

UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS

Highlights in Space 2007

*Prepared in cooperation with the International Astronautical Federation
and the International Institute of Space Law*



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UNITED NATIONS OFFICE AT VIENNA

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



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INTRODUCTION

This publication has been compiled from reports prepared for the United Nations Committee on the Peaceful Uses of Outer Space and covers the period from 1 November 2006 to 31 October 2007.

The report was prepared by the International Astronautical Federation (IAF). In addition, the International Institute of Space Law (IISL) provided information for the section on international cooperation and space law. 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. This publication is available in English only.

This 2007 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.

This year is particularly significant in the history of space exploration as we celebrate fifty years since the launch of the first man-made satellite, Sputnik I, the 40th anniversary of the entry into force of the United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, and as we mark fifty years since the International Geophysical Year by continuing its legacy of system-wide studies of the extended heliophysical domain in the International Heliophysical Year 2007 endeavors .

We hope that “Highlights in Space 2007” 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.

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I. OVERVIEW

Space Transportation. The U.S. continued development of its next major launch system, the Orion space vehicle, and its booster, the Ares-1. Specific projects that received attention this year were the Ares-1 main stage, the launch abort subsystem, the Ares-1 upper stage and its booster engine, and the Orion's re-entry heat shield.

Progress on the development of vehicles to support the nascent space tourism industry accelerated this year, with Zero-G (USA) initiating microgravity-experience flights for commercial customers on its G-Force-1 aircraft; Space-X (USA) conducting the second demonstration launch of its Falcon-1 vehicle (see below); the U.S. Federal Aviation Administration releasing new guidelines for reusable-vehicle experimental launch permits; Blue Origin (USA) conducting the first flight test of its New Shepherd reusable launch vehicle; and EADS space division Astrium (Europe) releasing their design of a reusable space plane to be developed for the wealthy tourist trade.

In other space tourism developments, Sweden signed an agreement with Virgin Galactic for space tourist flights from the Esrange Space Center and launch facility near Kiruna, and NASA signed a memorandum of understanding with Virgin Galactic to explore the prospects for collaboration in several technologies.

Launch failures this year included Sea Launch's Zenit-3SL, which exploded immediately after launch from its ocean-going platform due to blockage of a propellant feed line; Space-X's Falcon-1 rocket, whose upper stage shut down prematurely due to propellant sloshing in its tank; early shutdown of the Centaur upper-stage of an Atlas-5 rocket due to a propellant leak in the fuel feed-line valve; and International Launch Service's Proton, when a faulty cable prevented separation of the vehicle's first and second stages. An explosion during a non-firing ground-test of the hybrid engine for Scaled Composites' SpaceShipTwo killed three people.

Progress on Europe's small Vega launcher continued with the parallel designs of new upper stages and their engines by both Italy and Germany, who decided late in the year to support studies of a new upper-stage engine for the vehicle. Vega's massive P-80 first-stage engine was also successfully test-fired.

Satellite Communications. The world's first dedicated Ka-band broadband spacecraft, WildBlue-1, was launched this year. An Ariane-5 ECA launched SES Astra's Astra-1L and Intelsat's Galaxy-17, whose total payload mass of 9.4 tonnes set a new record for launch to a geosynchronous transfer orbit.

The European Space Agency (ESA) awarded Inmarsat a contract this year for test operations of the next-generation 7-tonne, 18-kW Alphasat. Inmarsat's 6.5-tonne I-XL test satellite, planned for launch in 2012, will carry an extended 7-MHz L-band payload to broaden Inmarsat's existing mobile satellite service.

Navigation and Position Location. After Europe's Galileo satellite navigation system's prospective service entry date was postponed to 2012 - 2013 due to management concerns, the European transport ministers agreed to scrap the public-private partnership (PPP) funding scheme and finance Galileo wholly with government funds, and the European Commission laid out the details of a new policy for Galileo's management structure, operation, and procurement. In November, the European Union secured Galileo's future by allocating additional funds to the Galileo project from its unused budget funds.

The U.S. and Europe signed an agreement on a common civil signal for their future navigation and positioning satellite constellations.

The first spacecraft of the operational Chinese Compass satellite navigation system was launched by a Long March-3A rocket from the Xichang launch center, and placed in an orbit similar to those of other navigational satellite systems GPS, Glonass, and the future Galileo system. The Compass satellites are planned to begin operational service in 2008.

Japan's parliament enacted legislation to fund the first satellite in the three-spacecraft Quasi-Zenith Satellite System for navigation and position location, the constellation, in a highly elliptical orbit, is envisioned to have a positioning accuracy measured in centimeters.

Earth Observations. The world's space agencies signed an agreement with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) to use their space assets to support the protection of the 830 UNESCO natural and cultural sites, such as Australia's Great Barrier Reef, the Great Wall of China, the Copan ruins in Honduras, the Pueblo de Taos in New Mexico, USA, and the Mahabodhi Temple complex in Bodh Gaya, India.

European countries launched three new radar satellite systems this year: the first of Germany's five SAR-Lupe radar-imaging satellites, Germany's TerraSAR-X radar satellite, and the first of Italy's four CosmoSkyMed radar-satellite constellation. They are integral parts of Europe's Global Monitoring for Environment and Security (GMES) system. Germany also initiated the design of another GMES element, a hyperspectral Earth observation satellite named EnMap (Environmental Mapping and Analysis Programme). Japan, too, launched a radar-imaging satellite, completing the four-satellite constellation of Japan's initial Information Gathering Satellite (IGS) system, which consists of two radar-imaging and two optical-imaging spacecraft.

Earth-Orbit Operations for Humans. Construction of the space station continued with the resumption of Space Shuttle flight operations, bringing the station's solar power supply up to the level required for operation of the European Columbus and Japanese Kibo modules, planned for launch late this year and early next year. The station was visited by its fifth space tourist, Charles Simonyi, and by "Teacher in Space" Barbara

Morgan.

Bigelow Aerospace launched its second privately funded inflatable space station, Genesis-2, into orbit and announced ambitious plans for future operations of larger inflatable space stations to be occupied by humans.

Space Adventures (USA) booked a passenger for a trip around the Moon, and is in negotiation with several other potential space tourists. Their flight plan involves the use of a Russian Soyuz vehicle, which had originally been designed for circumlunar missions. They have also received conditional approval from the Russian space agency to provide a space-walk experience from the International Space Station for a trained tourist.

Space Science and Astronomy. Launches this year featured France's Corot, which is studying stars to determine their internal structure, age, and composition, and is exploring 120,000 stars seeking new planets.

NASA launched the five small Themis satellites (Time History of Events and Macroscale Interactions During Substorms) to resolve competing theories about the aurora borealis, and the Aeronomy of Ice in the Stratosphere satellite, which is seeking and studying noctilucent (night-shining) clouds consisting of ice crystals that form near the edge of space about 80 km above the Earth's poles. It is the most recent addition to NASA's 16-spacecraft Heliospherical Observatory studying the Sun's influence and interactions with Earth and the rest of the Solar System.

