme Ultraviolet Variablity Experiment*). The components of the *SDO*'s programme are as follows:

- To measure the extreme ultraviolet spectral irradiance of the Sun at a rapid cadence;
- To measure the Doppler shifts due to oscillation velocities over the entire visible disk;
- To make high-resolution measurements of the longitudinal and vector magnetic field over the entire visible disk;
- To make images of the chromosphere and inner corona at several temperatures at a rapid cadence;
- To make those measurements over a significant portion of a solar cycle to capture the solar variations that may exist in different time periods of a solar cycle.

After receiving the data from *SDO*, the Science Teams process, analyse, archive the data which are then available to the world. It is instructive to compare the resolution capabilities of *SDO* with those of *STEREO* and *SOHO: SDO*'s *AIA* instrument has twice the image resolution of *STEREO* and four times greater imaging resolution than *SOHO*. The image cadence also varies: *SDO* takes one image every second, whereas at best *STEREO* takes one image every three minutes and *SOHO*

takes one image every 12 minutes. All three missions have been operated in close collaboration. In addition, observations of the Sun made simultaneously with other experiments such as those carried on other satellites, sounding rockets and balloons, as well as with ground-based telescopes, are organized regularly and have proved particularly fruitful for investigating solar activity.

Other solar physics oriented experiments include operational satellite-, sounding rocket- and balloon-borne experiments. For example, a hard X-ray spectrometer, provided by the Czech Republic, now monitors the Sun from the *Multispectral Thermal Imager* satellite, which is a US Department of Defense Earth observing satellite. Similarly, the *Solar X-ray Spectrometer* (*SOXS*) on board an Indian applications satellite has been monitoring solar flares continuously since June 2003. In addition, many spacecraft, designed for the study of the heliosphere and the geomagnetosphere, such as *Ulysses*, *Wind*, *ACE*, *Cluster*, *Double* Star (which ended its operations on 14 October 2007), carry instruments that provide relevant data to be analysed together with those from the solar physics missions described above.

Missions Currently in Development

The *Radiation Belt Storm Probes Mission*, part of NASA's Living With a Star programme, is designed to investigate the physical dynamics of the radiation belts and provide the data needed for predicting changes in the critical region of space where major space weather activity occurs and many spacecraft operate. Beginning in 2012, two probes will orbit the Earth following the same path, taking identical measurements of the particles, magnetic and electric fields, and waves that fill geospace.

Solar Orbiter is a mission proposed for ESA's Cosmic Vision programme (2015-2025). By approaching as close as 62 solar radii, Solar Orbiter will view the solar atmosphere with high spatial resolution.

Conclusions

As may be seen from the above, solar physics activities in space include extensive international cooperation, a rich variety of research goals over the next decade, and both the continued operation of existing spacecraft as well as the preparation and planning for future missions. Studies of the Sun have a dual importance in that the Sun is not only a prototypical object for much of astrophysics, but also has the driving role in defining the heliosphere, in influencing the Earth and in controlling the near-Earth environment. It is to be hoped that the long-standing tradition of international cooperation in solar research will be strengthened still further.

VI. LIFE SCIENCES AS RELATED TO SPACE

VI.1 Gravitational Biology

Here, we focus on gravity perception, genetic and physiological modifications in response to microgravity or simulated gravity. Genetic studies are typically paired with physiological manipulations and space flight experiments. Research has to rely on what are, unfortunately, limited chances for flight experiments, either in sounding rockets or on board the Space Shuttle. The objective is to provide a broad framework for gravitational biology, particularly with reference to spaceflight, generating data and results that are applicable to humans, animals and plants, including

microorganisms and cell preparations. The terms of reference include: spaceflight low-G effects; effects of ground-based low-G simulation; gravity perception and orientation; gravity scale effects; centrifuge high-G effects; vibration effects.

Important environmental factors that control development and growth of plants are light and gravity. With regard to gravity, this is quite obvious due to the spatial orientation of shoots, main roots and first-order secondary roots. Investigations into gravitational sensing give evidence for a cascade of biophysical and biochemical responses. This holds as much for fungi and algae as for higher plants.

Recent progress in unravelling plant responses to a changing gravitational environment are mainly due to focusing on model systems such as *Euglena* (unicellular Euglenophyte), *Chara* (a multicellular alga), *Brassica napa* and *Arabidopsis thaliana* (both higher plants). The latter is increasingly used because it has become the model plant. Together with the application of up-to-date molecular tools, many groups try to dissect signal perception and early steps of signal transduction.

There is increasing evidence, that changes in gravity are sensed as environmental stress, causing responses with similarities to both abiotic and biotic stress (drought, high salt concentrations, pathogen attacks, etc.). Such signals involve NO, hydrogen peroxide, as well as altered oxygen consumption. These early events are accompanied by rapid changes of subcellular calcium concentrations as well as a rapid modulation of proteins by phosphorylation/dephosphorylation, and expression of stress-related genes.

Important progress is also being made with regard to the involvement of phytohormone transport (gravity-induced changes in the localization of auxin carriers) and effects (ethylene) using fluorescent proteins and phosphoproteomics. A new aspect in the regulation of protein expression is the function of small RNAs (sRNA, 18-24 nucleotides long). These are key elements in regulating gene expression in response to biotic and abiotic changes, consist of several classes, are phloem-mobile, affect transcript stability, DNA methylation, and cause transcriptional silencing.

The precise function of the cytoskeleton in gravisensing remains an open question. In rhizoids of the alga *Chara*, studies on the interaction between statoliths and actomyosin indicate that actomyosin primarily guides statoliths to a specific graviperception site. Thus, statolith-related effects are probably due to surface interactions, and not to the weight of the sedimenting particles. In higher plants, new data indicate that the cytoskeleton is possibly not essential. Disruption of actomyosin is without effect in early phases of gravity reception, but can optimize statolith-receptor interaction. Thus, a suggested function is to keep statoliths in motion thereby causing an extended activation of gravireceptor molecules.

Due to the increased use of the *International Space Station* (*ISS*), data for long-term exposure to a microgravity environment have become increasingly available. In addition to phenotypic studies on plant growth or movement (e.g. self-sustained oscillations without impact of gravity), gene expression studies prevail, but detailed data are not yet available. One issue with future *ISS* studies is the impact of the retirement of the shuttle in 2011.

Part of the progress that has been made derives from the introduction of novel technologies. By introducing real-time imaging, sedimentation of amyloplasts has been recorded. It is still, however, a matter of debate as to how far microgravity can

be simulated on Earth. Methods for the simulation of hypogravity have been extended. In addition to traditional approaches such as clinorotation (2D) or (newer) random positioning (3D clinostat), magnetic levitation is increasingly being used. All these methods have their drawbacks. Clinorotation has been shown to affect the graviresponse and to introduce secondary effects which depend on rate and direction of rotation. Gene expression studies indicate similarities with hypergravity. Magnetic levitation varies along relatively short zones, where 0, 1 and 2 g follow each other. This creates problems with larger objects such as seedlings and is best used with cell cultures. In addition, magnetic fields exert effects by themselves. One g samples inside the magnet behave different from one g controls outside. Also, weak magnetic fields can influence calcium distribution inside a plant cell and thus affect signalling cascades. Very low geomagnetic fields are also of interest with regard to long-term space missions. Under less than 250 nT, germination rates and gravitropic responses can be enhanced

In order to further examine specific steps of gravity sensing and signal transduction, genetically modified plants will be increasingly used. Combined with recent methods for the study of gene and protein expression, together with the analysis of protein moduation and metabolite pools, we expect considerable progress in this field within the coming years, especially as the ISS now is fully operational.

VI.2 Radiation Environment, Biology and Health

The natural radiation environment outside the magnetic shielding of the Earth is rather complex and consists of a mixed field of high energy protons, electrons, alpha particles and heavy ions. The focus here includes the influence of external factors such as radiation quality, weightlessness and environmental stress on radio-biological processes; radiation risk and protection in solar particle events; dosimetry in manned spaceflight; radiation standards and radiation protection in manned spaceflight.

Knowledge of the effects of space environment can be gained through a combination of ground-based research using a linear accelerator and from in-flight experiments. Several years ago, NASA initiated a Space Radiation Research Programme, which is currently supporting biological experiments performed at the Brookhaven National Laboratory. The NASA Space Radiation Laboratory (NSRL), a $34-million facility, jointly managed during a four-year construction project by the DoE's Office of Science and NASA's Johnson Space Center, employs beams of heavy ions extracted from Brookhaven's Booster accelerator to simulate the cosmic and solar radiation environment found in space. Through the Ground-Based Research in Space Radiation Biology programme, NASA has funded 56 research projects in the past three years. In addition, five NASA Specialized Centers of Research (NSCOR) have been funded that cover areas in radiation carcinogenesis and effects of high energetic particles on the central nervous system. More recently, studies have been conducted aboard the *ISS* (by scientists from partner nations) to ascertain the radiobiological effects of space radiation using a variety of *in vitro* and *in vivo* endpoints.

To train the next generation of space radiation scientists, NASA has initiated a summer school programme which has been run since 2005. Application to the programme is open to graduate students, postdoctoral fellows and faculty staff with an interest in radiation biology. Both foreign nationals and US citizens are eligible to

apply for the three-week course. For 2011, the scientific director of the summer school is Dr Dudley Goodhead, emeritus director of the Medical Research Council Radiation and Genome Stability Unit, UK.

To promote international collaboration on space radiation research, an International Open Laboratory on Space Radiation Research group was established by the Japanese National Institute of Radiological Sciences in Chiba in 2008. A distinguished foreign scientist (Professor Tom Hei of Columbia University Medical Center in New York) has been appointed to head the group together with a Japanese team leader from the host institute (Dr Yukio Uchihori) to examine both the physics and biology of space radiation exposure using a variety of endpoints.

The InterComparison of Cosmic rays with Heavy Ion Beams at the NIRS (ICCHIBAN) is an ongoing international collaboration to inter-calibrate and to inter-compare the response of different detectors and dosimeters used for radiation dosimetry aboard spacecraft. The results of the study will serve to corroborate the data obtained based on the Matroshka project onboard the *ISS*.

An international consortium of scientists from various space agencies and universities launched the *ALTEA* project to ascertain the effects of the space environment and of cosmic rays on the central nervous system aboard the *ISS*. Endpoints including particle flux, electrophysiology and behavioural patterns of brain functions are measured. Based on the final recommendation of investigations into the biological effects of radiation (*IBER*) (http://iber.na.infn.it), European Accelerator-based space Radiation biology Programme (*EARP*) has been devised to support the safe human exploration of the solar system and is described herein. *EARP* should develop the database and the knowledge required by ESA for accurate prediction and efficient management of the radiation risk for manned interplanetary missions. The knowledge will be acquired by means of a peer-reviewed, ground-based and investigator-initiated science research programme in a way similar to NASA procedures. The ultimate goal of *EARP* should be to allow human colonization of the Moon and exploration of Mars by the year 2020 with an acceptable risk from exposure to space radiation. Finally, Towards Human Exploration of Space: a European Strategy (the *THESEUS* project) is coordinated by the European Science Foundation and funded by the European Commission (www.theseus-eu.org). The project enlists an international panel of experts in various aspects of space research to develop an integrated life sciences strategic research roadmap.

Major conferences in this field include the 55th Annual Meeting of the Radiation Research Society (3-7 October 2009 in Savannah, Georgia), the 15th International Microdosimetry meeting (25-30 October 2009 in Verona, Italy), the 21st Annual NASA Space Radiation Investigators' Workshop (16-19 May 2010 in Prot Jefferson, New York). The 9th International Workshop on Microbeam Probes and Cellular Radiation Response (15-17 July 2010 in Darmstadt, Germany), and the 38th COSPAR Scientific Assembly, 18-25 July 2010 in Bremen, Germany).

VI.3 Astrobiology

The principal objective here is the study of: the pathway (chemical) by which life may have arisen – extraterrestrial organic chemistry, chemical evolution; the early (pre-Cambrian) geological record as it pertains to the origin and early evolution of life; the interaction of life with the planet in physical-chemical and evolutionary terms; terrestrial life forms in unusual and extreme environments; and, finally, the

search for life (including intelligence) in the universe. Also of interest is the development of planetary protection plans in solar system exploration and sample return missions.

The years 2009 and 2010 were exciting for scientific advances in astrobiology, and include the following:

Detected through their molecular remains, fossils of early sponges have been observed in ancient rocks in Oman. Using a scientific technique known as hydropyrolysis (using hydrogen gas at high pressure), fossils discovered in sedimentary rocks in Oman have been dated. The high-precision technique has shown that these fossil steroids, remnants of a type of sponge known as Demosponges, are between 635 and 750 million years old. They date back to around the time of the Marinoan glaciation, the last of the huge ice ages at the end of the Neoproterozoic era. This discovery suggests that shallow waters contained dissolved oxygen in concentrations sufficient to support early animal life at least 100 million years before the Cambrian explosion. Members of the MIT team that led the investigation have published their findings in *Nature*, 5 February 2009.

Leading off 2009 with a flurry of press attention, the NAI (NASA Astrobiology Institute) team at NASA Goddard Space Flight Center and their colleagues announced their discovery that methane occurs on Mars in extended plumes, and that the methane is likely released from discrete regions at specific times. Since methane can be produced by subsurface geological/chemical processes as well as by life processes, there is still much to be done to determine the methane's source and its implications for life on Mars. The team's results were published in *Science* 20 February 2009.

NAI's Deep Time Drilling Project acquired several pristine cores from ancient rocks in Western Australia in 2004. In a paper on the analysis of these cores (published in *Science* 20 February 2009), University of Washington astrobiologists reported clues about when and how the Earth's atmosphere became oxygen rich. The analysis indicates that atmospheric oxygen rose in a temporary 'whiff' about 2.5 billion years ago. The whiff lasted long enough to be recorded in the nitrogen isotope record, then oxygen dropped back to very low levels before the atmosphere became permanently oxygenated about 2.3 billion years ago. The timing of the rise of oxygen in the Earth's atmosphere is a key question in astrobiology. It is coupled not only to the question of when organisms capable of oxygenic photosynthesis first evolved on Earth, but also what signs of life might be found on young Earth-like planets around other stars.

Gases rising from deep within the Earth are fueling the world's highest-known microbial ecosystems, which have been detected near the rim of the 6,100 m high Socompa volcano in the Andes by a research team from the University of Colorado at Boulder. The new study shows that the emission of water, carbon dioxide and methane from small volcanic vents near the summit of Socompa sustains complex microbial ecosystems new to science in the barren, 'sky-high' landscape. A paper on the subject by Steve Schmidt and his colleagues was published in the February 2009 issue of *Applied and Environmental Microbiology*.

A study of iron within hydrothermal vents, led by former NAI Postdoctoral Fellow Brandy Toner (now at the University of Minnesota) together with members of the NAI's Emeritus team at the Marine Biological Laboratory, was published in

Nature Geoscience in March 2009. The research showed that iron emitted from the vents can bind to organic particles and be distributed within the oceans. This bound iron does not oxidize, and so is much more easily processed by living organisms, thus affecting the potential for a 'natural iron fertilization mechanism'.

Scientists from NASA's Goddard Space Flight Center have published a paper in *Proc. (US) Nat. Acad. Sci.*, 16 March 2009 describing the distribution and enantiomeric composition of certain amino acids in carbonaceous meteorites. Their results show an increased amount of 'left handed' l-isovaline, a non-biological amino acid, in several meteorites. These results are inconsistent with UV circularly polarized light as the primary mechanism for l-isovaline enrichment and indicate that amplification of a small initial isovaline asymmetry in the Murchison and Orgueil meteorites occurred during an extended aqueous alteration phase on the meteorite parent bodies. The large asymmetry in isovaline and other amino acids found in altered CI and CM meteorites suggests that amino acids delivered by asteroids, comets and their fragments would have biased the Earth's prebiotic organic inventory with left-handed molecules before the origin of life.

Members of the Penn State and Carnegie Institution of Washington Teams reported (*Science*,17 April 2009) that certain sulphur isotopes found in many sedimentary rocks older than 2.4 billion years may not be the result of photochemical reactions in an oxygen-free atmosphere as previously thought. Their research shows that the isotopic signature could instead be due to reactions between organic carbon-rich sediments and sulphate-rich seawater in ancient hydrothermal systems. If so, then the disappearance of the signature in sediments younger than 2.4 billion years may indicate changes in the Earth's hydrothermal system, rather than signaling the rise of oxygen in the Earth's atmosphere.

NAI Postdoctoral Fellow Oleg Abramov (University of Colorado, Boulder) led a modelling study (*Nature*, 21 May 2009) investigating the degree of thermal metamorphism of the young Earth's crust caused by the Late Heavy Bombardment (LHB) which ended 3.9 billion years ago. The analysis revealed that there is no plausible situation in which the habitable zone could have been fully sterilized. The authors conclude that subsurface microbial life could have persisted throughout the LHB. They also propose that multiple, impact-induced temperature anomalies could have driven widespread hydrothermal activity, and that this was conducive to life's emergence and early diversification.

According to a study from NAI's Virtual Planetary Laboratory team at the University of Washington and colleagues at Caltech, the lifespan of the Earth's aerobic biosphere could be prolonged, even as the Sun's luminosity increases over the next 2-3 billion years. The study (*Proc. US Nat Acad. Sci*., 1 June 2009) points to the substantial reduction in atmospheric total pressure as life fixes and buries most of Earth's present-day atmospheric nitrogen. This would decrease atmospheric pressure and with it the greenhouse effect, thereby regulating the Earth's surface temperature. This could add an additional 1.3 billion years onto the lifespan of the Earth's aerobic biosphere, and have implications for the lifetime of aerobic biospheres on planets around other stars.

The Wet Chemistry Laboratory on the *Phoenix* Mars Lander performed aqueous chemical analyses of Martian soil from the polygon-patterned northern plains of the Vastitas Borealis. The solutions contained perchlorate (ClO_4) – a highly oxidized form of chlorine (findings published in *Science*, 3 July, 2009). This has been

the biggest surprise found by the *Phoenix* mission because it was widely thought that soil chlorine was in the form of chloride. Perchlorate, which strongly attracts water, makes up a few tenths of a percent of the composition in all three soil samples analysed by *Phoenix*'s wet chemistry laboratory. It could extract moisture from the Martian air. At higher concentrations, it might combine with water as a brine that stays liquid at Martian surface temperatures. Some microbes on Earth use perchlorate as food. Human explorers might find it useful as rocket fuel or for generating oxygen.