India launched Italy's Agile satellite, which is studying high-energy astrophysics phenomena, including X-rays and gamma radiation generated by black holes, gamma-ray bursts, pulsars, supernova remnants, active galactic nuclei, and other phenomena.

NASA approved the fifth and final repair mission for the Hubble telescope by a 7-person crew aboard Space Shuttle Atlantis, now scheduled for September 2008. The mission should enable Hubble telescope operation through 2013, when the James Webb follow-on telescope is scheduled for launch.

Space Exploration. India announced its intent to initiate a human space exploration programme, a planned landing of an Indian astronaut on the Moon in 2020. Initial funding of the programme began this year and is expected to require from \$2.5 billion to \$3 billion annually.

As the first step in the U.S. "Vision for Space Exploration," NASA laid out its plan for establishing an outpost on the Moon. It calls for an open lunar architecture that other nations and commercial interests could add to. Later in the year Japan launched Selene (renamed Kaguya), the heaviest spacecraft sent to the Moon since Apollo, to conduct a year-long detailed study of the Moon's features, and China launched Chang'e-1 to conduct scientific surveys of the Moon.

Radar data from ESA's Mars Express orbiter indicated massive deposits of water ice under Mars' south pole. Radar soundings down to 4 km below the Martian surface revealed water ice deposits, 90% pure, of sufficient magnitude that, if melted, would cover the entire planet with water 11 m deep.

NASA's Phoenix lander was launched to Mars to retrieve soil and ice samples in the North Polar Region. Its main objectives are to search the Martian soil for organics, which have yet to be discovered on Mars, and to test ice and water samples for acidity and the potential to hold food sources for life.

Technology Advancement: Propulsion. Two major development efforts in supersonic combustion ramjet ("scramjet") development were pursued this year: the U.S.-Australian Hypersonic International Flight Research Experimental Programme, which achieved a speed of Mach 10 and is to conduct ten flights from the Woomera test range over a period of five years, and the U.S. X-51 "Waverider" programme, which ground-tested a scramjet engine successfully at Mach 4.6 and Mach 5.

Orbital Debris. A Chinese medium-range ballistic missile destroyed an obsolete Chinese weather satellite, ejecting a cloud of debris estimated to contain about 35,000 objects. Four other debris-creating events occurred shortly afterward: an auxiliary engine on a Russian missile exploded; the upper stage of a Proton rocket broke into 60 observable pieces; the retired China-Brazil Earth Resources Satellite-1 (CBERS-1) broke into about 25 pieces; and a Russian Breeze-M stage exploded, leaving an amount of debris of the same order of magnitude as the Chinese test.

International Cooperation and Space Law. The Global Exploration Strategy (GES) was signed this year. GES represents a voluntary, non-binding, open-ended forum for sharing cooperation plans and supporting exploration activities of China, Europe, India, Japan, Russia and the U.S.

Ministers from the 27-nation European Union and the 17-nation European Space Agency, after three years of debate, agreed unanimously on an overall space policy for Europe. Accordingly, the European Commission (EC) will set the European space priorities and ESA will serve as the technical manager of the EU space programmes. Its effects will, among others, reduce duplication in space spending and offer taxpayers assurance that their money is being well spent.

Global Space Market Issues and Opportunities. Total 2005 revenues of the space industry were reported at \$180 billion, \$110 billion from commercial sources and \$70 billion from governments. 2006 global satellite industry revenues were \$106.1 billion, up 19.5% over 2005, nearly double the rate of increase over the past five years. 27 commercial geostationary-orbit satellites had been ordered in 2006, a substantial gain over 2005's total of 19. Transponder demand was forecasted to outstrip supply by 2014.

United Launch Alliance (ULA), a joint enterprise of Boeing and Lockheed Martin (both USA), initiated operations this year. ULA combines the manufacturing and U.S.

government marketing of Boeing's Delta and Lockheed Martin's Atlas rockets.

Major space-industry mergers this year included the consolidation of four Russian launch vehicle and spacecraft manufacturers under the control of the Khrunichev Space Center; an agreement by GE Capital (USA) and SES Global (Luxembourg) to set up a new company, SES International Holdings, Inc., which now holds many of the cosigners' assets; BC Partners' (Europe) purchase of 76% of Intelsat (Bermuda); the purchase of Telesat Canada by Loral Space & Communications (USA) and Bell Canada affiliate BCE; the merger of U.S. satellite radio companies XM Satellite Radio and Sirius Satellite Radio (pending the U.S. government approval); the acquisition by Thales (France) of Alcatel's 67% share of Alcatel Alenia Space and its 33% share of Telespazio, creating a new company, Thales Alenia Space; the purchase of Kayser-Threde by OHB Systems (both Germany); and the purchase of 100% of Scaled Composites, builder of SpaceShipOne and SpaceShipTwo, by Northrop Grumman (both USA).

India's Ministry of Communications eliminated satellite C-band users' rights to the upper end of C-band, from 3.7 to 4.2 GHz, in favor of terrestrial broadband wireless users. The order was appealed, but was reaffirmed by the Ministry. The United Nations International Telecommunications Union's quadrennial World Radiocommunication Conference began in October. Competition for C-band spectrum between satellite and terrestrial users was the primary issue under consideration.

II. SPACE TRANSPORTATION

A. Current Launch Activities

The first space launch from the commercial Mid-Atlantic Regional Spaceport (USA) took place on 16 December 2006, when an Orbital Sciences Corporation's Minotaur-1 rocket orbited the U.S. Air Force TacSat-2 experimental payload and NASA Ames Research Center's 10-kg GeneSat-1 biology experiment. The spaceport, formerly operated by NASA as the Wallops Island launch facility, had been used previously only for sounding-rocket launches. Eleven of TacSat-2's instruments were activated on 3 January, and GeneSat-1 returned data in January on genetic changes in E.coli bacteria caused by exposure to the space environment. Operations of TacSat-2's high-resolution imager and its signal-intelligence instrument were delayed to clarify any misconceptions that they were being used for spying purposes. Initial difficulties with TacSat-2's downlinks were resolved on 15 March by some software changes.

On 1 March Zero Gravity Corporation (Zero-G, USA) announced that renowned theoretical physicist Stephen Hawking would fly aboard the company's Zero-G Experience aircraft G-Force-1 on 26 April. Following a training session the Cambridge University professor, who suffers from amyotrophic lateral sclerosis, was wheeled aboard the aircraft accompanied by four doctors and two Zero-G coaches to assist him in maneuvering through the flight. He was lifted from his wheelchair and placed on the cushioned floor of the airplane to experience microgravity, floating up to the center of the cabin during eight parabolic-flight maneuvers.

Zero-G also began flying commercial customers aboard the aircraft on regularly scheduled flights from Las Vegas's McCarran International Airport (USA) on 21 April. The price per passenger is \$3,500 (+tax), which includes 15 flight parabolas over a period of 90 minutes as well as a videodisc of their experience. Charter flights for up to 35 people each are priced at \$115,000. On 28 March Zero-G announced that flights aboard G-Force One were to be marketed exclusively by the U.S. retailer "The Sharper Image", effective 15 May, selling them through its retail outlets, its catalogue, and its website.