Researchers from Penn State Marine Biological Laboratory and UCLA completed a study of the sub-seafloor marine biosphere, which may be one of the largest reservoirs of microbial biomass on Earth. Their metagenomic analysis indicated that the subsurface environment is a distinct microbial habitat, different from other environments studied by metagenomics, particularly because of the predominance of uncultivated Crenarchaeota; results are published in *Proc.US Nat. Acad. Sci*., 29 July 2009.

NASA scientists have discovered glycine, a fundamental building block of life, in samples of the comet Wild 2 returned by NASA's *Stardust* spacecraft. The discovery of glycine in a comet supports the idea that the fundamental building blocks of life are prevalent in space, and strengthens the argument that life in the universe may be common rather than rare. The results of the investigation were presented at the meeting of the American Chemical Society in Washington, DC, on 16 August 2010, and will be published in *Meteoritics and Planetary Science*.

NASA scientists studying the origin of life have reproduced uracil, a key component of our hereditary material, in the laboratory. They discovered that an ice sample containing pyrimidine exposed to ultraviolet radiation under space-like conditions produces this essential ingredient of life. The resulting research paper was published in *Astrobiology*, 1 October 2009.

Two new papers, based on data from NASA's *Cassini* spacecraft, report an examination of the complex chemical activity on the surface of Saturn's moon Titan. One shows that hydrogen gas flowing throughout the planet's atmosphere disappeared at the surface suggesting that alien forms could in fact breathe (*Icarus*, August 2010). The second paper, in *J. Geophys. Res.* (accepted on line 26 April 2010), concluded that there was lack of hydrogen on the surface. While non-biological chemistry offers one possible explanation, some scientists believe these chemical signatures bolster the argument for a primitive, exotic form of life or precursor to life on Titan's surface. According to one theory, the signatures fulfill two important conditions necessary for a hypothesized 'methane-based life'.

Experiments prompted by the 2008 surprising finding from NASA's *Phoenix* Mars lander (namely, that perchlorate was present in soil samples from Mars) suggest that the soil examined by NASA's *Viking* Mars landers in 1976 may have contained carbon-based chemical building blocks of life. A study, published online in *J. Geophys. Res. – Planets* (on 19 August 2010), reanalysed the results of the *Viking*'s tests for organic chemicals in Martian soil which had shown that the only organic chemicals identified (when the samples of Martian soil were heated) were chloromethane and dichloromethane -- chlorine compounds interpreted at the time as likely contaminants from cleaning fluids. But those chemicals are exactly what the new study found when a little perchlorate -- the surprise finding from *Phoenix* -- was added to desert soil from Chile containing organics and analysed in the manner of the *Viking* tests. This does not say anything about the question of whether or not life has

existed on Mars, but it could make a big difference as to how we look for evidence to answer that question.

Scientists and non-scientists now have easy access to information about when living species and their ancestors originated, information that previously was difficult to find or was inaccessible. Free access to the information is part of the new Timetree of Life initiative, developed by NAI's Blair Hedges (Professor of Biology at the Penn State Astrobiology Research Center) and Sudhir Kumar (Professor of Life Sciences at Arizona State University): see http://www.timetree.org/.

VI.4 Natural and Artificial Ecosystems

The problems of sustainable development on Earth and of supporting human life in space have the same scientific and methodological grounds connected with a long-term maintenance of a balanced material cycle in natural and artificial ecosystems. Different experimental ecosystems and their links, designed in Europe (Germany, France, Italy), China, Japan, the Russian Federation and the United States are regularly considered at COSPAR Scientific Assemblies and published in *Advances in Space Research* issues devoted to the Life Sciences. Some issues relating to the research in the field are listed:

1. Issues and problems associated with quantitative criteria of natural and artificial ecosystem functioning connected, for example, with the closure as a specific property of man-made ecosystems and the biosphere;
2. Advanced life support systems and facilities, their designing, mathematical and computer simulation;
3. Special attention to environment/ecosystem interactions, concerning stability, sustainability of ecosystem links including, for example, space agriculture and human health.

At the 38th COSPAR Scientific Assembly in July 2010, there were eight sessions (symposia) in the area of 'Natural and Artificial Ecosystems Studies for Earth and Space Applications' at which there were discussions of new experimental and theoretical data and advanced technology findings. At the meeting, devoted to the problems of life-support systems studies and development, many questions and comments concerned the most pressing and unsolved tasks and challenges which inhibit development of works in this range. These issues include psychological, professional, international restrictions and the apparent gap between life support scientists and space engineers concerning acceptance of bioregenerative methods for life-support systems. On this topic, there have been two relevant international meetings of late:

1. European Advanced Life Support Workshop (2-4 June 2009, Barcelona, Spain), which provided the opportunity to European industries and entities to exchange experience, information and produce a roadmap related to Advanced Life Support Systems for space exploration.

2. The 40th International Conference on Environmental Systems (ICES) (10-15 July 2010, Barcelona, Spain), a conference covering topics related to humans living and working in hostile environments with applications inside or outside both terrestrial and outer space habitats or vehicles, including aerospace human factors, environmental control and life-support system technology, environmental monitoring and controls, life sciences, and planetary habitats and systems.

VI.5 Human Physiology in Space

Human physiology in space focuses on the effects of microgravity on the human body. In this respect, it is also of interest how different physiological systems are affected by microgravity, but also – in a sense of system biology – how they interact with each other.

Most of the relevant activities in the various space agencies are focusing on countermeasure development and the effects of confinement. In this respect, ESA will start in 2010 their short (5 days) – and medium-term (21 days) bed-rest campaigns in Toulouse and Cologne in which artificial gravity, exercises and nutritional measures will be tested. Four campaigns, two short-term and two medium-term studies will be carried out. ESA has also initiated further studies in Antarctica and will start a series of campaigns in the winter of 2010.

The Russian Federation's Institute of Bio Medical Problems (IBMP) started an international project in 2007 simulating aspects of an interplanetary manned space flight called Mars500 (mars500.imbp.ru/en/index_e.html; www.esa.int/SPECIALS/Mars500/) in 2010. The project is supported by institutes and agencies in China, Germany, Italy, Malaysia, Republic of Korea, the Russian Federation and the United States. Six healthy male test subjects, three Russians, 1 Chinese, 1 Italian and 1 French test subject will stay in an isolation chamber for 520 days, ending November 2011. A series of experiments (tests for the subjects) is included in the project covering different aspects of an interplanetary flight. A major objective of the Mars500 project is to develop countermeasures to maintain the well-being of long-duration astronauts and cosmonauts.

The results of research and details of problems are shared and exchanged at such meetings as the those of the International Society of Gravitational Physiology (http://www.isgp.org/), the Humans in Space meeting (http://www.dsls.usra.edu/meetings/IAA/), the International Astronautics Conference (http://iaaweb.org/content/view/228/355/) and the 39th COSPAR assembly (http://www. cospar2012india.org/).

VII. MICROGRAVITY RESEARCH

Access to space opens up new frontiers for scientific research and human exploration endeavours. In space laboratories like the *International Space Station* (*ISS*), unique research has become possible in a variety of disciplines, making use of the special conditions of the space environment such as weightlessness, radiation and extreme vacuum. During the past two decades, microgravity research in space has developed into a mature activity. In the physical sciences, we have tested fundamental physical theories to degrees of precision not possible in Earth-bound laboratories. These findings and accomplishments have been obtained using the *ISS* supplemented by substantial Earth-based studies and research on low orbits.

Microgravity research involves the study of low gravity on physico-chemical phenomena as applied to fluid physics, materials science, combustion and biotechnology.

Fluids are present everywhere in the everyday life. They are also the fuels of spacecraft and are widely used in satellites and for life support. But it is an everyday experience that fluids are very sensitive to gravity: on Earth, liquids flow down, gas mostly rises. Under the weightlessness conditions of space, other forces (capillary,

osmotic, thermo-capillary, inertia…) that are usually negligible with respect to gravity, can dominate fluid behaviour and can make their management hazardous. The objectives of the fluid research in microgravity are thus twofold:

(i) To investigate the fluid behavior to manage fluid and fluid mixtures in space,and
(ii) To take benefit of the absence of gravity forces to detect new behaviour, both type of research are driven by industry and fundamental considerations.

Fluid physics includes a number of application-oriented fields which will need new emphasis, such as: liquid-vapour flows and heat transfer in microgravity; thermoconvective flows, better understanding of emulsion flows, especially drainage and phase separation in micro-channels with application to micro-fluidic machinery; bio-fluidics for health and life science. Attention is focused on the hydrodynamics, heat/mass transfer in mixtures including diffusion and thermodiffusion, chemically reacting fluids, thermal and phase transition behaviour of fluids, either pure – and here supercritical fluids are especially interesting – or mixed up.

In combustion science, there is an even stronger evidence of the need for microgravity research. Liquid or solid fuels need to be vaporized to form a flammable mixture with air. As compared to fluid science, inertia is a much smaller factor, diffusivity is about ten times higher and the temperature gradients driving buoyancy on Earth are extreme. Attention is also addressed to the influence of gravity on the combustion of dust particles, flame geometry and speed of propagation.

The cornerstones of Materials Science are: thermophysical properties of fluids for advanced processes and the design of new and improved materials in space with better performance. There is a wide range of materials science topics in microgravity condition that include solidification, bulk crystal, liquid crystals, alloys, carbon materials, magnetic materials, colloids and nanotechnology; metastable phase. Consequently, both ground-based and flight research is necessary.

The application of biotechnology research results range from the design of new drugs, to protein engineering, synthetic vaccines, and biochip technology for the electronics industry. Biotechnology research under microgravity conditions has focused on the study of isolated bio-macromolecules, such as proteins and the study of cells in controlled fluid and chemical environments.

Currently, the *ISS* is the only space platform available for studies that require long-duration exposure to microgravity. While the *ISS* is unique, it is not the sole operational microgravity platform. Other platforms as drop towers, parabolic flights, sounded rockets, recoverable satellites continue to be important for executing a coherent, integrated and multidisciplinary scientific programme being in line with terrestrial studies.

For Europe, a new era opened up in February 2008 with the attachment of the Columbus orbital laboratory to the *ISS*. This module is equipped with flexible research facilities, Standard Payload Racks (ISPRs) that offer extensive science capabilities. Each rack is able to host its own autonomous and independent laboratory, complete with power and cooling systems, and video and data links back to researchers on Earth.

Intensive scientific studies evolved in the framework of the *European Programme for Life and Physical Science in Space* (*ELIPS* 3). Some of these deserve to be mentioned. In 2009, an experiment – *PROTEIN*, targeting the examination of

depletion zones of protein and/or impurity and nucleation, was successfully conducted in the ISS Protein Crystallisation Diagnostic Facility (PCDF).

The experiment, called *Geoflow*, was performed in the Fluid Science Laboratory (FSL) inside the Columbus laboratory Module on the *ISS* in 2008. *Geoflow* studied thermal convection in the gap between two concentric rotating spheres to model the Earth's liquid core. Understanding the flow of the silicone oil, used in the experiment, under different conditions will be of importance in such areas as flow in the atmosphere, the oceans, and the movement of Earth's mantle on a global scale, as well as other astrophysical and geophysical problems.

The very recent experiment, *IVIDIL* (*Influence of Vibrations on Diffusion in Liquids*), has been performed with the *Selectable Optical Diagnostics Instrument* (*SODI*) mounted inside the Glovebox (MSG) facility in the Columbus laboratory. This experiment was prepared with participation of Canadian and Russian scientists. 55 experimental runs, each of 18 hours durations, were successfully conducted during three months on the *ISS* in 2009-2010. The *IVIDIL* experiment examines how vibrated fluid mixtures mix through diffusion and how they separate through thermodiffusion (Soret effect). In addition to fundamental research, the experimental results are also useful in a variety of engineering applications. For example, better understanding of the Soret effect will improve the mathematical models used in the petroleum industry. Currently, another European experiment, *COLLOID*, is being started in the same facility.

Recently, the first results were obtained from another European (mini)-laboratory: DECLIC (*Dispositif pour l'Etude de la Croissance et des Liquide Critiques*), which include three modules to study the liquids near the critical point.

For the preparation of these and other *ISS* experiments, smaller platforms were actively used, such as the drop tower in Bremen, parabolic flights using an Airbus and sounding rockets. Successful experiments *SOURCE* and *BIOMIX* should be mentioned for the latter platforms.

Following the First Phase Utilization of Japanese Module KIBO that lasted from 2008 through the middle of 2010, tens of scientific experiments, as well as studies aimed at technology developments and commercial uses, have been conducted in this Module on the ISS. The series of the *Marangoni Experiment in Space* (*MEIS*) were performed in the JAXA Fluid Physics Experiment Facility. Marangoni flow, or flow driven by thermocapillary force, was examined in these experiments. By setting the experiment in near weightlessness, buoyancy-driven convection can be eliminated from the data. This facilitates the isolation of the effects of Marangoni convection, providing a clearer picture of how instabilities form in the solid-liquid interface, knowledge that can be applied to future semiconductor crystal production.

The research programmes in Europe and Japan are good examples of space utilization for microgravity research. In addition, Europe and Japan have developed joint scientific programmes through the International Topical Teams. One of the examples of this provenance is an experiment known as *JEREMI* (*Japanese European Research Experiment on Marangoni instabilities*), which is being prepared by the international team in readiness of being performed in JAXA's FPEF facility.

The Chinese microgravity research programme has been concerned with experiments relating to physics and life sciences in several runs in a Russian module onboard the *ISS*.

Results from all the above-mentioned experiments were presented during the 38th COSPAR Scientific Assembly in Bremen and attracted a large audience. As there were severe reductions in the content and extent of the USA's microgravity science programme dealing with microgravity fluids and combustion between 2006 and 2008, there were fewer US participants in the microgravity sessions of the COSPAR Assembly in Bremen. Along with the scientific results presented at the Assembly, a large number of the papers dealt with preparations for future large missions using terrestrial and low orbit platforms. In the recent past, Japan and China have successfully organized Microgravity Workshops where the primary focus has been to review developments in the progress of space utilization in several areas related to science and technology. To further enhance the participation of other countries and increase the scope of the conference, the Korean microgravity community was welcomed in the year 2009. Since 2006, Japanese community has independently been collaborating with scientists from Malaysia and Thailand in the utilization of aircrafts for short-duration microgravity experiments. The Japanese community is also preparing experiments using Indian satellite systems.

VIII. FUNDAMENTAL PHYSICS

This section covers the topics of gravitation, general and special relativity, fundamental forces, symmetries, cosmology and high energy processes. The world-wide fundamental physics community is growing quickly and an illustration of this is its contribution to the recent COSPAR Assembly, which was greater than the previous assembly by nearly a factor of three.

The field is still dominated by the inability of known physics to unite General Relativity and Quantum Mechanics into a coherent theoretical picture. A major aim is therefore to propose and carry out experiments in space which may be decisive in suggesting a way forward to resolve this impasse. The emergence of new issues such as the postulation of dark energy emphasizes how important it is to have a coherent understanding of the fundamental laws of nature if mankind is to understand the world around him and safely benefit from its resources. A number of fundamental physics missions have made progress in their development during the last year and these are reported in the following paragraphs.

Gravity Probe-B (US with some data analysis support from Saudi Arabia), launched in 2004, has now essentially reached the end of its data analysis task. Sophisticated modelling was required to account for unforeseen torques on the gyros used to measure geodetic and frame dragging motions with respect to an inertial frame. The results are to be announced at a NASA press conference late in 2010 and are expected to confirm the predictions of General Relativity to new levels and in new ways.

Progress is being made in the development of *Microscope*, a joint CNES-ESA mission (France, Germany, ESA), to search for violations of the Equivalence Principle. *Microscope* is the third in a series of small satellites being prepared by CNES. It should be ready for launch in 2013 now that a decision has been made to use a cold gas drag-free control system.

The antimatter search experiment *AMS* (involving China, Denmark, Finland, France, Germany, Italy, Mexico, Portugal, Republic of Korea, Spain, Switzerland, the Netherlands and the United States) is scheduled for delivery to the *ISS* in 2011 on one of the last shuttle flights; the science area it addresses has been stimulated by data

from *Pamela*, the joint Russian-US mission which has measured significant antiparticle excesses.

Deploying high stability clocks in space remains a high priority as a method of testing both Special and General Relativity. The *T2L2* payload (Czech Republic, France, Germany, Switzerland) is currently working on *Jason-2* providing a means of intercomparing ground-based atomic clocks *via* laser links. The *ACES* (France, Germany, Switzerland) mission has passed all its tests at engineering model level and is now cleared for flight model production with a view to being placed on the *ISS* by 2014. An important part of the *ACES* facility is a module to provide the means of intercomparing the two clocks in orbit with many clocks on the ground *via* a microwave link.

In Europe, a new call for Medium class missions has been released and it is expected that there will be proposals from the fundamental physics community. ESA has set up a panel of scientists to create a roadmap for fundamental physics in Europe. The recommendations included possible missions to be formulated for the current Cosmic Visions programme, new technology developments that are required to bring important experimental techniques to the level of technical readiness need for mission selection, and suggestions for the better organization of the fundamental physics community. One special feature of fundamental physics in space is that the instrumentation required to make these sophisticated and difficult measurements has significant potential in other applications such Earth observation, geodesy, navigation, etc, and the benefits of such uses requires new working methods between industry and academia.

IX. SATELLITE DYNAMICS

The scope of the Panel on Satellite Dynamics (PSD) is the positioning of a wide range of objects on scales from gigametres to nanometres. These objects include Earth orbiting satellites, such as geopotential missions (*CHAMP*, *GRACE*, *GOCE*, Swarm), altimetry missions (*Jason-1*/*2*, I*CESAT*, *CryoSat-2*), multi-disciplinary (e.g. altimetry and SAR) missions (*ERS-1*/*2*, *Envisat*) and navigation satellites (*GPS*, *GLONASS*, Galileo, including *GIOVE-A* and *B*, *Beidou*, etc.). In addition, planetary research is rapidly expanding, leading to more and more (plans for) satellite missions (*MGS*, *MRO*, *MSL*, *Selene*, *GRAIL*, *New Horizons*). Moreover, formations of satellites are being realized and proposed for Earth observation (*Tandem-X/TerraSar-X*) and fundamental science (*LISA, Darwin, XEUS*) that pose very high demands on (relative) positioning and orbit and attitude maintenance systems (such as micro-propulsion). Satellite orbit determination requires the availability of tracking systems (SLR, DORIS, GNSS, VLBI, DSN) as well as accurate solutions for ground station positions expressed in well-established terrestrial reference frames – such as the newly available ITRF2008, detailed force and satellite models – such as gravity, drag and/or solar pressure force models, detailed models describing satellites' geometry and surface properties, and high-precision time and frequency standards. Orbit determination methods and strategies are still evolving and are the subject of scientific discussions.