A Sea Launch Zenit-3SL exploded on 25 January just seconds after first-stage engine ignition as it was attempting to launch SES New Skies 5.9-tonne NSS-8 satellite from the Sea Launch's floating Odyssey platform in the Pacific Ocean. Despite being engulfed in a massive fireball created by the first-stage's 325 tonnes of oxygen and kerosene propellants and the second-stage's 82 tonnes, the Odyssey platform sustained very limited damage.

The major damage to the launch platform was destruction of its gas deflector. Its replacement as well as refurbishment of other minor damages to the platform were subsequently completed at a cost of less than \$50 million. The platform was insured for \$260 million, plus coverage for other ground equipment, by energy-sector and other insurance markets, not by the space-insurance industry, which covered the spacecraft and its launch with a \$256-million policy.

Investigations of the failure concluded that it was due to blockage of an oxygen feed line by a foreign metallic substance that starved the Zenit's RD-171M first-stage engine, which uses an oxygen-rich cycle, and caused the failure about 4 seconds after engine ignition. It was concluded that the failure was not caused by a design flaw in the RD-170-class engine, whose design was the basis for the RD-180 engine that powers Lockheed Martin's Atlas-V launch vehicle.

On 29 June a two-stage Zenit launched a Russian military satellite from the Baikonur Cosmodrome, demonstrating successful recovery of the vehicle's first-stage RD-171M engine from the abovementioned Sea Launch failure. The launch also inaugurated the launch pad and ground facilities for Sea Launch's new Land Launch capability. Repair and refurbishment of the damaged Sea Launch ocean platform were completed in mid-July, clearing Sea Launch for its next mission.

On 6 September an International Launch Services (ILS) Proton-M rocket failed 139 seconds after launch from the Baikonur Cosmodrome, at an altitude of 76 km, when all four second-stage engines failed to ignite. Those stages, along with the rocket's third and fourth stages and the JCSAT-11 payload, impacted about 50 km south of the Kazakhstan town of Zhezkazgan, spreading over 200 tonnes of toxic propellants there. No injuries or property damage were reported. Cause of the failure was subsequently traced to a faulty cable on the interstage truss between the Proton's first and second stages, preventing activation of the pyrotechnic-powered bolts that separate the two stages, which therefore did not separate. The Proton-M returned to flight on 26 October,

when it successfully launched three units of Russia's Global Navigation Satellite System (Glonass) from the Baikonur Cosmodrome into their planned 19,000-km, 65-degree orbit.

JSAT Corporation's (Japan) \$200-million JCSAT-11 spacecraft, lost as a result of the Proton failure, was built by Lockheed Martin Commercial Space Systems (USA) on the company's A2100 bus. It carried 40 Ku-band and 12 C-band transponders for Asia-Pacific service, and had a design life of 15 years. JSAT placed an order with Lockheed Martin for a replacement satellite, JCSAT-12, and on 19 September contracted with Arianespace (France) for a mid-2009 launch. JCSAT-11 and its launch were insured for about \$185 million, which is expected to cause the space insurance industry a net loss for the year.

The Centaur upper stage of a United Launch Alliance Atlas-5 rocket shut down too early after its launch from Cape Canaveral Air Force Station on 15 June, leaving its two U.S. reconnaissance payloads in lower altitudes and inclinations than planned: 846 km x 1,182 km and 62.7 degrees instead of 1,000 x 1,200 km and 63.4 degrees. Initial evaluations of the source of the failure pointed to a leak in a liquid-hydrogen fuel valve on the Centaur stage, not its RL-10 engine, which depleted the stage's propellant during the coast period between firings and led to the early shutdown.

It was later found by extensive ground testing that the valve, a relatively new design introduced because the vendor of the original well-proven fuel valve was shutting down its manufacturing line, did not have sufficient force to close fully after the initial long Centaur firing (about 15 minutes). ULA had enough of the original fuel valves in inventory to cover future flights until the new valve could be redesigned properly. A subsequent launch of a U.S. military payload by a Delta-4, which also uses the Centaur upper stage, remained on schedule at 28 August. The next Atlas-V flight, to launch a U.S. military payload, was conducted successfully on 10 October.

Space Exploration Technologies' (SpaceX's, USA) Falcon-1 rocket failed on 20 March during its second launch from Kwajalein, due to premature shutdown of its 31-kN-thrust second-stage Kestrel engine. An unexpected roll prevented the stage from reaching the required orbital injection speed and caused it to reenter the atmosphere. The root cause of the roll was identified by telemetry as an unexpected coupling between the thrust vector control system and the sloshing of propellant in the second-stage tank after a rough first-stage separation transient, causing excessive stage oscillations that were exacerbated by a non-damaging post-separation collision between the Kestrel's nozzle and the vehicle's interstage. The coupling produced the roll that caused propellant to spin away from the stage's sump and thereby starve the engine, which shut down after 6 minutes of a planned 7.5-minute burn. According to SpaceX, this roll oscillation was easy to fix once the flight data had been analyzed, by adding baffles to the second-stage liquid-oxygen tank and adjusting the control software. Space-X also corrected seven other performance issues that, although not responsible for the 20 March failure, were considered significant.

A previous launch attempt on 19 March had been aborted due to a software

problem, but a second preliminary attempt on 20 March, after which the rocket was refueled and launched, demonstrated the “operationally responsive” character desired by SpaceX’s U.S. Air Force sponsor. Since the launch was classed as a demonstration, the Falcon-1 carried no satellite, but it did have two NASA payloads and 50 kg of extensive instrumentation. The mission sponsors on 22 March said that no additional demonstration flight was needed and that the payload for Falcon-1’s next launch would be the experimental satellite TacSat-1, as was originally planned.

On 26 April Space-X was awarded a 5-year license by the U.S. Air Force Space Command to launch rockets from Cape Canaveral’s Space Launch Complex 40, which was previously used for Titan-3 and Titan-4 launches. Space-X expects to invest several tens of millions of dollars in the complex to ready it for the planned debut of the company’s Falcon-9 rocket in late 2008. Eleven Falcon-9 flights from Complex 40 are manifested through 2010; most are for U.S. government payloads, although two commercial launches are scheduled: MacDonald Detwiler’s (Canada) Cassiope technology mission in 2008 and Avanti Communications’ (UK) Hylas satellite (see last year’s report) between March and November of 2009. The smaller Falcon-1 will continue to be launched from the Kwajalein site.

Arianespace (France) and Ariane-5 prime contractor EADS Astrium Space Transportation (Germany) signed an agreement on 15 February to increase production of the Ariane 5 ECA vehicle from 5 – 6 per year to 7, beginning in February 2008, and also to produce one non-ECA variant annually. The cost of contractor retooling for the increased production rate was estimated at \$65 - \$130 million. On 23 June Arianespace also concluded a preliminary agreement with EADS Astrium to proceed with the construction of long-lead items for 35 more Ariane-5 launch vehicles. The current stock of 30 Ariane-5 launchers will be exhausted in 2010.