In recent years, more advances have been made in many areas associated with the field of satellite dynamics. An overview is given below including a summary of selected highlights. This overview has been divided into a part addressing Low Earth Orbiting (LEO) satellite missions, Global Navigation Satellite Systems (GNSS), and

solar system missions (to the Moon, Sun, planets and inter-planetary). This contribution will be concluded with an outlook.

IX.1 Low Earth Orbiting Satellites

The ESA *Envisat*, the ESA/EUMETSAT *MetOp*, the NASA/GFZ *GRACE* and NASA/CNES *Jason-1* satellites continue to operate and provide new results in the fields of geopotential modelling (Earth's gravity and magnetic fields), oceanography (altimeter based), glaciology (e.g. by InSar), seismology (also InSar) and atmospheric research (radio occultation, *SCIAMACHY*). The DLR (Germany) *CHAMP* satellite celebrated its 10th anniversary in July 2010 and has provided an unprecedented data set for geopotential and atmospheric research. *CHAMP* is expected to re-enter and burn up in the atmosphere during the autumn of 2010 after far exceeded its originally projected lifetime. Precise orbits that are close to cm-precision are computed on a routine basis for these satellites; these are required to fully exploit the information content of the observations taken by the diverse instruments on board (such as altimeters, accelerometers and inter-satellite ranging instruments).

The successful launches of the ESA *GOCE* satellite (17 March 2009), equipped with a very advanced gradiometer, and *CryoSat-2* (8 April 2010), carrying a sophisticated radar altimeter (SIRAL), have opened the possibility of further enhancing the observation of the Earth's gravity field and changing ice masses (including free-board of drift ice). *GOCE* orbits are already computed with high precision on a routine basis, thereby strongly supporting mission operations and gravity field determination from a complement of gradiometer, GPS satellite-to-satellite tracking and star tracker observations. All instruments on board of *CryoSat-2* have been switched on successfully and first releases of SIRAL observations and DORIS-based orbits are being checked and scrutinized.

The successful launch of the German *TanDEM-X* radar mapping satellite in June 2010 will lead to operations in synergy with the *TerraSAR-X* satellite launched three years before. For optimally exploiting the data collected by this formation of two satellites, mm-precision baseline determination is required, for which the algorithms were successfully tested using data from the *GRACE* mission. Especially high-precision relative positioning of formations of satellites is a growing application field of precise orbit determination.

Finally, substantial efforts are being supported and reported by several space agencies (ESA, NASA) to reprocess orbits and data from many past and still flying Earth observing satellites to enable the newest insights, models and standards to be applied. This will provide strong support for the study of climate changes from already multi-decadal data records of satellites equipped, for example, with altimeters.

IX.2 Global Navigation Satellite Systems (GNSS)

Many activities are going on related to the maintenance, upgrade, development and implementation of global navigation satellite systems. The account below is just a selection about these activities and merely serves to provide an impression. The United States is continuing to maintain and upgrade its GPS network and is working to provide more frequencies for civil access (e.g. L5) to facilitate easier access to real-time high-precision positioning applications. The Russian Federation has launched many *GLONASS* satellites in previous years and it is foreseen that soon the full nominal constellation will be completely filled. In Europe, progress is being made

with the *Galileo* system and it is foreseen that, in the coming years, there will be a steady build up and implementation of its network. China is expanding its *COMPASS/Beidou* system. Also, other Asian-Pacific countries (India, Japan) and Brazil, for example, are actively developing and implementing (overlay) navigation satellite systems. It will be clear that efforts are required to coordinate all these systems in order to maximize the benefit for users world-wide. The UN International Committee on GNSS (ICG) is playing an active role and organizes regular meetings where the several GNSS providers can inform each other and coordinate their plans. COSPAR is represented in the ICG through its Panel on Satellite Dynamics.

IX.3 Solar System and Interplanetary Missions

Advances continue to be made in the field of precise orbit and gravity field determinations from Lunar and Mars orbiters. More and more data from the Japanese *Kayuga*/*Selene* mission are being analysed, resulting in improved orbit solutions and, especially, more detailed maps of the far side of the Moon (for which this mission provided, for the first time, tracking measurements by means of data relay techniques). The NASA *Lunar Reconnaissance Orbiter* (*LRO*) reached lunar orbit on 23 June 2009 and has now marked more than one full year of scouting on the Moon. *LRO* carries multiple laser technology components: a laser altimeter (LOLA) for topographic mapping and a laser transponder for one-way laser ranging (LR) by Earth-based tracking stations for precise orbit determination. In only the first year of the mission, *LRO* has gathered more digital information than any previous planetary mission in history. The *LCROSS* mission was launched together with *LRO*. Careful orbit planning led to a successful impact in the southern lunar crater Cabeus, thereby demonstrating the existence of water.

Continued analysis of tracking data from Mars orbiters such as *MGS* and *Mars Odyssey* has led to improved gravity field models for Mars and a better observation of temporal gravity field changes at very long wavelengths, which reflect, for example, the seasonal waxing and waning of the ice caps.

ESA and NASA continue to study the feasibility of the *LISA* mission which aims at the detection of gravitational waves. *LISA* is planned to comprise three satellites in a triangular formation with equal legs of about 5 million km at 1 AU distance from the Sun. The mission objectives require extremely precise inter-satellite ranging of the order of picometres (pm) to nanometres (nm), which might be achievable by Laser Doppler Interferometry (LDI). The *LISA* concept is not only very challenging from the point of view of observing the relative motion of its satellites, but also with respect to attitude and constellation control and maintenance.

IX.4 Outlook

The success of many future missions, be it single satellites or formations, relies on the capability of precise (relative) orbit determination and orbit/formation control. Concerning Earth orbiting satellites, one example is the *Swarm* mission, which aims at observing and better separating/interpreting the many sources that together form the continuously changing magnetic field of the Earth. This mission will consist of three satellites, a lower flying tandem to facilitate ‘differential’ magnetometry, and a higher satellite which strongly enhances the temporal sampling of the magnetic field. High-precision absolute and relative orbit determination will facilitate precise geo-location of the scientific observations. Moreover, precise orbit determination is required for accurately calibrating on-board accelerometers, which

will be used to derive thermospheric density and winds. In addition, a group of scientists from many parts of the world is actively participating in regular workshops pertaining to geopotential missions. This group is working on the preparation and submission of proposals to ESA and NASA for more advanced future gravity field satellites, relying on very precise inter-satellite laser ranging technology (precision level 10 nm or better) and advanced ultra-sensitive accelerometers (precision level better than 0.1 nms^{-2}).

An important development concerns the family of *Sentinel* missions that are planned in the framework of the European Union GMES programme. The first series of foreseen *Sentinel* missions includes a satellite carrying a C-band SAR (Sentinel-1) and altimeter (Sentinel-3), requiring fast and high-precision orbit solutions.

Further away from the Earth, a nice example is the NASA *GRAIL* mission, which can be seen as a *GRACE* mission to the Moon. *GRAIL* aims at very precise mapping and further improving knowledge of the lunar gravity field for both the near and far side of the Moon by inter-satellite tracking in combination with Earth-based tracking by the DSN.

It is evident that satellite dynamics and precise orbit determination continue to play an important, crucial role in the exploitation of artificial satellites, be it scientific or commercial.

X. SCIENTIFIC BALLOONING

International and national scientific balloon programmes continued their dynamic role in carrying out space research *via* the low-cost approach of flying payloads to heights of 20-50 km. Activities in 2009-10 reflected the vital contribution of scientific ballooning to space research. Fields of research included aeronomy, cosmic rays, astronomy and astrophysics, and the increasingly significant area of atmospheric sciences. Further important improvements were made in the development of materials and technologies to enable observing periods to be extended to several weeks.

The 'New Worlds, New Horizons in Astronomy and Astrophysics' report recently released by the National Academies in Washington, DC, recommended priorities for the most important scientific and technical activities of the next 10 years in astronomy and astrophysics. These include a balance of small-, medium-, and large-scale initiatives, with ground-based and space-based telescopes across the electromagnetic spectrum. The report noted that balloon programmes provide fast access to space for substantive scientific investigations and flight-testing of new technologies. Balloons are now perceived as offering major opportunities for advancing exoplanet observations. All these programmes provide a training ground for the principal investigators of tomorrow's major missions.

X.1 Flight Programmes and Missions

NASA flew 20 science and technology development balloon missions in the period covered by this report. The majority of these missions were heavy-lift flights, carrying science payloads upwards of 3,600 kg to altitudes of 36 km or more. The launch sites used were at McMurdo (Antarctica), Fort Sumner (USA), Kiruna (Sweden) and Alice Springs (Australia). NASA remains committed to its objective of achieving longer duration missions and expanded capabilities that can be offered to the scientific community. It increased its combined balloon mission average annual

long duration capability of around 800 hours to over 1200 hours.

The Indian National Balloon Facility (INBF) conducted seven balloon flights using balloons ranging in volume from 110,000 m^3 to 739,000 m^3. Four flights carried X ray astronomy payloads; one flight carried an optical remote sensing experiment, while the remaining two flights carried payloads to study regional atmospheric dynamics and composition. April 2009 marked fifty years of scientific ballooning in India, a total of 477 flights having been carried out since the first launch in April 1959.

The Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency (ISAS/JAXA) conducted eight balloon flights from the Taiki Aerospace Research Field (TARF) in Hokkaido. After 37 year of scientific ballooning at the Sanriku Balloon Center, TARF came into operation in 2008. The first two flights from TARF were dedicated to validating operational procedures while the remaining flights were conducted for scientific observations, technical verifications of space engineering, and new balloon development. The newly constructed balloon operations facility and the unique sliding launcher enabled the launch of larger balloons and heavier payloads than was previously possible.

The French Space Agency, *Centre National d'Etudes Spatiales* (CNES), conducted two high altitude balloon campaigns from the Swedish Space Corporation's Esrange Balloon and Rocket range. Eleven flights were carried out with zero-pressure balloons of volumes ranging from 35,000 m^3 to 400,000 m^3. The flights, devoted to the study of atmospheric chemistry, involved nine different European scientific payloads.

X.2 Technology and Mission Concepts

The NASA/Columbia Scientific Balloon Facility (CSBF) has implemented significant capability enhancements to its operations. A Micro-Instrument Package offers global communications between control centres and the balloon; this lightweight; low-power system provides increased opportunities for smaller payloads for extended duration missions. On board high density video recording systems now support technology development and provide general use capability for enhanced in-flight video use. The development of next generation pointed antenna systems able to communicate between the balloon platform and orbiting satellites is now well underway. New power systems that offer lower mass and higher efficiency at lower cost have been brought online.

A number of NASA super-pressure balloons have been test flown over the past two years. These flights have incorporated incremental changes to refine the balloon design. A record-setting heavy-lift super-pressure balloon test flight flew for over 54 days over Antarctica.

Besides scientific ballooning used for terrestrial missions, NASA/Jet Propulsion Laboratory (JPL) has been undertaking technology development of balloons capable of long-duration flights in the atmospheres of other planets, namely Venus, Mars and Titan, for over a decade To carry minimal sized payloads in the rarified Martian atmosphere, the balloon must have a large size, the material must be lightweight and strong, and the balloon must be deployed and inflated while descending into the planetary atmosphere. Significant progress by 2010 included construction of a number of 10 m and 12 m diameter balloons while several fully or partially successful aerial deployment and inflation tests have been conducted in the

Earth's stratosphere that reproduced the aerodynamic conditions in the Martian atmosphere.

NASA has led the development of balloon materials that can survive corrosive environments and withstand large solar flux variations, while maintaining the low permeability that is required for extended duration flights. NASA/JPL/Wallops Flight Facility and ILC Dover have pursued the development of a balloon for a Discovery-class mission to Venus in the middle cloud layer (55 km altitude) that could complete many high priority scientific objectives as identified in a number of NASA strategic studies. Finite element analysis and end cap burst tests have confirmed the balloon strength and verified that it will survive day-night solar flux variations on Venus. A successful aerial deployment and inflation test was also performed in the Earth's troposphere under aerodynamic conditions comparable to those to be expected at Venus. Collectively, these developments have matured the Venus balloon technology to the point where they can support a flight mission.

The Southwest Research Institute of San Antonio, Texas and Raven Industries, Inc. of Sioux Falls, South Dakota have continued work in the development of a stratospheric airship for small payloads and associated technologies.

INBF revived its tethered balloon activity in India for the calibration of indigenously- developed high altitude instruments, thus allowing real-time monitoring of various parameters by providing a physical connection to the ground equipment. An historic 'proof of concept' experiment in cellular telephony for future rural connectivity in India was carried out using a 275 m^3 balloon. A CDMA microwave-based trans-receiver system weighing 133 kg and radiating 17 watts power was hoisted to an altitude of 490 m. Direct communication between two stations separated by over 60 km was successfully established for the first time using conventional mobile phones, thereby providing an area coverage of ~8,000 m^2, 30 times greater than that available with a ground-based system.

A joint exercise for the evaluation of a world-wide stratospheric airship system and its possible development in India was taken up by several laboratories under the leadership of the Indian National Aeronautical Laboratory. The INBF was assigned the key task of developing the methodology for the airship launch and recovery, and lift-gas management for this project.

Balloon fabrication is an integral part of the INBF facility at Hyderabad which includes in-house production of all the key components as well as film characterization. Six balloons of volumes ranging from 109,755 m^3 to 739,039 m^3 were fabricated at the facility, two of these being supplied to an external vendor. A double-capped balloon of volume 598,039 m^3, capable of carrying a 2-tonne payload to an altitude of 36 km, was designed and manufactured for the first time. In addition, 64 balloons, each of volume 4,000 m^3, were fabricated from 4~6 μm thick film, for probing the upper atmosphere up to 43 km altitude.

INBF participated actively in the multi-institutional national project 'Cloud-Aerosol Interaction and Precipitation Enhancement Methodologies'. Phase I of the project was conducted between May and September 2009, and was devoted to intensive cloud and aerosol observations over various parts of India using balloon-borne sondes, and aircraft observations. 71 flights were carried out from different part of the country before, during and after the monsoon season.

CNES carried out several flights of zero pressure balloons to validate the efficiency of a new concept of tear panel at different rates of balloon deflation. The aim was to guarantee the complete deflation of balloon envelope after flight termination, thus speeding up the descent rate, and improving the landing position precision. The developed system is fully compliant with international aviation regulations which require two independent devices for flight termination.

In addition, CNES validated a stellar sensor in diurnal condition during the flight of an 800,000 m^3 volume balloon, in order to prepare for the first scientific flight of *PILOT* – a new astronomy gondola. The astronomy Fireball gondola, comprising a CNES pointing platform and a US scientific telescope, was successfully launched by CSBF from Fort Sumner.

In cooperation with JAXA, CNES started a feasibility study of a procedure for the recovery-at-sea of balloon envelope, flight train, housekeeping and the scientific gondola, following flight termination. The main goal is to increase the number of opportunities for balloon launches from CNES bases in France by reducing safety constraints during the flight termination phase, with a view to a landing in the Atlantic Ocean. This study deals with sea traffic regulation, organization of equipment retrieval using boats, and the modification of flight equipment to make it compatible with the marine environment.

CNES has developed a Tracking, Telemetry & Command system which permits the control and monitoring of long duration stratospheric balloon flights anywhere in the world, using the *Iridium* satellite system for communications. This system has been validated during a campaign with three super-pressure balloon flights, each lasting three months while circum-navigating the Earth. These 12 m spherical balloons were launched from the Seychelles Islands in February 2010, the flights being terminated in mid-May. The *Concordiasi* campaign, scheduled for September 2010, will be the next campaign to use this system, when 20 super-pressure balloons will be launched from McMurdo. The duration of each balloon flight is expected to be up to 6 months. CNES is developing a similar telemetry system for zero-pressure balloon flights, using two redundant links to *Iridium* and *Inmarsat* satellites.

ISAS/JAXA continued the development of ultra-thin polyethylene films for high altitude balloons floating in the mesosphere. The mechanical properties of such films were studied in detail, in order to verify the design of 60,000 m^3 balloons fabricated using 2.8 μm films, capable of reaching an altitude of 53 km with a 3 kg payload. ISAS/JAXA is also developing a lobed-pumpkin-shaped super-pressure balloon (SPB). After an unsuccessful engineering SPB flight in Brazil in 2007, a cap was added to the SPB envelope, in order to avoid possible damage to the film during launch operations. A 60,000 m^3 prototype SPB has been test flown from TARF. Future modifications include an additional cylindrical part to the equatorial region of the SPB balloon envelope. ISAS/JAXA are standardizing their balloon inventory to two sizes, a heavy balloon for heavy payloads, and a thin balloon for ultra-high altitude operations.

X.3 Scientific Research

In November 2008, the Advanced Thin Ionization Calorimeter collaboration led by Louisiana State University reported an unexpected abundance of high-energy electrons and positrons from space in the journal *Nature*. Using data collected during

long-duration balloon flights around Antarctica in 2000 and 2002, the researchers observed that these particles were 70 times more abundant at energies between 300 and 800 GeV compared to fluxes expected from extrapolations from lower energies. This result led to speculation that the electron excess could result from the collisions of dark-matter particles in the universe, or from acceleration from pulsars in some hitherto unknown manner. The *Fermi* Large Area Space Telescope also observed a similar excess in the electron flux, but not the abrupt feature reported by this experiment.

The international Cosmic Ray Energetics and Mass collaboration, led by the University of Maryland, reported a relative increase in the cosmic-ray flux at high energies rather than the continuous decrease expected from conventional models. It also observed that the energy spectrum for protons is different from those of helium and heavier nuclei. These new results were obtained with 156 days of exposure to the cosmic radiation above 99.5% of the atmosphere in five separate long-duration balloon flights over Antarctica. The results present a challenge to conventional models for the origin of cosmic rays in supernovae.

The Antarctic Impulsive Transient Antenna collaboration, led by the University of Hawaii, uses balloon-borne detectors flying around Antarctica to observe radio Čerenkov radiation from neutrino interactions in the Antarctic ice sheet (millions of km^3 of target). The primary scientific objective is to make the first definitive observations of neutrinos with energies greater than 10^{18} eV. Two engineering flights have been carried out from the Antarctica and further flights with improved sensitivity detectors are planned.