Arianespace (France) signed a contract on 20 June ordering four Soyuz launchers from builder Samara Space Center (Russia) for the initial Soyuz launches from the Guiana Space Center in Kourou, French Guiana (see previous reports). Construction time for the vehicles is estimated at 20 months; the first Soyuz launch from Kourou is planned for early 2009. The Soyuz ST-B can loft a 3,150-kg satellite into geostationary orbit (GEO) from the Guiana Space Center; the same vehicle can orbit only slightly less than 2,000 kg to GEO from the Baikonur Cosmodrome.

During the Paris Air Show in June, Arianespace signed nine launch contracts, five with SES (Luxembourg) and one each with Rascom (Ivory Coast), Arabsat (Saudi Arabia), ISRO (India), and Telenor (Norway). SES also signed five launch contracts with International Launch Services (ILS, USA).

India’s Geostationary Space Launch Vehicle (GSLV) returned to flight status on 3 September, following a failure last year due to malfunction of a pressure regulator in one of the vehicle’s four liquid-propellant booster rockets. The launch from the Satish Dhawan Space Center on Sriharikota Island successfully deployed Insat-4CR into a geosynchronous transfer orbit, although the orbit’s apogee was about 1,250 km lower

than intended and the orbital inclination of 20.7 degrees was one degree off. Nevertheless the 2,135-kg spacecraft, the heaviest ever launched by the Indian Space Research Organization (ISRO), was subsequently boosted into its proper geostationary orbit slot at 74 degrees east longitude, and the mission was declared a success by ISRO. Insat-4CR replaced Insat-4C, which was lost in last year's GSLV failure. Its 12 Ku-band transponders are delivering direct-to-home television broadcast and digital satellite news-gathering services to customers across all of India during the spacecraft's 10-year design lifetime.

On 24 September China's cabinet and Central Military Commission approved long-standing plans to develop a new space launch site at Wenchang on Hainan Island, a near-equatorial location that would permit higher payloads than current higher-latitude launch sites at Xichang and Jiuquan. According to China, the new facility is being planned to handle synchronous satellites, heavy satellites, large space stations, and deep-space probes.

B. Development Activity

Rebutting a series of rumors that NASA's Ares-1 rocket, being developed to launch the Orion Crew Exploration Vehicle after retirement of the space Shuttle (see last year's report), was overweight and would not be able to launch Orion, NASA on 14 November 2006 provided details on the Systems Requirements Review (SRR) of Ares-1-X test-vehicle development, completed on 10 November 2006, and on the then-ongoing Integrated Systems Review for the Ares-1 flight vehicle. Based on the SRR, the Ares-1 flight vehicle was estimated to have a 15% performance margin over the planned 22-tonne mass of the Orion vehicle, plus a potential mass growth reserve of 15% for several components whose final design had not yet been firmed up. On 16 May NASA's designers subsequently reduced Orion's mass-to-orbit requirement about 400 kg, by making the capsule's boost protection cover panels able to be jettisoned after main engine cutoff of the Ares-1 launch vehicle. The Ares-1-X test vehicle will conduct a suborbital test flight in April 2009 using a four-segment solid-propellant Shuttle booster, a dummy of the fifth segment that will complete the Ares-1 first stage, and a "boilerplate" upper stage and Orion crew exploration vehicle.

On 10 August NASA signed a \$1.8-billion contract with Alliant Techsystems to build the main stage of the Ares 1 launcher. The contract specifies delivery of a four-segment motor for the Ares 1-X suborbital test flight in April 2009, three five-segment solid-propellant motors for flight testing of the Ares 1, two motors for static test firings, and three qualification motors. The first Ares 1 flight test with a five-segment motor will be suborbital, in September 2012; the first orbital flight test, with an unpiloted Orion payload, will be in March 2013; and the first piloted Orion mission, to the International Space Station, is planned for September 2013.

A \$515-million contract for the Ares upper stage was awarded by NASA to a team led by Boeing Space Exploration on 28 August. The contract, which runs through 2016, covers the manufacture of a ground-test article, three flight-test units, and six

production flight units. The Boeing team includes Hamilton Sundstrand, Moog, Northrop Grumman, Orion Propulsion Inc., Summa Technology, United Space Alliance, and United Launch Alliance (all USA). The losing bidder was a team led by ATK Launch Systems, with partners Lockheed Martin Space Systems and Pratt & Whitney Rocketdyne (all USA).

NASA issued a \$1.2 billion contract to Pratt & Whitney Rocketdyne (PWR, USA) on 16 July for eight J-2X rocket engines for the Ares-1 upper stage. Derived from the J-2 engine used in Apollo's upper stage, the J-2X burns liquid hydrogen and liquid oxygen, develops 1.3 MN thrust at a specific impulse of 448 seconds, and weighs about 2,500 kg. These first eight engines are slated for use in ground testing. Subsequent production engines will power the Ares-1 upper stage in flight testing and operations.

On 4 October NASA downselected two bidders of the five who submitted proposals for the Ares-1 avionics package. The finalists for the nine-year Instrument Unit Avionics contract were Ball Aerospace and Technologies and Boeing Space Exploration (both USA). The other three bidders for the \$300-million initial contract award were BAE Systems, Honeywell Technology Solutions, and Raytheon Missile Systems (all USA). The avionics ring, to be mounted on the Ares-1 upper stage, will provide guidance, navigation, and control for the entire Ares-1 launch vehicle.

The Systems Requirements Review (SRR) for the Orion vehicle itself was conducted by NASA and Lockheed Martin on 1 March, clearing the way to begin detailed design work. On 23 April NASA issued a contract amendment to Lockheed Martin, adding \$385 million and delaying delivery by two years to 2013, in order to coordinate its schedule with that of its Ares-1 launch vehicle. The amendment also added two tests of the Orion's launch abort system, one in 2008 and one in 2009, each consisting of a pad abort and a high-altitude abort. Lockheed Martin was also told to drop its design of a pressurized cargo carrier for the International Space Station.

On 25 January the third of five planned drop-tests of the Ares-1's first-stage recovery system failed when the instrumented drop-test article (not an actual or dummy first-stage) broke away from its pilot parachute and crashed on the desert floor at the U.S. Army Yuma Proving Grounds. After being dropped from a C-130 aircraft at 5.2-km altitude, the drop-test vehicle inflated its 3.5-m pilot parachute satisfactorily, but then the three lines between the vehicle and the pilot chute broke before the drogue and three main chutes could be deployed. The lines that broke were not part of the recovery-system design, but were used only for the test vehicle. A successful drop-test of the Ares-1 first-stage recovery system's main parachute was conducted by NASA and ATK on 25 September, using an 18-tonne dummy load dropped from a U.S. Air Force C-17 flying at an altitude of 5 km.