As part of the *Climate and Weather of Sun Earth System* (*CAWSES*) programme in India, INBF conducted experiments to study changes in the vertical distribution of ozone during the solar eclipses of July 2009 and January 2010. A solar eclipse provides a unique opportunity to enhance the current understanding of the photochemistry and dynamics of the atmosphere due to fast perturbations caused by the solar UV flux. This complex experiment required payloads to be stationed at heights of 11, 17 and 24 km during the eclipses.

Using a tethered balloon onboard a research vessel, INBF made the first ever *in situ* measurements of size-segregated vertical profiles of aerosols in the atmospheric boundary layer at five different locations over the Bay of Bengal. The experiment demonstrated large spatial variability in aerosol properties over the entire region. These measurements are highly significant as the Bay plays a prominent role in the Indian monsoon. The study of seasonal heterogeneities in black carbon over Hyderabad is being continued at INBF. The measured parameters show a high black-carbon/organic-carbon ratio, typical of a fossil fuel origin. Using back trajectory models, it was found that the sources for transported black-carbon aerosols originate in the Indo-Gangetic Plain.

The main goal of the CNES two-summer Arctic campaigns was the dynamical and chemical analysis of the polar stratosphere, in order to validate the existing models' ability to simulate the involved mechanisms properly. All the associated scientific instruments, devoted to atmospheric chemistry, were developed and operated by teams from the Centre National de la Recherche Scientifique. The instruments involved were *ELHYSA* – a hygrometer for measurement of vertical water vapour profiles, *SPIRALE* – an infrared absorption spectrometer for measuring trace gases traces, *LPMA*/*SWIR* – a Fourier transform spectrometer for measuring the

thermal atmospheric emission of the surface/atmosphere by troposphere sounding, *MicroRadibal* for the measurement of radiance and polarization of scattered sunlight to characterize stratospheric aerosols; *SALOMON*, a spectrometer for measuring aerosol extinction by ultra-violet spectral absorption, *ISAO* – a spectrometer for measuring stratospheric ozone; *STAC*, for *in situ* measurement of the concentration of aerosols between the medium stratosphere and the medium troposphere, and *LDLE* for electric field measurements.

ISAS/JAXA carried out three flights for scientific observations, namely polarized hard X-ray observation from the Crab Nebula, high-energy cosmic electron and atmospheric gamma-ray measurement by the bCALET-2 detector (a prototype of the CALET detector which will be installed as part of the Japanese Experiment Module /Exposed Facility on the *ISS*), and Venus atmosphere observations by a balloon-borne telescope. They also provided two flights for space technology demonstrations, one for a drag-free micro-gravity experiment system, and the other for a membrane aeroshell evaluation system.

ISAS/JAXA, in collaboration with Brazil's *Instituto Nacional de Pesquisas Espaciais* (INPE), has completed preparations for the launch of scientific balloon flights for the Far-infrared Interferometric Telescope astronomy experiment in 2010.

XI. POTENTIALLY ENVIRONMENTALLY DETRIMENTAL ACTIVITIES IN SPACE

This section is a report by the PEDAS Panel of COSPAR. It covers the time span from October 2008 to September 2010. It only addresses space debris issues, which have dominated PEDAS activities since the mid 1990s. The main focus has been on the evolution of the space debris environment, and on means to mitigate its growth rate and to remediate the risk of long-term collisional cascading.

In 2009, there were 75 successful space launches that released 123 objects, plus 72 launch vehicle stages, together with 140 miscellaneous items of debris into space. Of these, 32 objects (30 spacecraft and 2 rocket bodies) were injected into the geostationary ring. In the reporting two-year time span, the observable space debris population larger than about 10 cm, as provided by the US Space Surveillance Network (SSN) catalogue, has increased from 12,850 at the beginning of October 2008 to more than 15,500 (+21%). The corresponding annual increase is a factor of five higher than the average annual growth rate during space history (1961-2006). Positive trends in debris mitigation, particularly towards the end of this time span, were negated by China's ASAT test that destroyed their *Feng Yun 1C* weather satellite on 11 January 2007. Today, trackable fragments from this event alone contribute 2,941 catalogue fragments (19% of the catalogue). The environment was further harmed by the first collision in space history between two intact objects. On 10 February 2009, the active US satellite *Iridium 33* collided with the retired Russian satellite *Cosmos 2251*, yielding 1,822 catalogue fragments to date (12% of the catalogue). Both, the Chinese ASAT test (at 860 km altitude) and the *Iridium 33*/*Cosmos 2251* collision (at 780 km altitude) released a large number of fragments into an altitude regime that had top-ranking object concentrations already prior to these events. As a result, the risk of catastrophic collisions with operational spacecraft in neighbouring orbit altitudes increased significantly (e.g. by a factor 2 for ESA's remote sensing missions *ERS-2* and *Envisat*). This elevated risk level will persist for several decades, due to the low levels of airdrag at these altitudes, leading to a poor

aerodynamic cleansing effect that is aggravated by unusually low solar activity levels for the current solar cycle. Apart from the major *Iridium/Cosmos* collision, there were three more break-up events in 2009 and 2010, caused by a Russian Proton ullage motor, the Russian *Cosmos 192* spacecraft, and the Chinese *Yaogan 1* spacecraft. So far, however, the three events combined produced no more that 70 catalogue fragments. A very recent, unusual event occurred on 21 June 2010 involving a tank of a Russian Briz-M orbital stage. To date, 77 debris have been catalogued from this break-up.

The elevated concentration of space debris led to an increasing number of collision avoidance manoeuvres. In 2009, NASA performed eight evasive manoeuvres, one being for the Space Shuttle, and two for the *ISS*. Of the eight conjunction objects, six were break-up fragments, with three thereof due to the Chinese ASAT test and the *Iridium/Cosmos* collision. Within one year, due to their proximity to the break-up altitudes of the ASAT test and the collision, the ESA satellites *Envisat* and *ERS-2* alone performed five avoidance manoeuvres, three of those being within a two-week period in early 2010. The highest risk was associated with the conjunction of a Chinese CZ-2C orbital stage of 4 tons mass with the 8.1 ton *Envisat* in January 2010, at a predicted miss distance of less than 50 m, with a collision probability of 1 in 80, if no manoeuvre had been performed. A two-impulse avoidance manoeuvre, consuming 400 grams of hydrazine, led to a safe fly-by distance. In addition, the French space agency CNES had to conduct several avoidance manoeuvres, one of them being for their *Parasol* satellite.

The collision between *Iridium 33* and *Cosmos 2251* and the resulting risk increase to operational satellites spurred activities at the Joint Space Operations Center (JSpOC) of the US Space Command (USSPACECOM) to provide all registered satellite operators with reliable conjunction event alert messages. As of mid-2010, these messages contained 'actionable' orbit state and error covariance information with an accuracy and information content that allowed operators to plan evasive manoeuvres with significantly lower false alarm rates and much lower propellant consumption than in the past.

Of 19 spacecraft (8 USA, 6 Russia, 2 China, 1 France, 1 Sweden, and 1 Kazakhstan) that reached the end of their life in the geostationary (GEO) ring in 2009, 12 were raised into a graveyard orbit, in accordance with national and international space debris mitigation guidelines. For another four spacecraft, the orbit raising was insufficient. No attempt was made for three spacecraft that were left in orbits librating around the stable longitude at 75^{o} East, and for two GEO injection stages that were left in orbits which will permanently cross the protected region of ±200km around GEO. However, the general trend of GEO disposals has been considerably improving during the past 10 years. In the time span 1997-2002, only 29% of the retired GEO missions were properly disposed, whereas in 2003-2009 this share increased to 57%. While re-orbiting is the preferred disposal option for GEO missions, de-orbiting is the recommended option for low Earth orbit (LEO) missions. To comply with this guideline, CNES applied a proven de-orbiting concept to *SPOT-2*, based on experience with *SPOT-1*. The 9-impulse de-orbiting operations in 2009 took two weeks, leaving the 1.9 ton spacecraft in an orbit of 570 km × 796 km (from 825 km × 825 km originally), with a remaining lifetime of less than 25 years.

Most of the deterministic knowledge on objects orbiting the Earth is obtained from the US Space Surveillance Network (SSN) which, under best conditions, can

detect and track objects down to 5 cm in low-Earth orbit altitudes (LEO), and down to about 30 cm at geostationary orbit altitudes (GEO). The resulting SSN catalogue is fairly complete for object sizes larger than 10 cm in LEO and 1 m in GEO. One of the main elements of the SSN is a set of three VHF transmitters and six receivers distributed over the continental US along the 33rd parallel. This electronic fence will within a few years be replaced by a much more permanent S-band system that will be able to track LEO objects down to 2 or 3 cm in size. This upgrade is expected to lead to an SSN catalogue of more than 100,000 objects. It will significantly reduce the currently existing gap between object sizes that can be shielded (i.e. ≤ 1.4 cm for the US manned modules of *ISS*), and objects that can be systematically tracked and avoided through manoeuvres (i.e. ≥ 2 cm).

For object sizes that are below the SSN catalogue threshold, there is a strong need for statistical models of the space debris environment. The two most prominent of these models, NASA's Orbital Debris Environment Model (ORDEM) and ESA's Meteoroid and Space Debris Terrestrial Environment Reference model (MASTER) have extended their measurement databases and performed major upgrades in the past few years. They will soon become available as ORDEM-2010 and MASTER-2009 to provide further support to impact risk assessments of the space debris analyst.

Long-term projections of the space debris environment indicate that there are orbit altitudes, particularly between 700 km and 1000 km, where space debris concentrations have reached and exceeded critical levels. In such regions, full compliance with debris mitigation guidelines, and even a complete halt to launch activities may not be able to preserve a safe environment. Debris of critical sizes (≥ 10cm), which today contribute more than 60% to the SSN catalogue, will start colliding with large-size targets, yielding more fragments of critical sizes that further escalate the process through collisional cascading (the so-called 'Kessler Syndrome'). To preserve a long-term stability of the space debris environment, the removal (de-orbit) of mass from the LEO region is essential. Initially, this refers to operational payloads and rocket stages after mission completion. Later, this should also include the active removal of large-size, inert objects from orbit. The latter activity is denoted as 'space debris environment remediation'. A related study on remediation methods and their effectiveness is in progress at the International Academy of Astronautics (IAA).

The idea of space environment remediation was raised to the agenda of the Scientific and Technical Sub-Committee (STSC) of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) in 2009. A related working group was formed in 2010, under the chairmanship of South Africa, to address the issue of the 'sustainable use of outer space', with space debris as one of the major drivers. As a regular STSC agenda item, national delegations and multi-national agencies or organizations continue their annual reporting on debris mitigation practices and on the development of related guidelines, requirements or legal frameworks, such as the French Space Law that will enter into force in 2010.

Several conferences, symposia and workshops in 2009 and 2010 have dealt with space debris in general, and with space debris environment remediation in particular: the 5th European Conference on Space Debris (hosted by ESA, in Darmstadt/Germany, March 2009), the 60th International Astronautical Congress (hosted by IAF/IAA, in Daejeon/Republic of Korea, October 2009), the International Conference on Orbital Debris Removal (hosted by NASA/DARPA, in Chantilly/USA,

December 2009), the 4th IAASS Conference (International Association for the Advancement of Space Safety, in Huntsville/USA, May 2010), the ISTC Workshop on Space Debris Mitigation (International Science & Technology Center, in Moscow/the Russian Federation, April 2010), the 1st European Workshop on Active Debris Removal (hosted by CNES, in Paris/France, June 2010), and the 38th Scientific Assembly of COSPAR (Committee on Space Research, in Bremen/Germany, July 2010).

Principles on space debris mitigation are also important for the design, procurement and operation of spacecraft and launch systems. ISO (the International Organization for Standardization, TC20/SC14) is working on a set of standards governing the implementation for space debris mitigation measures. The top level International Standard IS-24113 was approved in 2010. Lower-level implementation standards will follow by the year 2011.

Space debris is a global problem, which requires international cooperation and coordination for the elaboration and implementation of effective mitigation and remediation measures. The prime mover in this respect is the Inter-Agency Space Debris Coordination Committee (IADC), which has eleven members from all the major space faring nations. They meet annually to facilitate technical information exchange, and they are recognized as a knowledge pool for international bodies, such as UNCOPUOS and ISO. The 27th meeting of IADC was held in April 2009, in Darmstadt/Germany, hosted by ESA/ESOC, and the 28th meeting was held in March 2010, in Trivandrum/India, hosted by ISRO.

The main efforts of the space debris community are today concentrating on ‘space debris mitigation’ to control and reduce the population growth rate, and on ‘space debris environment remediation’ to remove already existing mass, particularly from low Earth orbits, and thus prevent collisional cascading, with the aim of maintaining an environment that will allow the sustainable use of outer space into the long-term future. Significant technological, financial and legal efforts will be required to achieve this goal. However, there is no viable alternative to secure the continued service from a space infrastructure that has become indispensable in everyday life.

XII. RADIATION BELT ENVIRONMENT MODELLING

Radiation belt modelling is in continuous progress, mainly due to the increasing number of available simultaneous multi-point *in situ* measurements and also due to the combination of complementary measurements (particles, waves, magnetic and electric fields etc.). Because it has become clear that wave-particle interactions play a major role in radiation belt electron dynamics (‘killer electrons’), most efforts have concentrated on describing all waves including both ULF and VLF present in the radiation belts and their detailed interactions with trapped electrons. Therefore, recent studies have led to an improvement in understanding global electron belt dynamics. Nevertheless, it is still difficult to reproduce, in detail, *in situ* observations because the magnetic field and waves can vary very quickly. Of course, more investigations are required and will be conducted in the future to refine the global description of the entire system (magnetic field topology and dynamics, waves distribution etc.) influenced by solar activity.

Over the past four years, a new hot topic has developed: data assimilation techniques adapted to the radiation belts. An ever-growing number of groups want to take advantage of hard-earned knowledge from oceanography and meteorology to

apply mature data assimilation methodology to the radiation belts. First attempts have already provided promising results. Such results are expected to be used to develop new engineering specification models alongside new empirical-statistical specification models, with capabilities and accuracy beyond the quasi-standard AE8/AP8.

Thanks to the increasing understanding of the global inner radiation belt system, and also because important outstanding questions have been clearly identified, it is now possible to envisage new dedicated missions in the radiation belts. To help scientists push progress forward, several new missions are planned in various countries. The Radiation Belts Storm Probes (part of NASA's Living With a Star programme) plan to make the necessary measurements in an ideal, GTO-like orbit on two identical vehicles. Also, because having simultaneous multiple measurements available is crucial, other countries have developed plans to provide complimentary measurements. In Japan, *ERG* (*Energization and Radiation in Geospace* satellites); in Russia *RELEC* (transient luminous event phenomena and energetic particles impacting the upper atmosphere) and *RESONANCE* (study of wave-particle interactions and plasma dynamics occurring along the same field line and within the same flux tube); and in Canada, *ORBITALS* (Outer Radiation Belt Injection, Transport Acceleration and Loss Satellite) missions have been proposed. According to current plans, most of these missions should fly at the same time, with launches scheduled during the next solar maximum (2012-2014). In most cases, instrument design is already complete and addresses current prime science requirements. In parallel, science teams have been set up to work out how these large new data sets will be stored and shared for the widest possible use by the community. At this stage, the COSPAR Panel on Radiation Belt Environment Modelling provides guidelines for standard particle data file format and particle measurements analysis and a forum for exchange of ideas, plans, and proposed mechanisms for data collecting and sharing.

XIII. SPACE WEATHER

This section highlights developments in the field of Space Weather that occurred in 2008-2010. Space weather can be defined as the 'conditions on the Sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health' [US National Space Weather Programme].

The domain of space weather includes many aspects from scientific research through to the engineering application of such research and, ultimately, the development of operational services. As we move towards the next solar maximum, work is ongoing to raise awareness of the prospective impacts of space weather on man-made systems.

XIII.1 Recent Solar Minimum

The recent 2008-2009 solar minimum period has displayed some unusual characteristics, and extended longer than expected, which led to considerable discussion about the nature of the upcoming solar cycle. The Solar Cycle 24 Prediction Panel, consisting of an international group of experts, reached a consensus in 2009 that this cycle would peak in May 2013, and be of lower than average intensity. At the same time, the observed sunspot number decreased until mid-2009,

following the previous maximum in 2001. The sunspot number began to increase at the end of 2009, and is expected to rise from now on towards the maximum of cycle 24. In order to explain the slow onset of the new cycle, Howe *et al.* (2009) compared flows observed in the upper solar convection zone during this and the previous minimum, finding that the new cycle flows have been moving more slowly towards the equator than during the previous cycle resulting in a gradual increase in the apparent cycle length during 2007-2008. Despite the slow build up of solar cycle 24, some evidence (Savcheva *et al.* 2009) has already been reported using *Hinode* spacecraft's X-ray telescope (*XRT*) showing solar cycle 25 emerging flux visible on the solar disk as early as 2008, thus indicating that solar cycle processes are continuing despite the extended period of very low sunspot numbers.

Observations from the ESA-NASA *Ulysses* mission's 3rd orbit during 2007-2008 showed that the solar wind had lower density and pressure than was measured during the previous solar minimum (McComas *et al.* 2008). Combining *Ulysses* data with that from the NASA *ACE* mission located at the L1 Lagrangian point indicated that this was a global solar phenomenon. The rate of coronal mass ejections also appears to be lower by a factor of two as observed with the *SECCHI/COR* 2 coronagraph on board the NASA *STEREO* mission when compared to the *SOHO*/*LASCO* rate recorded in 1996, excluding jet type coronal transients.

Studies of interplanetary space have been made using the IPS (Inter-Planetary Scintillation) technique. The STE Laboratory at Nagoya University is using four large UHF antennas located in Japan to study the solar wind as well as CME propagation in the interplanetary space. They have recently presented information on the long-term variation of the solar wind's 3D structure including CMEs, which is applicable both to space climatology and space weather.

XIII.2 Space Weather Modelling

Space weather modelling as well as numerical simulation is important both for our understanding of space weather phenomena and for moving towards the implementation of such models in an operational context.

Activities in both domain specific models and coupled modelling frameworks, such as the Space Weather Modelling Framework (SWMF), are showing considerable advances. Increasingly, Space Weather is making use of advanced computing architectures such as the newly opened Flanders ExaScience lab in Belgium, partnering university groups with industry, where space weather models will be used to test the performance of advanced computer systems. Metrics studies provide an important tool in translating research models into applications. Initiatives supported by the US Community Coordinated Modelling Centre (CCMC) in association with the GEM and SHINE workshops are some recent good examples.