NASA's contract for suborbital flight-testing of Orion's launch abort system was issued on 4 April to its builder, Orbital Sciences Corporation (OSC, USA). The testing will be conducted aboard surplus Minuteman intercontinental ballistic missile stages from the White Sands Missile Range beginning in 2009. Although the testing will be

supervised by NASA's Dryden Flight Research Center, the contract, worth \$35 million to \$57 million depending on the number of tests conducted, is being administered for NASA by the U.S. Air Force because the Air Force is sponsoring a number of other tests using surplus Minuteman stages. OSC's Minotaur, which launched TacSat-2 in December 2006, is based on a surplus Minuteman stage.

On 2 May NASA asked the space industry for ideas on how to conduct rescue and recovery operations for Orion's crews, suggesting they use the Apollo capsule as an analogy for developing their plans. The Orion command module will have the same conical shape as Apollo's, but is big enough to accommodate a crew of six, and will weigh about 9 tonnes in landing configuration.

NASA issued contracts on 4 May to Boeing and Textron (both USA) to develop and test alternative heat-shield materials for the Orion capsule. The development contract for the primary heat-shield material, phenolic impregnated carbon ablator, went to Boeing in September 2006 (see last year's report). The new \$10-million contract to Boeing is to investigate a proprietary material, the Boeing Phenolic Ablator, and the \$24-million contract to Textron is to examine two materials, Avcoat (which was used on the Apollo capsule) and Dual Layer. Heat-shield requirements for Orion, which will reenter the atmosphere from low Earth orbit missions at 11 km/s, are significantly more stringent than those of Apollo, whose re-entry temperatures were 30% lower, and those of the Space Shuttle, whose heating levels at its re-entry speed of 7.5 km/s are about one-fifth those expected for Orion.

The U.S. Air Force announced on 17 November that it would launch an experimental long-duration reusable Orbital Test Vehicle (OTV) aboard a Lockheed Martin Atlas-V rocket in 2008. Based on NASA's X-37 flight demonstrator, the X-37B OTV experiment will demonstrate autonomous flight, re-entry, and landing. Boeing (USA) is the prime contractor for both X-37 and X-37B. The vehicle will be launched from Cape Canaveral in Florida and recovered at either Edwards Air Force Base or Vandenberg Air Force Base, both in California.

On 8 November 2006 Alliant Tech Systems (USA) announced that its ATK Launch Systems Group had joined Rocketplane Kistler (RpK, USA) in developing a resupply vehicle for the International Space Station (ISS) under NASA's Commercial Orbital Transportation Services (COTS) contract (see last year's report). ATK's role was to have been to oversee the development, assembly, integration, and testing of RpK's K-1 reusable rocket at Lockheed Martin's Michoud Assembly Facility near New Orleans, and also to oversee the construction of the company's launch site at Woomera, Australia. ATK made an initial investment of \$2.5 million in RpK, and had expected to follow that up with investments in the form of goods and services.

However, on 7 September NASA gave notice to RpK that its COTS contract would be terminated in 30 days due to failure of the company to meet specified financing and critical-design-review milestones, and that under its agreement RpK had to stop NASA-funded work pending a final settlement. NASA then cancelled RpK's COTS

agreement on 18 October, and although RpK subsequently appealed that decision on 19 October, NASA released a solicitation on 22 October for a new full and open COTS competition for the \$175 million that would have gone to RpK. Proposals are due during the first quarter of 2008.

NASA signed nonreimbursable Space Act agreements with three firms on 18 June to support development of cargo deliveries to the ISS: Constellation Services International (CSI), SpaceDev, and Spacehab (all USA). Under these agreements NASA will provide information on the agency's projected demand for ISS cargo services, rendezvous and docking requirements, and unfunded support and technical assistance. Constellation's LEO Express employs proven launch vehicles in conjunction with CSI's design for a Russian-built orbital space tug modeled after Earth-based intermodal cargo systems using standardized containers. CSI claims their concept uses 100% off-the-shelf technology and is compatible with over a dozen existing launchers plus most of the new ones currently in development. On 27 September CSI signed a memorandum of understanding with United Launch Alliance to explore the launching of their LEO Express cargo canister on Atlas-V rockets. In February NASA signed Space Act agreements similar to CSI's with Transformational Space Corporation (t-Space) and PlanetSpace Inc. (both USA).

The U.S. Federal Aviation Administration released new guidelines for reusable-vehicle experimental launch permits on 6 April. Each one-year permit covers unlimited launches of multiple vehicles of a particular design, and limits the operator to a sparsely populated area large enough to contain the vehicle's full trajectory. License applicants must provide a programme description, a flight-test plan, safety documentation including a hazard analysis, and a plan for response to any mishap. The flights covered by this type of permit cannot be flown for profit. The FAA will review applications for renewal of annual experimental permits, and will determine what kind of design changes would invalidate an existing permit.

On 19 September Orbital Sciences Corporation (OSC, USA) selected the Aerojet AJ-26/NK-33 liquid oxygen-kerosene engine for the first stage of its new Taurus-2 launch vehicle. Two of the engines, originally developed and built for the former Soviet Union's N-1 Moon rocket programme and subsequently modified by Aerojet for Rocketplane-Kistler's K-1 launcher, will power the first stage of OSC's Taurus-2. OSC will invest \$100 - \$120 million developing the new vehicle, which is planned to lift Delta-2-class payloads weighing 4 - 6 tonnes to low Earth orbit beginning in 2010 at a projected recurring cost of \$50 - \$60 million per launch. OSC will hold the Taurus-2 preliminary design review by the end of this year.

On 26 January Sweden signed an agreement with Virgin Galactic that will facilitate space tourist flights of SpaceShipTwo (see last year's report) from the Esrange Space Center and Spaceport's Kiruna launch site through the aurora borealis in midsummer and midwinter. The agreement stipulates that the Swedish government will set up a regulatory regime modelled on that of the U.S. Federal Aviation Administration's Office of Commercial Space Transportation, and that Sweden will also negotiate the

technology-export approvals for exporting SpaceShipTwo and associated equipment under the U.S. International Traffic in Arms Regulations (ITAR). Sweden plans a test flight of a sounding rocket through the aurora in March 2008 to determine the radiation environment that SpaceShipTwo will encounter on the tourist flights, which are planned to begin in 2012. According to Sweden, no new facilities will be required at Kiruna to support the SpaceShipTwo flight and maintenance operations.

NASA also signed a memorandum of understanding with Virgin Galactic on 20 February to explore the prospects for collaboration on the development of spacesuits, heat shields, hybrid rocket engines, and hypersonic vehicles. The cognizant office at NASA for the two-year term of the agreement, which stipulates that no funds will be transferred between the parties, is the Ames Research Center.

On 30 August Virgin Galactic announced a contract with the National Aerospace Training and Research (Nastar) Center (USA) to train Virgin Galactic's first hundred suborbital space passengers. Nastar is conducting two-day training sessions over a three-month period to help the passengers endure the stresses of space flight. The Nastar Center is a wholly owned subsidiary of Environmental Tectonics Corporation (USA).

Blue Origin (USA) conducted the first flight test of its New Shepherd reusable launch vehicle on 13 November 2006 from its facility near Van Horn Texas (USA). The vehicle's two-stage propulsion module carried it to an altitude of about 600 m in a flight lasting about 30 seconds, returning to a concrete pad at its takeoff site and setting down safely in a powered landing on four rigid struts. The test vehicle, named Goddard, is conical in shape with nine gimbaled thrusters on its base, similar to the old DC-X "Delta Clipper." Its engines burn 90% hydrogen peroxide with 10% ROP grade kerosene. The test was the first of a series of 10 low-altitude flight tests (below 3,000 m) approved by the U.S. Federal Aviation Administration's Office of Commercial Space Transportation under the first experimental launch permit issued by the FAA (see above).

An explosion of Scaled Composites' SpaceShipTwo hybrid rocket engine occurred during cold-fire injector testing being conducted at the Mojave Spaceport rocket test facility on 26 July, resulting in a loss of lives of three Scaled Composites employees and injuring three others. The mishap occurred during transfer of the engine's oxidizer, nitrous oxide. Successful cold-run testing of the injector had already been completed at least once prior to the accident. In a subsequent review of the incident, the U.S. Federal Aviation Administration's office of commercial space transportation concluded that it was an "industrial accident, a fuel flow test gone terribly wrong," and did not involve any activities regulated by the FAA. The FAA therefore deferred investigation of the incident to the California state authority and Scaled Composites.

The Russian space agency Roskosmos announced on 15 November 2006 that an initial version of Parom, a planned reusable follow-on to the Soyuz Progress-M that has been the workhorse for cargo deliveries to the space station, could be launched in 2009. Parom's preliminary design calls for triple the cargo capacity of the Progress-M. A feasibility study and funding plan to be conducted in 2008 will be used to determine

whether ESA will participate in Parom development.

ESA completed full-scale rendezvous and docking tests on the space-station Automated Transfer Vehicle (ATV) at a naval test facility in Normandy, France on 15 November 2006. It was the 17th and final main functional ATV system test, using real flight sensors and software simulating operational parameters. Following the subsequent system verification testing at ESA's Estec facility in Noordwijk, Netherlands, the 19.4-tonne ATV was shipped to Europe's French Guiana spaceport on 17 July to prepare for its originally planned November launch to the ISS aboard an Ariane-5 variant, using a restartable upper-stage engine. However, it was decided on 14 June to delay the launch to mid-January at the earliest, due to the expected heavy traffic at the ISS during November (see below).

On 15 June EADS space division Astrium revealed their design of a reusable space plane to be developed for the wealthy tourist trade. The design resembles a business jet with extremely long wings, powered by two aft-mounted jet engines and a liquid methane-liquid oxygen rocket engine for the final boost into space. The flight profile would consist of takeoff from an as-yet undisclosed spaceport, climb to 12 km altitude on jet-engine power, ignition of the rocket engine, and coast to 100-km altitude, during which the passengers would experience about three minutes of microgravity conditions before reentering the atmosphere. The cabin design, released on 15 June, features five rows of side-mounted and ceiling-mounted windows for outside viewing. At the final landing, the jet engines would again be utilized; a total trip time would amount to about 90 minutes. Astrium envisions weekly flights by one of their planned initial five-craft fleet, each carrying four passengers at a ticket price of about \$270,000. Operations, which are to be managed by a subcontractor to Astrium, could begin by 2012, provided the estimated investment of about \$1.34 billion by Astrium.

ESA awarded two contracts worth \$28 million to NGL Prime SpA on 26 June to study next-generation rocket engines and to design a launch vehicle to test reusable rocket materials. NGL Prime, jointly owned by EADS Astrium Space Transportation (Germany, 70%) and Finmeccanica (Italy, 30%), will design the Intermediate Experimental Vehicle (IXV) to be placed in a 180 x 307-km orbit by a Vega rocket from Kourou in 2010, and then make a 20-minute controlled atmospheric reentry at 7.7 km/sec before landing via parachutes and airbags. The contract is part of ESA's Future Launcher Preparatory Programme (FLPP).

On 6 March Italy's space research center Cira conducted an initial drop test of its Unmanned Space Vehicle (UMV), that was developed as an aid on which to base future European reusable launch-vehicle technologies. The USV was dropped from a stratospheric balloon at an altitude of 33 km over the Sardinia test range, and before completing a series of transonic maneuvers, achieved a top speed of Mach 1.05. The 70-second flight ended with a sea recovery via a three-stage parachute system.

Italy initiated Phase 1 of the Lyra programme on 20 June. The \$47-million contract to study evolutions of the Vega launch vehicle went to a joint venture of Avio

and the Italian space agency. Lyra's goal is to enable Vega to boost a 2-tonne payload into a 700-km orbit by replacing the current Vega's Zefiro-9 solid-propellant third stage (see below) and Avum liquid-propellant fourth stage with a new Mira liquid oxygen-methane propulsion unit and developing a new navigation guidance control system. The full-scale Mira demonstrator engine is planned, but would require an additional \$93 million to \$106 million to complete its development.

On 24 July Germany decided to join the Vega team, as the German Aerospace Center DLR issued an 18-month \$690,000 contract to EADS Astrium Space Transportation (Germany) for a study of designs for an improved Vega upper stage, called Venus. Although the study does not necessarily imply a German replacement for Lyra and/or Vega's Avum fourth stage, that is being developed by NPO Yuznoye (Ukraine), it may motivate a decision for such a change after the first Vega demonstration launch next year.

III. ROBOTIC EARTH ORBITAL ACTIVITIES

A. Telecommunications

(1) Fixed-Base Communication Systems

The world's first dedicated Ka-band broadband spacecraft, WildBlue-1, was launched into its geostationary-orbit slot at 111 degrees west longitude by an Ariane-5 ECA from Kourou on 8 December 2006, along with SES Global's AMC-18. The 4.7-tonne Wildblue-1, which develops 9.6 kW of power, began commercial operations in March. Built by Space Systems/Loral (USA), its 35 spot beams cover the entire contiguous U.S., providing a downlink speed of 1.5 MB/sec and an uplink rate of 256 kB/sec to over 750,000 rural and small-town households and small businesses that are underserved by terrestrial data services. Monthly service fees range from \$50 to \$80, plus \$8 for remote dial-up. Ground equipment, including a 66-cm dish antenna, costs \$300 plus \$130 installation cost. Originally known as KaStar, Wildblue-1 was originally planned for launch in 2002. Wildblue Communications is owned by Liberty Media Corporation, Tennenbaum Capital Partners, Kleiner Perkins Caufield & Byers (all USA), Telesat Canada, and Intelsat (Bermuda).

AMC-18 was placed by the same launch into Americom HD Prime's geostationary-orbit slot at 105 degrees west longitude. Along with AMC-10 and AMC-11, the all-C-band spacecraft, built by Lockheed Martin (USA), is providing high-definition television and broadband data services throughout the Caribbean region, Mexico and the U.S.. It will also supplement AMC-1 and AMC-4, both at 103 degrees west longitude, in serving cable television broadcasters.