In response to the growing need for detailed reliable information on ionospheric conditions, ESA recently supported a study to review existing ionospheric models and to look at the necessary improvements, including how new and existing sources of data could be accommodated to improve these models. Performance tests were carried out on a number of models with the aim of identifying optimal modelling techniques, and recommendations were formulated for future monitoring activities.

The NOAA Space Weather Prediction Center, in partnership with various universities, the CCMC, and other US government agencies, is implementing a model of solar wind disturbances. The Wang-Sheeley-Arge-Enlil-Cone model will, for the

first time, enable operational, physics-based-model predictions of the arrival at the Earth of large solar wind disturbances. This model will facilitate one- to three-day advanced warnings of large geomagnetic storms that can damage the electric power infrastructure and impact numerous other space-based and ground-based activities.

XIII.3 Data Availability and Service Provision

NOAA space-based assets have continued to provide continuous publicly-available space environment data. This is complimented by a space environment monitor onboard the EUMETSAT *MetOp-A* spacecraft, the data from which is also available *via* the NOAA Space Weather Prediction Center. Space weather monitoring continues to make extensive use of data collected from networks of ground-based observatories (solar, geomagnetic, ionospheric) as well as scientific space-based instruments.

Solar wind monitoring from a point upstream of the Earth, for space weather nowcast and forecast, continues to be a key data source for space weather prediction. Current activities rely on data from the NASA *ACE* spacecraft located at the L1 Lagrangian point, which is currently the primary source of near-real time data and has been in operation since its launch in 1997. In an effort to replace the aging *ACE* satellite, the US is pursuing a partnership with NASA, NOAA, and the US Air Force to launch the *Deep Space Climate Observatory* (*DSCOVR*). The currently expected launch date for *DSCOVR* is December 2013.

The NASA *Solar Dynamics Observatory* (*SDO*), launched on 11 February 2010, carries a suite of instruments that will further our understanding of the solar dynamics that drive variability in the Earth's environment leading, *inter alia*, to a better understanding the solar cycle and investigating the conditions for the generation of solar activity. In addition to the scientific goals of the mission, a subset of the data will be available to forecasters in a beacon mode, allowing their incorporation into existing monitoring and forecasting tools.

ESA´s *PROBA-2* (Project for Onboard Autonomy) spacecraft was launched into a Sun-synchronous orbit on 2 November 2009. It is the second in a series of technology demonstration missions which are testing new technologies for satellites and systems in-flight. In addition, the scientific payload consists of two instruments for solar observation (*SWAP* and *LYRA*) and two instruments measuring the local plasma environment (*DSLP* and *TPMU*). These are currently making regular measurements and data are being made available *via* the science centre located at the Royal Observatory of Belgium, where the solar observations are also incorporated into operational forecasts.

The *STEREO* spacecraft continues to observe the Sun and interplanetary environment. The orbit has now taken both spacecraft out to approximately an 80º separation angle from the Earth allowing extended visibility of the solar disk and the inner heliosphere.

JAXA's space environment monitors are maintaining their provision of continuous publicly-available space environment data. The data from seven JAXA satellites are available *via* JAXA's Space Environment and Effects System (SEES).

Service provision and dissemination continues to be primarily supported through the International Space Environment Service (ISES). Members of ISES currently comprise 13 Regional Warning Centers and the European Space Agency´s

Space Environments and Effects Section, which acts as a collaborative expert centre. The latest regional warning centre joined in 2009 and is represented by INPE, Brazil.

XIII.4 International Cooperation and Cross-disciplinary Projects of Interest

In 2007, an informal working group on the long-term sustainability of space activities was set up to discuss and formulate an outline document to be presented for consideration by the Scientific and Technical Sub-Committee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). At its meeting of 7-8 February 2008, the group invited ISES to make a presentation on the relevance of space weather for the long-term sustainability of space activities. Space weather was formally accepted as a topic to be included in the outline document and ISES was invited to participate in the work of the informal working group. The final draft was distributed to COPUOS/STSC delegations in February 2010. The STSC decided to set up a formal working group on the issue of long-term sustainability of space activities and this group met for the first time on 14 June 2010, in parallel with the COPUOS plenary session in Vienna.

In 2010, an IAA study group was initiated with the aim to prepare a comprehensive, trans-disciplinary review of the present understanding of space weather-related events and their effect on human activities for different societies and for different economic sectors. The study will be performed in an international context and will review both national and international activities with a view to furthering international cooperation across the space weather domain. The study also aims to provide policy makers with a range of options dealing with space weather effects and providing balanced information to the public, press and governments, particularly in developing countries, about space weather causes and consequences. Two meetings have been held and the format of the study report is being discussed.

After the formal recognition of ‘space weather’ as an area of relevance to World Meteorological Organization activities, the WMO set up an Inter-Programme Coordination Team on Space Weather. The team initially comprised representatives from Belgium, Brazil, Canada, China, Colombia, ESA, Ethiopia, Finland, ICAO, ITU, OOSA, the Russian Federation and the United States. The team started its activities in May 2010. Initial discussions concentrated on an exchange of views concerning its role of and the appropriate interpretation of the terms of reference. These were given by WMO as follows:

(a) Standardization and enhancement of space weather data exchange and delivery through the WMO Information System (WIS);

(b) Harmonized definition of end products and services, including (for example) quality assurance guidelines and emergency warning procedures, in interaction with aviation and other major application sectors;

(c) Integration of space weather observations, through review of space-based and surface-based observations requirements, harmonization of sensor specifications, and monitoring plans for observations;

(d) Encouraging dialogue between the research and operational space weather communities.

The team has started to compile a list of observational requirements that are needed to develop and maintain a service of space weather monitoring and forecasting. This list will be added to the list maintained by WMO in an effort towards

standardizing names and definitions of geophysical parameters and of instrument types in order to facilitate the review of requirements, instrument plans, and related gap analysis. This work is currently ongoing.

There is a continued and growing interest in space situational awareness, in particular in Europe and the United States as the importance of space objects and environment effects on key assets is increasingly being recognized. In 2009, ESA embarked on a new Space Situational Awareness Preparatory Programme which includes a space weather element. Over the course of the programme (2009-2012), studies and activities will be carried out to develop a coordinated network of space weather services and also to investigate the measurement infrastructure required for a full scale programme.

With the support of the European Commission´s 7th Framework Programme, several space weather related studies are on-going or are expected to start in late 2010 or early 2011. These focus on a range of areas and are complementary to the activities supported by ESA. In addition, the EC COST (Coordination in Science and Technology) Office Action ES0803 supports European coordination of research underpinning the development of products and services in Europe. A further COST Action 'Towards a more complete assessment of the impact of solar variability on the Earth's climate' is expected to start in the near future. In this new and multidisciplinary action, atmospheric and space physicists will work together on the connection between Sun and climate. In addition, the THESEUS EC-supported study is working towards an integrated life sciences research roadmap to facilitate European human space exploration in synergy with ESA strategy, taking advantage of the expertise available in Europe and identifying the potential of non-space applications and dual research and development. Expert groups cover a range of domains including space weather. The individual thematic reports will then be integrated into a final European roadmap document.

Following the conclusion of the successful *International Heliophysical Year* (*IHY*) in 2007, the *International Space Weather Initiative* (*ISWI*) is a new programme of international cooperation to advance space weather science through a combination of instrument deployment, analysis and interpretation of space weather data from the deployed ground-based instruments in conjunction with space data. A strong emphasis is being placed on communicating the results to students and the public. The goal of the ISWI is to develop the scientific insight necessary to gain a better understanding of space weather phenomena, and to reconstruct and forecast near-Earth space weather. This includes instrumentation, data analysis, modelling, education, training, and public outreach.

The Planeterrella is an experiment which recently won a European award for outreach. This is a polar light simulator inspired by Birkeland's Terrella experiment. It allows simulation of auroras on planets with many magnetic configurations. It also allows the reproduction of stellar as well as of magnetospheric mechanisms (see http://planeterrella.obs.ujf-grenoble.fr). Several copies have been constructed and more are planned in the coming period.

XIV. PLANETARY PROTECTION

Planetary protection is concerned with biological interchange in the conduct of solar system exploration, including: (1) possible effects of biological and organic constituent contamination of planets other than the Earth, and of planetary satellites within the solar system; and (2) contamination of the Earth by materials returned from outer space carrying potential extraterrestrial organisms. This area of space policy and its implementation accord with the provisions of Article IX of the United Nations Outer Space Treaty of 1967, which states that:

"*…parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose…*"

Recent discoveries about the adaptations of life on Earth to extreme environments, data suggesting the potential for liquid water to have existed on and near the surface of Mars in recent times, and the continuing evidence supporting the existence of a liquid water ocean on Europa and warm ice on Enceladus all suggest that the contamination of other solar system bodies is possible and could jeopardize future scientific investigations. Furthermore, the potential for life elsewhere in the solar system demands prudence in the planning and execution of missions that will return materials from other bodies in the solar system to Earth.

During the period from September 2008 to August 2010, a variety of missions to other solar system bodies were launched in compliance with the planetary protection policy that is maintained by COSPAR (http://www.cosparhq.org/scistr/PPPolicy.htm) in support of the objectives of the UN Outer Space Treaty. In the COSPAR policy, the concern for contamination is given from Category I (no concern) through Category IV (greatest concern; landing spacecraft), with Category V reserved for Earth-return missions.

Solar system exploration has entered a new era of activity and multinational cooperation. A number of the missions under consideration are targeted to bodies that have significant interest with respect to the origin of life and chemical evolution, and the potential for biological studies. Over the past several years, a number of international teams have developed joint mission concepts to several targets in the outer solar system as well as international sample return missions from Mars or its moons. International cooperative missions are in operation to many targets including inner planets, comets, asteroids, and the giant planets and their moons.

COSPAR has an important role as the standard-setting international organization in the area of planetary protection – a required reference for international missions to such bodies. The Panel on Planetary Protection was formed in 1999 to consolidate and further develop the COSPAR planetary protection policy. As initially envisaged in the early 1960s, the COSPAR policy has come to form the basis for international agreements on provisions to protect other solar system bodies from Earth-source biological contamination, and to protect the Earth from potential extraterrestrial biological contamination. Accordingly, the Panel (with the assent of the COSPAR Bureau and Council) has become the forum within which the *de facto* international standard for planetary protection is forged and promulgated.

In addition to providing specific guidelines that incorporate policy requirements for solar system bodies that merit protection, the COSPAR policy recommends that launching parties provide information to COSPAR about the procedures and computations used for planetary protection for each flight. The COSPAR policy forms the basis for planetary protection measure to be undertaken consequent to bilateral or multilateral agreements for joint solar-system exploration missions, and has been employed for agreements between space agencies including CNES, CSA, DLR, ESA, JAXA, NASA and RSA.

Recent activities of COSPAR focus on two areas of planetary protection. One is on further policy development and the explicit maintenance and promulgation of the COSPAR policy. At the COSPAR Scientific Assembly in Bremen, July 2010, the Panel on Planetary Protection passed resolutions on several modifications to the policy that were subsequently recommended to the COSPAR Bureau, and will be further considered for adoption in March 2011. A resolution on technical changes to the COSPAR Policy of July 2008 was developed, including provisions that change neither the scope nor the nature of the requirements to be imposed on missions, but make the policy more explicit and comprehensive. In recognition of the potential relevance of planetary exploration to areas of human activity beyond science, the benefits of developing a parallel policy on ethical aspects of planetary exploration was discussed, based on recommendations from an international workshop that COSPAR initiated to explore these issues.

A second activity involves the dissemination of knowledge about the COSPAR policy and its implementation. This has been undertaken under the broad charter of the Panel on Planetary Protection, which continues to function as an essential meeting ground for space agencies conducting solar system exploration missions intent on understanding the potential for life, and life-related molecules within Earth's own neighbourhood. At the 2010 COSPAR Assembly, several resolutions were presented to the Bureau on expanding communication with the international community about the COSPAR's planetary protection policy and related activities, including plans for enhancing awareness through activities funded by COSPAR. Proposals for two workshops, to be held over the next two years, were accepted by the Bureau: one on establishing acceptable risk levels for a Mars Sample Return mission, and another follow-on workshop to develop foundational ethical principles applicable to planetary exploration.

XIV.1 Significant Mission Events

In general, events are reported for missions in Category II or above. However, in consideration of the recent reassignment by COSPAR of missions to Venus and the Earth's Moon (from Category I to Category II), information is provided on missions to those bodies that were originally designated as Category I.

NASA's *Phoenix* mission, a Category IVc lander, landed on the north polar plains of Mars and operated during the fall and winter of 2008, accessing the Martian subsurface *via* vertical mobility, with a robot arm that had been sterilized prior to launch and kept sterile until the lander reached Mars. Orbital imaging of the lander throughout the Martian winter and into the spring documented the winter ice-cover, which resulted in the collapse of the lander's solar panels. The *Phoenix* mission confirmed that high concentrations of water ice are present cm below the surface of the northern plains of Mars, and the data suggest the presence of perchlorates, energy-

carrying compounds that are used as food by Earth organisms and represent a potential energy source for organisms on Mars.

The NASA *MErcury Surface Space ENvironment, GEochemistry, and Ranging* (*MESSENGER*) mission has completed three Mercury flybys and is set to become the first spacecraft to orbit the planet Mercury, on 18 March 2011. *MESSENGER* is designated Category II due to several encounters with Venus en route to Mercury. Data from the Mercury flybys have provided new views of the planet, including confirmation of extensive volcanism in its history. *MESSENGER* is the second spacecraft to encounter Mercury, with the third (BepiColombo) being prepared by ESA for launch early in the next decade (2013).

JAXA's *Hayabusa* mission successfully returned to Earth on 13 June 2010, landing in Australia. The mission encountered asteroid 1998/Itokawa (formerly 1998 SF36) in August 2005 and undertook scientific investigations of the asteroid. Possible asteroid particles, that may have been collected in the sample return capsule despite some anomalies with spacecraft operations, are being investigated at the JAXA Sagamihara Campus sample containment facility. The return phase of this mission (Category V) had been designated as 'unrestricted Earth return' within the COSPAR policy framework following consultation with the Panel in 2002.

NASA's *Deep Impact*/*EPOXI* mission (Category II) performed an Earth flyby and gravity assist on 27June 2010, en route to a close encounter on 4 November 2010 with comet Hartley-2, which will be investigated using all three of the spacecraft's instruments. On the journey to Hartley-2, the *Extrasolar Planet Observations and Characterization* (*EPOCh*) segment of the mission used the larger of the two telescopes on *Deep Impact* to search for Earth-sized planets around a number of stars selected as likely candidates for such planets.

A number of lunar missions would be designated Category II under the revised 2008 COSPAR planetary protection policy, although these missions retained the Category I designations that were provided under the previous iteration of the policy. Lunar missions tend to be of short duration, due to gravitational anomalies that destabilize orbits, resulting in eventual lunar impact. These missions are:

• JAXA's *SELenological and ENgineering Explorer* (*Selene*), now known as *Kaguya*, was launched by an H-IIA rocket on 14 September 2007, and entered lunar orbit on 4 October. The major objectives of the *Kaguya* mission are to obtain scientific data with respect to the origin and evolution of the Moon, and to develop technology for future lunar exploration. *Kaguya* consists of the orbiter at about 100 km altitude and two small satellites (Relay Satellite and *VRAD* Satellite) in polar orbit. *Kaguya* descended to 50 km altitude from 1 February 2009 and then descended again to 10 -30 km in lower altitude (perilune) from 16 April 2009, finally impacting into the south-east of the near side of the Moon on 10 June 2009 (GMT).

• CNSA's *Chang'e 1* mission was scheduled to end in November 2008, but continued operating to 1 March 2009 when it impacted the surface of the Moon. Data gathered by *Chang'e 1* was used to create the most accurate and highest resolution 3-D map ever created of the lunar surface. *Chang'e 1* analysed the abundance and distribution of elements on the lunar surface and investigated characteristics of the lunar regolith.

• ISRO's *Chandrayaan I* spacecraft, a collaborative enterprise with a number of international partners, was launched in October 2008 and entered lunar orbit in

November 2008. On 14 November 2008, the Moon Impact Probe separated from the *Chandrayaan* orbiter and struck the lunar south pole near Shackleton Crater. The mission operated until August 2009, surveying the lunar surface to produce a detailed map of its chemical characteristics and 3-dimensional topography. The polar regions are of special interest as they appear to contain water ice.

• NASA's *Lunar Reconaissance Orbiter* (*LRO*) was launched in February 2009, with the objectives of finding safe landing sites for future human missions, locating potential resources, and characterizing the radiation environment of the Earth's Moon. The *Lunar CRater Observation and Sensing Satellite* (*LCROSS*) was launched on the same vehicle that carried *LRO*. LCROSS guided the launching rocket's upper stage to impact into the lunar surface near the south pole, and made observations while flying through the debris plume that provided data about the composition of the Moon, including indications of water ice.

XIV.2 Other Missions in Operation

Other missions currently in operation and of primary interest for planetary protection are listed below.

The NASA/ESA *Cassini* mission (Category II), continues in orbit around Saturn for an extended mission that will permit observations of Saturn's equinox and additional close encounters with a number of Saturn's moons, including Titan and Enceladus. Warm regions at Enceladus's south pole have been found by *Cassini* to spout water ice that forms the Saturnian E ring, and conclusive evidence has been obtained for hydrocarbon lakes on Titan. Detailed investigation of these phenomena continues to be a high priority from the standpoint of both science and planetary protection.

The NASA *Mars Odyssey* mission (planetary protection Category III) continues its mission–science phase in orbit around Mars. Results from *Odyssey* continue to document widespread hydrogen beneath the surface at medium to high Martian latitudes, which was confirmed as water ice by the *Phoenix* lander. The spacecraft also continues to act as a communications relay for landers on the planet's surface. Over 80% of all Mars Exploration Rover data has been relayed through *Mars Odyssey*, as well as a significant fraction of *Phoenix* data.

ESA's *Mars Express* orbiter (Category III) continues is mission science activities in polar orbit around Mars, in providing high resolution views of Mars through its stereo camera system and other instruments, and sounding the Martian subsurface with its long-wave radar. The mission extension has been approved until end of 2012. A further extension until end of 2014 is expected. The mission continues to meet orbital lifetime requirements in its 300 km x 10,000 km elliptical orbit.

The two NASA *Mars Exploration Rover* (*MER*) missions (planetary protection Category IVa) continue to operate on the Martian surface. Results from *Opportunity* demonstrated the past presence of standing liquid water on Mars, and that the rover continues on a long-range traverse towards a large impact crater. *Spirit*, on the other side of Mars, has not communicated with Earth since March 2010, when it entered a low-power state due to the advent of the Martian winter at its location. Power levels should be increasing as the rover experiences Martian spring, and communication may resume early in 2011. The two solar-powered spacecraft completed all science objectives within their nominal (90-sol) missions and, now in their seventh Earth year, continue on extended missions.

The NASA *Mars Reconnaissance Orbiter* (*MRO*) continues its science mission. Its initial science orbit was incompatible with orbital lifetime restrictions, so *MRO* has met total bioburden requirements, as per the COSPAR policy. Data returned by *MRO* have provided critical information for identifying a safe landing site for the Mars *Phoenix* mission and are being used to similarly to support other Mars lander missions, including *MSL* the NASA Martian (*Curiosity*) rover, the joint ESA-NASA *ExoMars* missions, and a future *Mars Sample Return* mission. Data from *MRO* have dramatically increased our understanding of conditions on the early Mars, which may even now be a more hospitable place for life than was previously suspected.

The ESA *Rosetta* mission (Category III due to Mars gravity assist) continues on its 10½-year comet odyssey to 67P/Churyumov-Gerasimenko. The mission, which will include the first soft landing, *in situ* analysis, and panoramic images from a comet's surface, is due to reach the four-km diameter comet in May 2014.

NASA's *Stardust New Exploration of Tempel-1* (*Stardust NExT*) (Category V) mission will visit, in February 2011, the comet P/Tempel-1 that was impacted by a projectile from the *Deep Impact* mission in July 2005. The *Stardust NExT* investigation will provide the first look at the changes to a comet nucleus resulting from its close approach to the Sun, and will mark the first time a comet has ever been revisited. The mission also will extend the mapping of Tempel-1, making it the most mapped comet nucleus to date, and refining our view of what comets are, and where and how they formed.

ESA's *Venus Express* mission (Category II) continues in orbit around Venus. *Venus Express*'s science objectives are to study the atmosphere, the plasma environment, and the surface of Venus in great detail. Data obtained by *Venus Express* recently demonstrated that Venus is still geologically active, contributing to our understanding of comparative planetology for Venus, Earth, and Mars.

NASA's *New Horizons* mission to Pluto (Category II) continues on its way to encounter Pluto in July 2015. The piano-sized *New Horizons* probe carries seven science instruments. On reaching Pluto and Charon, *New Horizons* will return the first detailed data on the surface properties, geology, interior makeup and atmospheres of these two bodies. After the Pluto/Charon flyby, *New Horizons* has the potential for an extended mission to investigate other Kuiper-Belt objects during the period 2016-2020.

NASA's *Dawn* mission (Category III due to a Mars gravity assist) continues on course, using an ion propulsion drive to reach the two main-belt asteroids Ceres and Vesta. *Dawn* is expected to reach Vesta in August 2011, and is planned to depart Vesta in May 2012 for an insertion into orbit around Ceres in February 2015. *Dawn's* goal is to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets remaining intact since their formations.

The CNSA's *Chang'e* 2 probe launched on 1 October 2010, carrying an upgraded payload from *Chang'e 1*, is expected to enter a 100 km orbit around the Moon, with subsequent lower orbits planned. The mission is intended to test key technologies, and acquire additional data in preparation for future surface activities.

XIV.3 Missions in Development/Planning

The RSA's *Phobos-Grunt* sample return mission is planned for launch in 2011 and includes a mini-satellite from CNSA, as well as experiments provided by DLR, CNES, and The Planetary Society (a non-governmental organization based in the USA). The mission's objectives are to collect soil samples from Phobos, a satellite of Mars, and to bring the samples back to Earth for comprehensive scientific research into Phobos, Mars and the Martian ~~space~~ environment. The *Phobos-Grunt* mission is expected to meet COSPAR's orbital lifetime requirements for missions to Mars, and the sample return portion is expected to meet requirements for Category V 'unrestricted Earth return'. Plans by RSA and The Planetary Society to send viable Earth organisms and communities on the round-trip mission are receiving considerable attention from the standpoint of planetary protection.

Work continues at NASA's Jet Propulsion Laboratory for the Category IVc *Mars Science Laboratory* (*MSL*) scheduled for the 2011 launch opportunity to Mars. This multi-instrument-carrying rover is anticipated to make a soft landing on Mars in 2012, and is intended to drill into Martian rocks. The plan for *MSL* to carry a cache that could store interesting samples for a potential future return mission has resulted in additional planetary protection assays that are intended to permit identification of Earth organisms that might be found in returned samples after a round-trip journey.

NASA's next Discovery-class mission, the *Gravity Recovery and Interior Laboratory* (*GRAIL*), is scheduled to launch in 2011. *GRAIL*, which has received a Category II designation, will map the gravitational field of the Moon using paired orbiting spacecraft.

NASA's *Lunar Atmosphere and Dust Environment Explorer* (*LADEE*) mission is also expected to launch in 2011, and will orbit the Moon to characterize the atmosphere and lunar dust environment. As Category II missions, both *GRAIL* and *LADEE* will generate an inventory of organic materials (>1kg) carried by the spacecraft, as well as provide documentation of mission operations and the final disposition of the spacecraft.

NASA's Juno mission (Category II) will launch in 2011, fly by Earth for a gravity assist in 2013, and arrive at Jupiter in 2016. Juno will map the gravity field, magnetic field and atmospheric structure of Jupiter from a unique polar orbit. These observations should lead to a better understanding of the formation of our solar system and planetary systems discovered around other stars. To avoid contamination of Europa and other icy Jovian satellites, NASA plans to deorbit the spacecraft into Jupiter at end of mission.

As part of NASA's Scout Program, development of the *Mars Atmosphere and Volatile EvolutioN* (*MAVEN*) is continuing as a Category III mission implementing bioburden control. The mission is scheduled for launch in late 2013, and will provide detailed information about the Martian atmosphere and its climate history, as well as its potential habitability.

ESA and NASA are developing a joint set of missions to Mars for launch in 2016 and 2018. The 2016 *ExoMars* mission, under the leadership of ESA, is to be launched from the USA and will have an orbiter (Category III) and a lander that will not access any Mars special regions and has no life detection capability (Category IVa). The 2018 mission, under the leadership of NASA, also to be launched from the United States, will have a set of rovers intended to search for life and to cache

samples for a future Mars sample return mission, that are landed on Mars with a carrier vehicle. The mission is Category IVb and thus will not access Mars special regions.

The *BepiColombo* mission, currently under development (Category II due to Venus gravity assist), is a joint mission between ESA and JAXA under ESA leadership, with two orbiters. Expected launch is in 2014 with arrival at Mercury in 2019.

XV. CAPACITY BUILDING

This section reports on the principal activities of the COSPAR Panel for Capacity Building, which manages COSPAR's capacity-building programme and organizes sessions on this and related topics at COSPAR assemblies. The capacity-building programme is a collaboration between COSPAR, IAU and OOSA.

XV.1 COSPAR Capacity-Building Workshops

These workshops are primarily intended to enable young scientists from developing countries to use archives of space data from current and past missions which are readily available to all comers *via* the internet and which are an indispensable asset for world-class research in most areas of space science. The workshops are practical in nature and aim to provide direct experience of accessing the archives and of the analysis tools required to use them. While those attending are selected on a regional basis, they are jointly funded by COSPAR, the host country, and a variety of other agencies. Generally speaking, an effort is made to relate them to a major project in, or a national policy objective of, the host country. The topics of the workshops cover the full range of science within COSPAR's remit. In the case of Earth observations, emphasis is given to the basic science which underpins applications.

Since the 2008 COSPAR assembly in Montréal, there have been two workshops in the two-year period covered by this report. The 10th COSPAR Capacity-Building Workshop on Planetary Surface Science was held in Harbin, China, from 6 to 19 September 2009, co-directed by Professor Norbert Kömle and Professor Cui Pingyuan. The workshop was held in the Deep Space Exploration Research Center (DSRC) – a department of the Harbin Institute of Technology (HIT). A total of 32 student participants and 10 lecturers and tutors took part. The former included eight from India and 10 from China, the reminder coming from Indonesia, Pakistan, the Russian Federation and Vietnam. The team of lecturers and tutors consisted of two experts from India, two from the United States and seven from European countries. The workshop focused on several actual space missions, in particular on the recent Moon-orbiting missions from the Chinese and Indian space agencies, *Chang'e-1* and *Chandrayaan-1*, respectively. The workshop offered an opportunity to exchange experiences and discuss results gained from these two missions. Other topics presented were associated with the latest NASA Mars Mission *Phoenix* and with the NASA Mars Rovers *Spirit* and *Opportunity*, which provided unprecedented insights into the nature of the Mars surface at low and mid latitudes. The third major topic was ESA's comet mission *Rosetta* and its lander *Philae*, which currently carries a large suite of instruments to the short period comet Churyumov-Gerasimenko, where it will arrive in 2014. DSRC provided a pleasant working environment. The participants completed an evaluation questionnaire at the end of the workshop, and both that and their individual comments made it clear that they had all found the workshop useful

and expected to use what they had learned in their future research. The travel costs of the participants were funded by COSPAR, IAU and OOSA, while local costs for food, accommodation and social events were covered by the Harbin Institute of Technology (HIT) and the Chinese Academy of Sciences (CAS). A webpage containing the presentations and student projects given at this workshop is available at http://astro.hit.edu.cn/cospar2009workshop. It will be maintained by HIT/DSRC for later reference to the workshop material.

The 11th COSPAR Capacity-Building Workshop on 'Data Analysis of the *Fermi* Gamma-ray Space Telescope' was held in Bangalore, India from 8 to 19 February 2010, co-directed by Professor Mariano Mendez and Professor Biswajit Paul. The principal objective of the workshop was to introduce young scientists to space-based gamma-ray astronomy and to provide them with training and experience on the analysis of data from the *Fermi* gamma-ray space telescope.

30 participants were selected from about 80 applicants by a five-member committee and all 30 selected candidates attended the workshop for the entire duration. 17 of the participants were from the host country, other 13 from China, Egypt, Indonesia, Republic of Korea, South Africa and Turkey. There were 13 female and 17 male participants. The lectures and data analysis training were provided by 15 scientists from India, Europe and the United States, including six who are actively involved with *Fermi* in various capacities. A total of 30 one-hour lectures were delivered on basics of high energy and gamma-ray astrophysics, gamma-ray instrumentation and instruments onboard *Fermi*, and data analysis guidance. The participants learned and carried out data analysis projects on various topics with archival data from *Fermi*. For the data analysis sessions, running for 4 to10 hours every day of the workshop, four groups were formed who worked on different types of objects: Active Galactic Nuclei, Gamma-ray Bursts, pulsars, and X-ray binaries. Each group had between two and four supervisors and at least one instructor for each group was from the *Fermi* team.

An evaluation of the workshop by the participants clearly showed that they had found the lectures very useful for learning about high energy astrophysics, gamma-ray astronomy and analysis of the data from *Fermi*. On the last day of the workshop, the participants made presentations based on their data analysis projects. Five presentations, that included future plans for using data from the *Fermi* observatory, were made from the four groups which represented the work carried out by all the participants.

The workshop venue was an 'eco-resort' at a distance of about 30 km from Bangalore. The lecturers and participants had a pleasant, isolated stay during the workshop. Individual desktop computers were arranged for each participant with moderate internet bandwidth. Most of the data required for analysis was downloaded in advance and the analysis software was pre-installed on each computer. The workshop was co-sponsored by the Raman Research Institute, COSPAR, IAU, NASA's Goddard Space Flight Centre, and OOSA. Additional financial sponsorship came from the Harbin Institute of Technology, the Chinese Academy of Sciences, the Raman Research Institute and Goddard Space Flight Centre. Overall, it was a very successful workshop and everybody involved in its organization looks forward to see the participants use this expertise in their future research.

COSPAR extends its thankful notes to the organizers of the workshops and their lecturing teams as well as to the members of the local organizing committees.

Both workshops took place within the framework of the on-going collaboration with the IAU and OOSA. The total number of developing country scientists who have participated in the Capacity-Building Programme is now well over 300, and among them many are now participating at COSPAR assemblies to give lectures.

The following three further workshops have been approved for 2010 and 2011:

- Earth Observation Understanding of the Water Cycle, to be held at FUNCEME Fortaleza, Ceará, Brazil, in November 2010, proposed by Antonio Geraldo Ferreira, Ernesto López-Baeza and Jérôme Benveniste;
- Remote Sensing of Atmospheric Aerosols: From Science to Applications, to be held at Sharda University, Delhi, India, in January 2011, proposed by Ramesh Singh and S K Mishra;
- X-ray Astrophysics, to be held at San Juan, Argentina in July 2011, proposed by Gerardo Juan Manuel Luna, Juan Facundo Albacete-Colombo and others.

The X-ray Astrophysics workshop will be held nearly 10 years after the first COSPAR workshop, which much was on the same topic, and also held in South America. It is particularly notable for the fact that the two co-directors who were students at that first workshop are now pursuing successful careers in X-ray astronomy.

XV.2 COSPAR Fellowship Programme

There has been a continuing need to ensure that participants who have started research projects with supervisors as part of the workshop activities could subsequently visit their supervisors' laboratories in order to continue the collaboration. To meet this need, a new COSPAR Fellowship programme was agreed by the Bureau in March 2008 for a trial period of two years, and in March 2010 it was confirmed as a permanent part of the Capacity-Building Programme. The Fellowhip programme provides for young scientists who have attended a workshop to pay visits to their supervisors for a period from two to four weeks. The funding for this is a joint effort between the receiving labs, COSPAR and the home country. So far, 14 laboratories in Europe, India and the United States have signed up to the programme, and 4 countries (China, India, Egypt and Turkey) have agreed to support travel costs. The first round of applications was received in September 2008; since then, 13 fellowships have been approved and 11 visits have taken place. The fellowship conditions include a requirement for a report on the scientific outcome of each visit. Although there have been some difficulties regarding visa issues and security requirements by some laboratories, the programme proves to meet a real need and targets to have 5 to 10 fellowships each year.

XV.3 Personnel

At the Bremen assembly, COSPAR Bureau appointed a new group to undertake the management of the Fellowship programme for the next four years. This group consists of:

- PBC Chair: Mariano Mendez
- Vice-Chair (Solar System and Magnetosphere): Ondrej Santolik
- Vice-Chair (Astronomy): Carlos Gabriel
- Vice-Chair (Earth Observation): Pierre-Philippe Mathieu
- Vice-Chair (Fellowships): Randall Smith

XV.4 COSPAR Scientific Assembly in Bremen

A two-day session - *PCB1 "From Ground-based facilities to Space observations"*- was held at the COSPAR Scientific Assembly in Bremen, Germany, that was announced as follows: "Many countries have ground-based facilities whose observations are paralleled by those from space (cosmic rays => heliospheric monitoring, ionosphere => magnetosphere). The meeting would explore experience of ways in which ground facilities can act as a springboard for either construction of space instruments or analysis of archival data (with emphasis on relevance to developing countries)." During the planning, it was decided to focus the Assembly around two topics: 1. Galactic cosmic rays and 2. Ionosphere and magnetosphere. Sufficient scientific papers were received to justify expanding the Assembly to a total of three half-days with a further half-day session dedicated to contributions related to matters of space policy, the kind of scientific papers that have been sought after at a number of recent assemblies in the past.

Detailed planning as well as the conduct of the whole session at Bremen was undertaken by Marius Potgeiter (Potchefstroom, South Africa) and Peter Sutcliffe (Hermanus Magnetic Observatory, South Africa). Both the invited and the contributed talks in the Cosmic Ray/Ionosphere-magnetosphere sessions were of a high standard, and the sessions attracted up to 30 people, though the number fluctuated due to people shuttling between sessions. Substantial support was received for financial grants; enabling some good papers to be delivered which otherwise would have had to be cancelled. The final session on space policy was particularly well attended, contrary to past experiences. COSPAR extends its thanks to the organisers, their assistants in the organizing committee, the invited and contributing speakers in making the session a successful component of what was a successful assembly.

XVI. EDUCATION

Much of the activities in space education around the world have been focused on the so-called K-12 (primary to secondary education), public outreach and graduate education. In the United States, the main funding for graduate education *via* fellowships has come from NASA's Graduate Student Researcher Programme managed principally from NASA centers. Likewise, funding for undergraduate student research has arisen from Undergraduate Student Researcher Programmes also managed by the NASA centers. K-12 education from NASA and its subsidiary agencies from the Space Grant Consortia has led to published lessons on the solar system, spectra and black holes, intended for students and teachers. In other efforts by NASA, summer space camps called *ASTRO camps* have encouraged young scientists to take an interest in environmental and space science. Microgravity research using drop towers for school students is funded by the *DIME* (*Dropping In a Microgravity Environment*). Efforts funded by NASA and the National Science Foundation have led to public awareness programmes, notably the NOVA programmes. The Challenger Center's network continues to create 'Learning Centers' throughout Canada, the United Kingdom and the United States with an emphasis on teacher training programmes.

Several space science programmes in Europe also aim at K-12 education. The first *European Space Education Resource Office* (*ESERO*) was opened at NEMO, the National Science and Technology Centre (NCWT) in Amsterdam, the Netherlands in 2006. Here, as in the Challenger centers, a major aim is teacher training. University

student activities include 'hands-on projects' on a variety of studies executed on microgravity platforms, atmospheric balloons and sub-orbital sounding rockets.

Japan's space agency JAXA established a Space Education Center in 2005 which serves as a base for working with school teachers. The Space Education Center is located within the Sagamihara Campus of JAXA which focuses on the K-12 range. The International Conference on Space Technology and Utilization (ISTS), started by Japan in 2009, continues to feature projects by Japan on space science outreach.

The *Space Technology and Research Students* programme (*S*T*A*R*S_* was launched several years ago to enable American and Chinese students to collaborate on science studies and space research, the internet. This programme will provide a unique blend of space-originated news, information and, education content.

Efforts by India have led to a community science centre in Ahmedabad for space education in addition to the launching of an education satellite (*Edusat*).

XVII. EXPLORATION

With the construction of new infrastructures, transport systems, and space probes to explore the Earth-Moon-Mars space, both robotically and with humans, we are entering a new era of space exploration. Many national space agencies are currently defining roadmaps and exploration architectures to plan ahead for future decades. At this point, it is vital to create a long-term sustainable space exploration programme involving international cooperation. Apart from the existing alliances of established space nations, the engagement of emerging and developing countries at an early stage and in a meaningful way will be a pillar to support a sustainable global space exploration programme.