The payload of the Sea Launch Zenit-3SL which failed on 25 January was SES New Skies 18-kW NSS-8, carrying 56 C-band and 36 Ku-band transponders. It was headed for a geostationary-orbit slot over the Indian Ocean at 57 degrees east longitude, where it was to replace NSS-703. It was built by Boeing Satellite Systems International

(BSSI) under a unique contract that retained BSSI ownership until the satellite was in orbit and operational. BSSI therefore claimed the estimated \$250-million insurance payment due because of the launch failure. The contract also stipulated that SES New Skies had the right to order an identical replacement satellite within 90 days, and once ordered, BSSI was obligated to deliver it within 26 months. SES New Skies announced on 27 April its intent to order the NSS-8 replacement, but on 30 April cancelled the contract. On 2 May SES Global announced that it would seek bids from other manufacturers, and on 10 May placed the order with Space Systems/Loral. The replacement satellite, named NSS-12 and being built on SS/L's 1300 platform, will carry 40 C-band and 48 Ku-band transponders to serve customers in Africa, India, and the Middle East from the 57-degree-east geostationary orbit slot intended for NSS-8. SES New Skies also plans a second new large hybrid C-band/Ku-band satellite.

SES New Skies on 1 February initiated construction by Orbital Sciences (USA) of all-C-band NSS-9, planned for launch in 2009 to a geostationary-orbit slot at 183 degrees east longitude. There it would replace NSS-5, which could then be moved to NSS-8's intended slot at 57 degrees east longitude as an interim measure until the NSS-8 replacement is launched.

Meanwhile, on 22 February SES moved its planned early-2008 launch of AMC-21, a 2.5-tonne spacecraft carrying 24 Ku-band transponders being built jointly by Alcatel Alenia Space (France and Italy) and Orbital Sciences (USA), from Land Launch to Arianespace because of concerns about using the same Zenit first-stage rocket that failed during the NSS-8 launch. Arianespace also announced on 1 March that Hughes Network Systems (USA) had transferred the launch of its 6-tonne Spaceway-3 from Sea Launch to an Ariane, when delays in other satellite manufacturing schedules opened a slot in August 2007 for Arianespace. On 23 March Intelsat switched the launch of two satellites, PAS-11 and Horizons-2, from Sea Launch to Arianespace.

Spaceway-3 was subsequently launched to its geostationary-orbit slot at 95 degrees west longitude by an Ariane 5 ECA from Kourou on 14 August, along with Broadcasting Satellite System Corporation's BSAT-3a (Japan), which was placed in an orbital slot at 110 degrees east longitude.

DirecTV-10 was launched from the Baikonur Cosmodrome on 7 July by an enhanced version of an International Launch Services Proton-M rocket. It was the first launch by the enhanced Proton-M, under development for two years, which can put payloads weighing up to 6.3 tonnes directly into the geostationary orbit. The 5.9-tonne DirecTV-10, built by Boeing Satellite Systems International (USA) on the company's 702 platform for owner DirecTV (USA), carries 44 Ka-band transponders for U.S. national television broadcasting and 70 spot-beam transponders that deliver high-definition television to 75 U.S. market locations. The satellite, which began commercial service in September from its geostationary-orbit slot at 102.8 degrees west longitude, generates 16 kW end-of-life power and has a design service life of 15 years.

On 3 May an Ariane-5 ECA launched SES Astra's 4.5-tonne Astra-1L and Intelsat's 4.1-tonne Galaxy-17 into their geostationary-orbit slots. The total payload mass, including the spacecrafts' interface hardware and the Ariane-5 multiple deployment system, was 9.4 tonnes and one of the heaviest ever for launch to a geosynchronous transfer orbit. Astra-1L, now orbiting at 19.2 degrees east longitude, was built by Lockheed Martin Commercial Space Systems on the company's A2100-AX platform, and began delivering high-definition broadcast television services to continental Europe on 10 July. Galaxy-17, built on a Spacebus platform by Thales Alenia Space (formerly Alcatel Alenia Space), is serving Intelsat customers with television and communications services over its 15-year design lifetime.

In contrast, the 5 October launch by an Ariane-5 GS variant orbited two much smaller satellites, both manufactured by Orbital Sciences Corporation (OSC, USA): the 2.5-tonne Intelsat-11 (Bermuda) and the 2.35-tonne Optus D2 (Australia). Intelsat-11, covering the Americas and part of Europe from its geostationary-orbit slot at 43 degrees west longitude, where it replaces Intelsat 6B and Intelsat 3R, is equipped with 16 C-band and 18 Ku-band transponders. Optus Networks' Optus D2, orbiting at 152 degrees east longitude, carries 24 Ku-band transponders to cover Australia and New Zealand. The launch also demonstrated the reignition capability of the Ariane's Aestus upper-stage engine which will be needed to launch ESA's Automated Transfer Vehicle (ATV) to the International Space Station next year.

A pilot programme for nationwide satellite delivery of first-run Hollywood movies to U.S. theaters was initiated on 7 March, when Microspace Communications Corporation (USA) signed an agreement with Carmike Cinemas, the fourth largest U.S. theater chain. The agreement calls for Microspace to install satellite-receiving equipment in over 200 Carmike theaters, providing digital satellite transmissions to more than 2,000 screens. 1,711 of Carmike's 2,447 total screens in 289 theaters are equipped for digital movies.

Telesat Canada ordered the Nimiq-5 direct-broadcast satellite from Space Systems/Loral (USA) on 4 January, shortly after the merger of the two companies was announced. Based on Space Systems/Loral's 1300 bus, the spacecraft will carry 36 Ku-band transponders, all pre-sold to Canadian satellite-television provider Bell ExpressVu. Nimiq-5 will operate from Telesat's geostationary-orbit slot at 72.5 degrees west longitude. The company's 4.64-tonne Anik-F3 satellite was launched from the Baikonur Cosmodrome on 10 April by an International Launch Services Proton-M rocket and was placed in Telesat's geostationary-orbit slot at 118.7 degrees west longitude. Anik-F3, built by Astrium Satellites (France) on the company's 11-kW Eurostar E3000 platform, carries 24 C-band, 32 Ku-band, and two Ka-band transponders.

On 13 June the Canadian Ministry of Industry granted provisional licenses for 12 new geostationary-orbit slots. Three went to Ciel Satellite LLP and four to Telesat Canada for the 17-GHz section of the radio spectrum, to be used for broadcast satellite services, including video and broadband Internet access. Two more provisional licenses went to Ciel and one more to Telesat for Ka-band services, and two were awarded to Ciel

for service in an extended Ku-band and a 12-GHz band. The first services under the new licenses are planned to begin in 2010, assuming the two companies provide the Ministry with ownership and operational plans adequate for the granting of operating licenses.

On 24 August Canada announced a new satellite-delivered broadband service to schools, government agencies, and individuals in a number of rural villages in Quebec, Ontario, and Manitoba. The service was financed by a \$26-million investment by the Canadian government (75%), by Telesat Canada, and the province governments of Ontario and Quebec. It will use two Ka-band transponders aboard Telesat's Anik F2 satellite.