The COSPAR Panel on Exploration (PEX) was created in 2008 at the COSPAR Assembly in Montréal. The mandate of the Panel is to provide independent science input to support a global space exploration programme while working to safeguard the scientific assets of our solar system. PEX compiled a report in June 2010 entitled: 'Toward a Global Space Exploration Programme: A Stepping Stone Approach', which is available from COSPAR at http://cosparhq.cnes.fr.

PEX has proposed a stepping stones approach of activities that support the transition period toward larger space architectures. The stepping stones include Earth-based analogue research programmes preparing for planetary exploration, an *International Space Station* (*ISS*) exploitation programme enabling exploration science, an international *Cubesat* programmes in support of exploration, as well as more complex endeavours – such as human outposts. Several of these preparatory activities should involve a wide range of actors from the global space community.

Space exploration is a multifaceted endeavour and a 'grand challenge' of the 21st century. The political agendas of a growing number of nations highlight space exploration as a goal and frame it as an international cooperative adventure. Activities during the last two years are leading to important decisions for a future global space exploration programme. In October 2010, the consultation process between the European Commission (EC) and the European Space Agency (ESA) on space exploration was to be continued with a high-level conference in Brussels. This conference will further define Europe's future in space exploration and its position within the international space exploration community. Japan's space policy and the exploration roadmap of the Japan Aerospace Exploration Agency (JAXA) are

currently under review. The Canadian Space Agency (CSA) is implementing its new space plan to participate in human and scientific exploration of the Moon, Mars and asteroids. During a meeting in Tokyo in March 2010, heads of *ISS* partner agencies agreed to plan for the prolongation of the *ISS* until 2028, concluding that they share a 'strong mutual interest in continuing operations and utilization for as long as the benefits of *ISS* exploitation are demonstrated'. All space partners involved in the *ISS* are engaging in new programmes that prepare for research during its prolonged lifetime. Finally, the International Academy of Astronautics (IAA), which is celebrating its 50th anniversary, is preparing for a 'Space Agency Summit' in November 2010 that will address four key areas, among which are 'Human Space Flight' and 'Planetary Robotic Exploration'. The target is to reach broad consensus on international cooperation in order to consider new concrete initiatives.

U.S. President Barack Obama took the National Aeronautics and Space Administration (NASA) in new directions with his Fiscial Year (FY) 2011 Budget Request. The latest plan includes new destinations for human space exploration such as near-Earth asteroids and focuses on technology development and creating opportunities for the commercial sector. NASA's Exploration Systems Mission Directorate (ESMD) is planning robotic precursor missions to the Moon, Mars and near-Earth asteroids to scout targets for future human activities as well as identify the hazards and resources that will determine the future course of human expansion beyond Low Earth Orbit (LEO). Long-term cooperation between NASA and ESA has been initiated through the Mars Exploration Joint Initiative. This programme provides a framework that will expand the collective capabilities of the two agencies as they jointly define and implement their scientific, technological and programmatic goals for Mars exploration. Launch opportunities during the 2016 to 2020 time frame should ultimately lead to a multi-element Mars sample return mission within the next decade.

Europe's space exploration environment is not only evolving and but is currently under review in a joint effort between ESA and the EC. ESA is the main scientific user of the *ISS* and has recently contributed a number of main infrastructure parts such as the Columbus laboratory, the *Automatic Transfer Vehicle* (*ATV*) and the *Cupola* observation module. ESA has not yet defined specific exploration targets beyond LEO, apart from the aforementioned cooperation with NASA to send an orbiter and two rovers to Mars under the *ExoMars* programme during this decade.

A number of orbiter, lander and sample return missions are being prepared by China, India, Japan and the Russian Federation. Russia's *Phobos-Grunt* mission will be launched in 2012 to return samples from the Martian moon Phobos and Japan's *Hayabusa* spacecraft recently returned to Earth in June 2010 with a potential sample from the asteroid Itokawa. Several lunar orbiter or lander missions are planned for this decade, including China's *Chang'e-2*, India's *Chandrayaan-2* (as a part of Russia's *Luna Resource-1* mission) and Japan's *Selene-2* and *Selene-3.* Contact and *in situ* robotic missions to the Moon are also envisaged for later in this decade, such as China's *Chang'e-3* (lander) and *Chang'e-4* (sample return) as well as *Russia's Luna Resource-1* (Russian lunar lander with Indian orbiter) and *Luna Resource-2* (Russian lander, rover and retransmitting satellite).

In addition to historical space-launching powers such as the Russian Federation and the United States, newcomers including China and India are now pursuing or considering pursuing human space exploration. China performed a three-

person extra vehicular activity (EVA) mission on *Shenzhou-7* in 2008. In 2011, China will launch Tiangong-1, its first space lab module, followed by an unmanned Shenzhou-8 to dock with it. China plans to deploy an inhabited space station around 2020. India's budget for pursuing human space exploration is currently under discussion.

With all of the activity taking place in the human exploration of the solar system, there are still some essential activities that have not yet been adequately covered in the programmes of international space agencies. For example, the efficient preparation on Earth and in low Earth orbit of analogue missions and test-beds so necessary to execute a successful space exploration programme. Such programmes should also allow countries with limited space capabilities to engage in space exploration and educate and excite their young generation. Extreme environments on Earth often provide similar terrain conditions to landing/operation sites on the Moon and Mars. Expertise obtained from Earth-based field research campaigns world-wide should be exploited to generate a coordinated international exploration test-bed.

Through its 7th Framework Programme, the European Commission (EC) has supported a project 'Coordination Action for Research Activities on Life in Extreme Environments (CAREX)'which is designed to encourage cross-disciplinary interests in microbes, plants, and animals in diverse marine, polar, and terrestrial extreme environment as well as in outer space. The Scientific Committee on Antarctic Research (SCAR) is charged with the coordination of scientific research in Antarctica and provides international, independent scientific advice to the Antarctic Treaty system and other bodies. CAREX and SCAR can serve as excellent models for Earth-based research programmes that pursue compelling scientific goals in taxing environments and prepares for future robotic and human exploration of the Earth-Moon Mars space.

Securing the science-based exploitation of the *ISS* using recently integrated facilities and an enhanced crew of six provides opportunities to advance our knowledge of living and working beyond LEO. Contributing to this objective is the coordination enterprise entitled – 'Towards Human Exploration of Space: a European Strategy' (THESEUS), which is funded by the European Commission 7th Framework Programme and executed by the European Science Foundation (ESF), both being active in defining an integrated life sciences research roadmap. The US National Research Council (NRC) is providing science directions for US space exploration in the next decade through the decadal survey on 'Biological and Physical Sciences in Space'. COSPAR will investigate how scientists from developing countries could be integrated into research activities with *ISS* partners.

As a means of effecting world-wide collaboration on small missions, an international *CubeSat* programme in support of exploration can act as a model that could be particularly interesting for less-advantaged partners, such as small space agencies and developing countries. Participation in planetary analogue field operations, science experiments on the *ISS* and science payloads for small satellites can provide ample opportunities for developing countries that are financially limited in their participation in global space exploration programmes while enabling mature space actors to tap into a global robotics talent pool. COSPAR's Exploration Panel will support the UN-Basic Space Technology Institute (BSTI) programme by helping to compile science payload databases.

In summary, PEX has elaborated a bottom-up approach to strengthen a long-term global space exploration programme, by offering opportunities to integrate many countries and stakeholders into scientific investigations of the Earth's space environment. COSPAR unites institutions from 44 countries and works with numerous associated bodies and, in this way, can provide and engage a world-wide scientific network in cooperative enterprises. To this end, COSPAR's Panel on Exploration organizes workshops, issues official reports and helps engage developing countries in the world-wide space exploration efforts.

CONTRIBUTORS

The report submitted by the International Astronautical Federation (IAF) for Part Highlights in Space Technology and Applications for 2010 was prepared by Scott Hatton of the IAF (for Tetsuo Yasaka, Vice-President, Technical Activities of IAF and Stanislav Konyukhov, Vice-President, Scientific Activities), and was approved by Berndt Feuerbacher, President of the IAF.

The International Institute of Space Law (IISL) contributed to the section on International cooperation and space law and was prepared by Sylvia Ospina, Member of the IISL Board of Directors. Information was compiled from submissions of IISL Members and other sources. The IISL contribution is intended to highlight important events, and does not pretend to be all-inclusive. The IISL regrets any inconsistencies and/or omissions it may contain.

Part Two of the report (Progress in Space Research 2009-2010) was prepared by the Committee on Space Research (COSPAR) and provides an overview of the progress in the various disciplines of space research science during the years 2009 and 2010. The report is organized in a manner that reflects the scientific domains of COSPAR's Scientific Commissions and Panels. Although many people contributed to this report, the major part of the scientific input was provided by the following persons:

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COSPAR expresses its gratitude to all those who contributed to the report but particularly to the above named persons and to R.A. Harrison (UK) and C. Argent (UK) who edited the report.

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

ACE	Advanced Composition Explorer
ABC	net Astrobiology Lecture Course Network
ACES	Atomic Clock Ensemble in Space
ACES-2	Auroral Current and Electrodynamics Structure
ACS	Advanced Camera for Surveys
AFRL	Air Force Research Laboratory
AGILE	Astro-rivelatore Gamma a Immagini Leggero (ASI)
AIA	Atmospheric Imaging Assembly
AIM	Aeronomy of Ice in the Mesosphere
Akari	Previously known as ASTRO-F or IRIS - InfraRed Imaging Surveyor (JAXA)
ALTEA	Anomalous Long Term Effects in Astronauts' central nervous system
AMIE	Advanced Moon micro-Imaging Experiment
AMISR	Advanced Modular Incoherent Scatter Radar
AMS	Alpha Magnetic Spectrometer
ANDE-RRA	Atmospheric Neutral Density Experiment Risk Reduction - Active
ANDE-RRP	Atmospheric Neutral Density Experiment Risk Reduction - Passive
API	Artificial Periodic Irregularities
ANGKASA	National Space Agency of Malaysia
APXS	Alpha Particle X-ray Spectrometer
Ar	Argon
ARGOS	Advanced Research and Global Observation Satellite
ASAT	Anti-Satellite
ASI	Agenzia Spaziale Italiana/Italian Space Agency
ASPERA	Analyser of Space Plasma and Energetic Atoms
ASR	Advances in Space Research (the official journal of COSPAR)
ASTEP	Astrobiology Science and Technology for Exploring Planets
Astro F	See Akari
ASTP	Apollo-Soyuz Test Project
ASTRO-H	X-ray observation satellite, formerly NeXT/SXS (Japan)
ASTROSAT	Planned multiwavelength astronomy satellite (India)
ATV	Automatic Transfer Vehicle
AU	Astronomical Units
BATSE	Burst and Transient Source Experiment
bCALET	balloon-borne CALorimetric Electron Telescope
BepiColombo	Proposed ESA/JAXA Mercury orbiter (2013)
BESS	Balloon-borne Experiment with a Superconducting Spectrometer
BIOS-3	Closed ecosystem at the Institute of Biophysics in Krasnoyarsk, Siberia
BLAST	Balloon-borne Large Aperture Sub-millimeter Telescope
BSTI	Basic Space Technology Institute
CALET	CALorimetric Electron Telescope
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CARE	Charged Aerosol Release Experiment
CAREX	Coordination Action for Research Activities on life in Extreme Environments
CAS	Chinese Academy of Sciences

CASCADES-2	the Changing Aurora: in Situ and Camera Analysis of Dynamic Electron precipitation Structures
CAWSES	Climate and Weather of the Sun-Earth System
CCD	Charge Coupled Device
CCMC	Community Coordinated Modelling Centre
CDMA	Code division multiple access
CEDAR	Coupling, Energetics and Dynamics of Atmospheric Regions
CELSS	Controlled Ecological Life Support Systems
CEOS	Committee on Earth Observation Satellites
CEST	Central European Summer time
CFOSAT	China-France Oceanography SATellite
CH_4	methane
CHAMP	Challenging Mini-Satellite Payload (for Geophysical Research and Applications)
CHAMPS	Charge and Mass of meteoric smoke Particles
Chandra	X-Ray Observatory (NASA)
Chang'E1	Lunar orbiter (China)
Chang'E2	Lunar rover (China)
Chang'E3	Lunar soft lander and rover (China)
Chang'E4	Lunar sample return mission (China)
ClO_4	perchlorate
CIRA	COSPAR International Reference Atmosphere
CISM	Center for Integrated Space Weather Modelling
CIXS	Chandrayaan-1 Imaging X-Ray Spectrometer
CLAF	Centro Latinoamericano de Fisica
CLRTAP	Convention on Long-Range Transport of Air Pollutants
CME	Coronal Mass Ejection
CNES	Centre Nationale d'Etudes Spatiales (French Space Agency)
C/NOFS	Communications/Navigation Outage Forecasting System
CNRS	Centre National de la Recherche Scientifique (France)
CNSA	China National Space Administration
COMS	Communication, Ocean and Meteorological Satellite
COROT	COnvection, ROtation & Planetary Transits (France)
CONAE	Comisión Nacional de Actividades Espaciales (Argentina)
COS	Cosmic Origins Spectograph
COSMIC	Constellation Observing System for Meteorology, Ionosphere and Climate
COSPAR	Committee on Space Research
COSPAR C2	COSPAR Commission C2 - The Earth's Middle Atmosphere and Lower Ionosphere
COST	Coordination in Science and Technology (EC)
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
COTS	Commercial Orbital Transportation Services
CREAM	Cosmic Ray Energetics And Mass
CRYOSAT-2	Cryogenic Satellite (ESA satellite to measure Arctic ice)
CSA	Canadian Space Agency
CSBF	Columbia Scientific Balloon Facility (formerly National Scientific Balloon Facility NSBF)
CTIM	Coupled Thermosphere-Ionosphere Model
CTIP	Coupled Thermosphere-Ionosphere Plasmasphere
CTX	Context Camera

CubeSat	miniaturised cubic satellite for space research
DARPA	Defense Advanced Research Projects Agency (USA)
D-CIXS	Demonstration of Compact Imaging X-ray Spectrometer
D-region	lowest region of the ionosphere
DECLIC	Dispositif pour l'Etude de la Croissance et des Liquides Critiques
DELTA-2	2nd Dynamics and Energetics of the Lower Thermosphere in Aurora
DEMETER	Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions
DICE	Dynamic Ionosphere Cubesat Experiment
DIME	Dropping In Microgravity Environment
DIXI	Deep Impact Extended Investigation of comets
DLR	Deutsches Zentrum fuer Luft-und Raumfahrt (German Aerospace Centre)
DMSP	Defense Meterorological Satellite Program
DOAS	Differential Optical Absorption Spectroscopy
DOE	Department of Energy (US)
DORIS	Doppler Orbitography and Radio-positioning Integrated by Satellite
DSN	Deep Space Network
DSCOVR	Deep Space Climate Observatory
DSERC	Deep Space Exploration Research Center
DSLP	Dual Segmented Langmuir Probe
EARP	European Accelerator-based space Radiation biology Programme
EC	European Commission
ECOMA	Existence and Charge State of Meteoric Dust Particles in the Middle Atmosphere
ECSS	European Committee on Scientific Standards
EDUSAT	Education satellite (India)
EIS	EUV Imaging Spectrometer
EISCAT	European Incoherent Scatter
EIT	SOHO's Extreme ultraviolet Imaging Telescope
EJSM	Europa Jupiter System Mission
ELHYSA	Etude de l'Hygrométrie StrAtospherique--a hygrometer for measurement of vertical water vapour profiles (CNRS/CNES)
ELIPS	European Programme for Life and Physical Sciences
Envisat	ENVIronmental SATellite
EO	Earth Observation
EPDP	Electric Propulsion Diagnostic Package
EPIC	Equatorial Processes Including Coupling
EPOCh	Extrasolar Planet Observations and Characterization
EPOXI	combined DIXI/EPOCh mission
ERG	Energization and Radiation in Geospace (Japan)
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESERO	European Space Education Resource Office
ESF	European Science Foundation
ESMD	Exploration Systems Mission Directorate
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
ETI	Electrodynamics Thermosphere Ionosphere
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUV	Extreme Ultraviolet

eV	electron volts
EVA	extra vehicular activity
EVE	Extreme Ultraviolet Variability Experiment
EXO-Mars	ESA Exobiology mission to Mars (Planned launch 2011)
F-region	highest region of the ionosphere
far-IR	far Infra-Red
FISM	Flare Irradiance Spectral Mode
FLIP	Field Line Inter-hemispheric Plasmasphere
FORMOSAT2	Remote sensing satellite, formerly ROCSAT-2 (Taiwan Province of China)
FPEF	Fluid Physics Experiment Facility
FSL	Fluid Science Laboratory
FUNCEME	Fundação Cearense de Meteorologia e Recursos Hídricos / Ceara's Foundation for Meteorology and Water Resources (Brazil)
FUSE	Far Ultraviolet and Spectroscopic Explorer (NASA)
FY	fiscal year
G	Earth gravity
GAIM	Global Assimilation of Ionospheric Measurements
GALEX	Galaxy Evolution Explorer (NASA)
GAW	Global Atmospheric Watch
GCOS	Global Climate Observing System
GCMP	GCOS Climate Monitoring Principles
GCPM	Global Core Plasma Model
GEM	Geospace Environment Modelling
GEMS	Gravity and Extreme Magnetism SMEX
GEO	Geostationary Earth Orbit
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
Geotail	ISTP magnetotail mission (ISAS/NASA)
GeV	giga electronvolt
GFZ	GeoForschungsZentrum (Helmholtz-Zentrum Potsdam)
GHz	gigahertz
GI	Guest Investigator
GIOVE	Galileo In-Orbit Validation Element
GITM	Global Ionosphere Thermosphere Model
GLAST	Gamma-ray Large Area Space Telescope
GLONASS	Global Navigation Satellite System (Russia)
GMES	Global Monitoring for Environment and Security
GMT	Greenwich Mean Time
GNM	Global Numerical Model
GNSS	Global Navigation Satellite System
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environmental Satellite
GOES	Geosynchronous Operational Environmental Spacecraft
GP-B	Gravity Probe B
GPID	Global Plasmasphere Ionosphere Density
GPS	Global Positioning System
GR	General Relativity
GRACE	Gravity Recovery and Climate Experiment
GRAIL	Gravity Recovery and Interior Laboratory

GRS	Gamma Ray Spectrometer
GSFC	NASA Goddard Space Flight Center
GTO	Geosynchronous Transfer Orbit
GUVI	Global Ultraviolet Imager
HAARP	High Frequency Active Auroral Research Program
Halca	Highly Advanced Laboratory for Communication and Astronomy (Japan) formerly VSOP
Hayabusa	An ISAS/NASA mission to bring back a sample of asteroid 1998/Itokawa. (Formerly MUSES-C)
HCN	Hydrogen Cyanide
Herschel	Formerly FIRST (Far Infra Red and Submillimeter Telescope) (ESA)
HEUVAC	High-resolution version of the solar EUV irradiance model for Aeronomic Calculations
HF	High Frequency
HF Radar	A decametric waves radar
Hinode	Observation mission with optical, X-ray and EUV telescopes (JAXA), formerly Solar-B
HiRISE	High Resolution Imaging Science Experiment
HIT	Harbin Institute of Technology (China)
HMI	Helioseismic and Magnetic Imager
HRSC	High Resolution Stereo Camera
HST	Hubble Space Telescope (NASA/ESA)
HST-SM4	Hubble Space Telescope Servicing Mission 4
HY-2	Hai Yang-2 satellite
IAA	International Academy of Astronautics
IAASS	International Association for the Advancement of Space Safety
IADC	Inter-Agency Space Debris Coordination Committee
IAF	International Astronautical Federation
IASI	Infrared Atmospheric Sounding Interferometer
IAU	International Astronomical Union
IBER	Preliminary study of Investigations into Biological Effects of Radiation
IBEX	Interstellar Boundary Explorer
IBMP	Institute of Biomedical Problems (Russia)
ICAO	International Civil Aviation Organisation
ICCHIBAN	InterComparison for Cosmic-ray with Heavy Ion Beams At NIRS
ICES	International Conference on Environmental Systems
ICESat	Ice, Cloud and Elevation Satellite
ICG	International Committee on GNSS
ICSU	International Council for Science (formerly International Council of Scientific Unions)
IHY	International Heliophysical Year
ILC Dover	A Dover, Delaware-based company
ILWS	International Living With a Star program
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
INBF	Indian National Balloon Facility
INPE	National Institute for Space Research (Brazil)
INSAR	Interferometric Synthetic Aperture Radar
INTEGRAL	International Gamma Ray Astrophysics Laboratory imaging and spectroscopy project (ESA)
IPCC	Intergovernmental Panel on Climate Change

IPS	Inter-Planetary Scintillation
IPY	International Polar Year
IR	Infrared
IRAS	Infrared Astronomical Satellite
IRI	International Reference Ionosphere
ISAO	spectrometer for the measurement of the stratospheric ozone
ISAS	Institute of Space and Astronautical Sciences (Japan)
ISCS	International Solar Cycle Study
ISES	International Space Environment Service
ISGP	International Society of Gravitational Physiology
ISO	International Organization for Standardisation
ISPR	International Standard Payload Rack
ISR	Incoherent Scatter Radar
ISRO	Indian Space Research Organisation
ISS	International Space Station
ISSI	International Space Science Institute
ISTC	International Science and Technology Center (Russia)
ISTP	International Solar-Terrestrial Physics programme
ISTS	International Symposium on Space Technology and Science (Japan)
ISWI	International Space Weather Initiative
ITM	Ionosphere, Thermosphere and Mesosphere
ITRF	Internationational Terrestrial Reference System
ITU	International Telecommunications Union
IUCAA	Inter-University Centre for Astronomy and Astrophysics
IVIDIL	Influence of Vibrations on Diffusion in Liquids
IXO	International X-Ray Observatory
IZMIRAN	Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation (Russia)
JARE	Japanese Antartctic Research Expedition
JAXA	Japan Aerospace Exploration Agency
JB	Jacchia-Bowman Thermospheric Density Model
JB2008	Jacchia-Bowman Thermospheric Density Model 2008
JEREMI	Japanese European Research Experiment on Marangoni Instabilities
JPL	Jet Propulsion Laboratory (NASA)
JspOC	Joint Space Operations Center (USA)
JWST	James Webb Space Telescope
K	Kelvin
K-12	Kindergarten to 12th grade education
KARI	Korean Aerospace Research Institute
KATE	Ka-band Telemetry and telecommand Experiment
KBO	Kuiper Belt Object
keV	kilo electronvolts
Kr	Krypton
kW	kilowatt
L1	Lagrange Point 1
L2	Lagrange Point 2
LADEE	Lunar Atmosphere and Dust Environment Explorer
LASCO	Large Angle and Spectrometric Coronagraph experiment
LCROSS	Lunar Crater Observation and Sensing Satellite (NASA)
LDI	Laser Doppler Interferometry

LDLE	Lunar Dust Lifting Experiment
LEO	Low Earth Orbit
LEO	Low Earth Orbiting (satellite)
LHB	Late Heavy Bombardment, a period in Earth's early history ending 3.9 bn years ago
LIBS	Laser Induced Breakdown Spectroscopy
LISA	Laser Interferometer Space Antenna
LISA Pathfinder	Mission to test LISA technology
LOLA	Lunar Orbiter Laser Altimeter
LPMA	Limb Profile Monitor of the Atmosphere
LR	Laser Ranging
LRO	Lunar Reconnaissance Orbiter
LWS	Living With a Star
LYRA	Lyman alpha Radiometer
LYRA	Large-Yield Radiometer
MARCI	Mars Color Imager
MARIE	Martian Radiation Environment experiment
MaRS	Mars Radio Science experiment
MARS EXPRESS	An ESA Mars exploration mission also known as MEX
MARSIS	Mars Advanced Radar for Sub-Surface and Ionosphere Sounding
MASTER	Meteroid and Space Debris Terrestrial Environment Reference model
Matroshka	facility for radiation measurements under EVA conditions (ESA/Russia)
MAVEN	Mars Atmosphere and Volatile EvolutioN
MAXI	Japanese Monitor of All-Sky X-Ray Image
MB	Mössbauer Spectrometer
MCS	Mars Climate Sounder
MEIS	Marangoni Experiment in Space
MEJI	Mars Exploration Joint Initiative
MER	Mars Exploration Rover
MESSENGER	MEcury Surface Space ENvironment, GEochemistry, and Ranging mission
MetOp	Meteorological Operational satellite
meV	mega electronvolt
MEX	Mars Express
MF	Medium Frequency
mGal	milli-Gallileo, unit of acceleration in gravimetry
MGS	Mars Global Surveyor (NASA)
MHD	MagnetoHydroDynamics
MHD wave	fast-mode magneto-hydrodynamical wave
MHz	mega hertz
MI	Microscopic Imager
MINERVA	Micro/Nano Experimental Robot Vehicle for Asteroid (miniature rover of Hayabusa)
Mini-TES	Miniature Thermal Emission Spectrometer
MIRA	Martian International Reference Atmosphere
MIRAS	Microwave Imaging Radiometer with Aperture Synthesis
MIT	Massachusetts Institute of Technology
MLT	Mesosphere and Lower Thermosphere
MRO	Mars Reconnaissance Orbiter
MSG	Microgravity Science Glovebox
MSIS	Mass Spectrometer Incoherent Scatter

MSL	Mars Science Laboratory
MST	Mesosphere/Stratosphere/Troposphere
MUSES-C	See Hayabusa
NADIR	Nanosatellite per l'Ambient, la Didattica et la Ricerca
NAI	NASA Astrobiology Institute
NAOC	National Astronomical Observatories, Chinese Academy of Sciences
NASA	National Aeronautics and Space Administration (USA)
NCAR	The National Center for Atmospheric Research (Boulder, CO, USA)
NCWT	National Science and Technology Centre, Amsterdam
NDMC	Network for the Detection of Mesopause Change
NEMO	Science Centre in Amsterdam
NEOWISE	NASA programme to study and catalogue Near Earth Objects seen by WISE
NeXT/SXS	New X-ray Telescope/soft X-ray Spectrometer, now known as ASTRO-H
NIRS	National Institute of Radiological Sciences (Japan)
NO	nitric oxide
NOAA	National Oceanic and Atmospheric Administration (USA)
NOAA-12	National Oceanic and Atmospheric Administration's third generation polar orbiting meteorological satellite
NOVA	NASA Opportunities for Visionary Academics
NRC	National Research Council (USA)
NRL	Naval Research Lab (USA)
NRLEUV	EUV model at NRL
NRLMSIS	MSIS model completed at NRL
NRLMSISE-00	The new empirical model of the atmosphere
NSCOR	NASA Specialized Centers of Research
NSRL	NASA Space Radiation Laboratory
NuSTAR	Nuclear Spectroscopic Telescope Array
ODIN	1.1 m telescope to study interstellar chemistry and atmospheric ozone
OH	hydroxide
OMEGA	Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (IR imaging spectrometer)
OOSA	(UN) Office of Outer Space Affairs
ORBITALS	Outer Radiation Belt Injection, Transport, Acceleration, and Loss Satellite
ORDEM	Orbital Debris Environment Model (NASA)
OSIRIS-Rex	Origins Spectral Interpretation Resource Identification Security Regolith Explorer
Pancam	Panoramic Camera
Pan-STARRS	Panoramic Survey Telescope And Rapid Response System
PANSY	Program of the Antarctic Syowa MST/IS radar
PCB	COSPAR Panel on Capacity Building
PCDF	Protein Crystallisation Diagnostic Facility
PE	COSPAR Panel on Education
PEDAS	COSPAR panel on Potentially Environmentally Detrimental Activities in Space
PEX	COSPAR Panel on Exploration
PFISR	Poker Flat AMISR
PFS	Planetary Fourier Spectrometer
PI	Principal Investigator

Planck	Formerly COBRAS-SAMBA (Cosmic Background Radiation Anisotropy Satellite / Satellite for Measurement of Background Anisotropies)
PLANEX	Planetary Science and Exploration program (India)
PNAS	Proceedings from the National Academy of Sciences of the USA
POLAR	Polar Plasma Laboratory (NASA satellite)
POD	Precise Orbit Determination
PPARC	Particle Physics and Astronomy Research Council (UK)
PPP	COSPAR Panel on Planetary Protection
PRBEM	COSPAR Panel on Radiation Belt Environment Modelling
PRL	Physical Research Laboratory (India)
PROBA2	Project for Onboard Autonomy
PSB	COSPAR Panel on Technical Problems Related to Scientific Ballooning
PSD	COSPAR Panel on Satellite Dynamics
PSLV	Polar Satellite Launch Vehicle
PSMOS	Planetary Scale Mesopause Observing System
PSW	COSPAR Panel on Space Weather
RAPS	Reference Atmospheres for the Planetary System
RAT	Rock Abrasion Tool
RAX	Radio Aurora Explorer
REDD	Reducing Emissions from Deforestation and Degradation
RELEC	Relativistic Electrons project (Russia)
RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Imager
RISR-N	Resolute Bay Canada AMISR North Face
RISR-S	Resolute Bay Canada AMISR South Face
RKA	Russian Federal Space Agency
RNA	RiboNucleic Acid
ROCSAT1	Scientific satellite of Taiwan Province of China
Rossi-XTE	Rossi X-ray Timing Explorer (NASA)
RPI	Radio Plasma Imager
RRI	Raman Research Institute (India)
RSA	Russian Space Agency
RSIS	Radio Science for SMART-1 experiment
RWC	Regional Warning Center
SABER	Sounding of the Atmosphere using Broad-band Emission Radiometry
SAGE	Surface and Atmospheric Geochemical Explorer
SALOMON	Spectromètre d'Absorption Lunaire pour l'Observation des Minoritaires Ozone et Nox (CNRS/LPCE)
SAR	Synthetic Aperture Radar
SARA	Sub-keV Atom Reflecting Analyser (ESA)
SARAL	Satellite with ARgos and ALtika
SBC	Sanriku Balloon Centre
SC	Scientific Committee
SBI	Solar Bolometric Imager
SCAR	Scientific Committee on Antarctic Research
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SCOPE-CM	Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring initiative
SCOSTEP	Scientific Committee on Solar-Terrestrial Physics
SDO	Solar Dynamics Observatory
SECCHI	Sun Earth Connection Coronal and Heliospheric Investigation

SED	Storm Enhanced Density
SEE	Stimulated Electromagnetic Emissions
SEES	Space Environment and Effects System (JAXA)
SELENE/KAGUYA	Selenological and Engineering Explorer orbiter mission (JAXA)
SEM	Space Environment Monitor
SGAC	Space Generation Advisory Council in Support of the United Nations Programme on Space Applications
SHARAD	Shallow Radar
SHINE	Solar, Heliospheric & INterplanetary Environment
SIM	Space Interferometer Mission (NASA)
SIP	Solar irradiance platform
SIR	SMART-1 Infrared Spectrometer
SIRAL	Synthetic Aperture Interferometric Radar Altimeter
SIRTF	Space Infra-Red Telescope Facility, now Spitzer Observatory (NASA)
SLR	Satellite Laser Ranging
SMART-1	Small Missions for Advanced Research in Technology (ESA)
SMEX	Small Explorer
SMOS	Soil Moisture and Ocean Salinity
SODI	Selectable Optical Diagnostics Instrument
SOFIA	Stratospheric Observatory For Infrared Astronomy
SOHO	Solar and Heliospheric Observatory
SOLAR-2000	Solar irradiance model
SOLARFLARE	high time and high spectral resolution model for predicted flare evolution
SORCE	Solar Radiation and Climate Experiment
SOT	Solar Optical Telescope
SOTERIA	Solar-Terrestrial Investigation and Archives
SOXS	Solar X-ray Spectrometer
SPB	super-pressure balloon
Spectrum RG	Spectrum Roentgen-Gamma
SPEDE	Spacecraft Potential, Electron and Dust Experiment
SPICAM	Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars
SPIRALE	Spectromètre InfraRouge pour l'étude de l'Atmosphère par Diodes Laser Embarquées (CNRS/LPCE)
Spitzer	NASA space infrared telescope facility
SPL	Space Physics Laboratory (India)
SQUID	Superconducting Quantum Interference Device
SRAMP	STEP Results, Applications and Modelling Phase
SRON	Netherlands Institute for Space Research
SRPM	Solar Radiation Physical Model
SSA	Space Situational Awareness
SSN	Space Surveillance Network (USA)
SSOEL	Society for the Study of the Origin and Evolution of Life
STAC	Stratospheric and Tropospheric Aerosol Counter
STARDUST-NExT	New Exploration of Comet Tempel 1
S*T*A*R*S ™	Space Technology and Research Students programme
STE	Solar-Terrestrial Environment
STEP	Solar-Terrestrial Energy Programme
STEREO	Solar Terrestrial Relations Observatory
STIS	Space Telescope Imaging Spectrometer

STP	Solar Terrestrial Probes
STSC	Scientific and Technical Sub-Committee (of UNCOPUOS)
SuperDARN	Super Dual Auroral Radar Network
SUPIM	Sheffield University Plasmasphere Ionosphere Model
SURA	Ionospheric heating facility near Nizhniy Novgorod, Russia
Suzaku	Japanese X-ray astronomy satellite
SVOM	Space-based multi-band astronomical Variable Objects Monitor
SWAP	Sun Watcher with APS Detector and Processing
SWEETS	Space Weather and Europe - an Educational Tool with the Su
SWENET	Space Weather European Network
Swift	Medium explorer, gamma-ray observation (NASA/UK/Italy)
SWIM	Surface Wave Investigation and Monitoring
SWIR	Short-Wave Infra Red
SWMF	Space Weather Modelling Framework
T2L2	Transfert de Temps Lien Laser
T/I	Thermospheric/Ionospheric
TanDEM-X	TerraSAR-X add-on for Digital Elevation Measurement
TARF	Taiki Aerospace Research Field
TC	Technical Committee
TEC	Total Electron Content
TEGA	Thermal and Evolved Gas Analyzer
TerraSAR-X	X-band SAR mission for scientific reasearch and applications
TESIS	Telescopes for EUV Spectral Imaging of the Sun (Russian Academy of Sciences)
TG	Task Group
TGF	Terrestrial Gamma-ray Flash
THEMIS	Thermal Emission Imaging System
THEMIS	Time History of Events and Macroscale Interactions during Substorms (NASA)
THESEUS	Towards Human Exploration of Space: a EUropean Strategy
TIEGCM	(NCAR) Thermosphere-Ionosphere-Electrodynamics General Circulation Model
TIGER	Thermospheric-Ionospheric Geospheric Research
TIMED	Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics
TNT	Trinitrotoluene
TOPEX	(Ocean) TOPography EXperiment
TPMU	Thermal Plasma Measurement Unit
TRACE	Transition Region and Coronal Explorer
TS	Technical Specification (ISO)
UCLA	University of California, Los Angelas
UHF	Ultra High Frequency
ULDB	Ultra Long Duration Balloon
ULISSE	An EC programme focusing on the exploitation of scientific data including space weather data
ULF	Ultra Low Frequency
UN	United Nations
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change

UN/OOSA	UN Office for Outer Space Affairs
URSI	Union Radio-Scientifique International
US(A)	United States (of America)
USC	University of Southern California
USSPACECOM	United States' Space Command
USU	Utah State University
UV	UltraViolet
VHF	Very High Frequency
VIMS	Visual and Near Infrared Mapping Spectrometer
VIRA	Venus International Reference Atmosphere
VIRTIS	Visible and Infrared Thermal Imaging Spectrometer
VIS	Visible Imaging System
VLBI	Very Long Baseline Interferometry
VLF	Very Low Frequency
VRAD	VLBI satellite, part of Japan's SELENE/Kaguya mission
VSOP	VLBI Space Observation Programme (now Halca)
VUV	Vacuum Ultra Violet
WACCM	Whole Atmosphere Community Climate Model
WADIS	Wave Dissipation in the Middle Atmosphere
WFC	Wide Field Camera
WGs	Wideband Global SATCOM
WIND	NASA spacecraft to study solar wind and terrestrial plasma
WIS	WMO Information System
WISE	Wide-field Infrared Survey Explorer (NASA)
WMAP	Wilkinson Microwave Anisotropy Probe (NASA)
WMO	World Meteorological Organisation
WRMISS	Workshop on Radiation Monitoring for the International Space Station
WSW	World Space Week
Xe	Xenon
XEUS	X-ray Evolving Universe Spectroscopy mission to detect black holes (ESA)
XMM-Newton	X-ray Multi-mirror Mission (ESA)
XRT	X-ray telescope
XTE	X-ray Timing Explorer
µm	micrometre

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The United Nations Office for Outer Space Affairs is responsible for promoting international cooperation in the peaceful uses of outer space and assisting developing countries in using space science and technology.

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United Nations publication
Printed in Austria
Sales No. E.11.I.3
ST/SPACE/57

V.11-80947—March 2011—475

USD 15
ISBN 978-92-1-101236-1

9 789211 012361 51500