Intelsat also placed an order with Space Systems/Loral on 19 January for Intelsat-14, to be built on Loral's 1300 bus and to be placed in a geostationary-orbit slot at 45 degrees west longitude. Its 40 C-band and 22 Ku-band transponders feed four beams that will provide coverage of North and South America and parts of Europe and Africa. Intelsat-14 will replace PAS-1R, launched in 2000 but equipped with what were later found to be defective solar arrays that limit its life.

Telenor Satellite Broadcasting (Norway) placed a \$219-million order with Thales Alenia Space (France and Italy) on 24 April for Thor-6, a direct-broadcast television satellite carrying 36 Ku-band transponders to replace Thor-3 in serving the Nordic countries and the Central and Eastern Europe from the geostationary-orbit slot at 1 degree west longitude. It was the first satellite order to be received by Thales Alenia Space since the company was bought by Thales.

The four other bidders included Orbital Sciences Corporation (USA), who had won Telenor's previous (2005) order for the 2.45-tonne Thor-5 spacecraft that is to be launched late this year from the Baikonur Cosmodrome by an International Launch Services (Russia) Proton-M rocket. The 3.8-kW Thor-5, which carries 24 Ku-band transponders, will replace Telenor's Thor-2, scheduled to be retired in 2008, in the same orbital slot as Thor-3. Telenor's total cost for Thor-5, including the launch and a ground station also built by Orbital Sciences, was \$196 million. Telenor delivers television broadcast service, including high-definition TV, to 3 million Nordic homes and 1 million in the Central and Eastern Europe.

The Arabsat 4B/Badr-4 satellite was launched from the Baikonur Cosmodrome on 9 November 2006 aboard the International Launch Services (ILS) Proton Breeze M rocket. The 3.3-tonne spacecraft will assume the traffic load originally planned for Arabsat 4A, which was lost after its Proton Breeze launcher's upper stage failed in February 2006 (see last year's report). Badr-4 carries 28 Ku-band transponders to provide 130 million customers with regional television broadcasts from its geostationary-orbit slot at 26 degrees east longitude. The spacecraft was built by Astrium (France); its payload was provided by Alcatel Alenia Space (France and Italy; now Thales Alenia Space). The spacecraft covers the area from Morocco and Algeria to the Arabian Gulf, inhabited by 324 million people. Its design service life is 15 years.

Eutelsat (France) ordered its W7 all-Ku-band satellite from Alcatel Alenia Space (France and Italy; now Thales Alenia Space) on 21 December 2006. Based on Alcatel's Spacebus 4000 platform, the 5.6-tonne satellite will carry up to 70 Ku-band transponders, broadcasting via six beams to Africa, Central Asia, the Middle East, and Russia, plus a reconfigurable beam targeting Central Asia. It is to be launched to Eutelsat's geostationary-orbit slot at 36 degrees east longitude by a Sea Launch rocket in mid-2009.

On 19 February Eutelsat (France) and ViaSat (USA) jointly announced the initiation of two-way consumer broadband satellite services to small and rural markets in Western Europe, beginning in June with customers in Germany, Portugal, Spain, and Switzerland. The open-standards network is based on ViaSat's Surfbeam system, used previously by Wildblue Communications (USA) to deliver broadband connectivity to rural markets in North America. The new service, called Tooway, is using 67-cm rooftop antennas built in the UK and other components from Taiwan. Service began in June via the four Ka-band transponders on Eutelsat's Hot Bird 6 satellite at 13 degrees east longitude, to be followed by a new all-Ka-band Eutelsat spacecraft in 2010.

Eutelsat's Hot Bird 2 satellite was forced to transfer all traffic to Hot Bird 8 on 14 March, when it was hit by a solar flare. Subsequent checks indicated that despite the initially observed anomaly in the satellite's power subsystem, it had suffered no damage that would affect its operability, and it was subsequently returned to full service.

On 8 May SES Americom ordered a replacement satellite, AMC-5R, and a ground spare from Orbital Sciences Corporation (OSC, USA), along with options for three more spacecraft. All five are to employ a new "quasi-standard" design, based on a 5-kWe version of OSC's Star-2 bus with two deployable reflectors and a complement of 24 C-band and 24 Ku-band, 36-MHz transponders. Some transponders will be cross-strapped, allowing transmission and reception in different frequencies to facilitate load adjustment in accordance with voice, data, and video traffic demands. AMC-5R is planned for launch in 2009; the ground spare for delivery late the same year.

Hispasat (Spain) signed a contract with Astrium Satellites on 6 June for Amazonas-2, to be launched in 2009 into a geostationary-orbit slot at 61 degrees west longitude. It will supplement the Amazonas satellite launched there in August 2004, which has suffered a fuel leak that will end its expected 15-year service life before 2014. The 5.4-tonne Amazonas-2, built on Astrium's E3000 satellite bus, will carry 54 Ku-band and 10 C-band transponders to serve the rapidly growing South American market.

ESA announced on 17 January that it will fund a contractor to place a commercial payload aboard the agency's first small geostationary-orbiting satellite platform, "Small-GEO," which is being designed by OHB System (Germany) on the company's 1-2-tonne Lux bus for payloads requiring the order of 3 kW. The \$131-million framework contract for Small GeO, officially known as Artes-11, was issued to OHB System by ESA on 6 March; industry is expected to contribute an additional \$20 million. Subcontractors to OHB are Swedish Space Corporation, Oerlikon Space (Switzerland) and Lux-Space (Luxembourg), a fully owned OHB subsidiary. Full-scale development is expected to

begin in March or April 2008. The 2.5 – 2.7-tonne demonstrator satellite will carry a 300-kg payload, generate 3 kW of power, and will have a design lifetime of 15 years. Launch is planned for 2011.

The Small-GEO project parallels ESA's existing Alphasat satellite programme, whose platform is being built jointly by Astrium Satellites (France) and Thales Alenia Space (France and Italy) for payloads requiring 12 – 18 kW. ESA's telecommunications budget, which is almost all committed to Alphasat and Small-GEO, is 8% of the Agency's total 2007 budget, released on 17 January. ESA and the French space agency CNES (Centre National d'Études Spatiales) have committed a combined \$298 million to Alphasat development; the private-sector investment in the big satellite is expected to total about \$260 million.

On 26 March ESA received bids for test operations of the 7-tonne, 18-kW Alphasat spacecraft from Inmarsat (UK) and Eutelsat (France), teamed with Telespazio (Italy). Eutelsat proposed using the Alphasat for Ka-band broadband fixed data transmission in Europe, whereas Inmarsat offered to place an extended 7-MHz L-band payload on the satellite to broaden Inmarsat's existing mobile satellite service. On 15 May ESA selected Inmarsat, and following negotiations signed the testing contract in September. Launch of Inmarsat's 6 – 6.5-tonne I-XL satellite is planned for 2012 into a geostationary-orbit slot at 25 degrees east longitude.

Startup satellite operator ProtoStar Ltd (Bermuda) announced on 15 November 2006 that it had raised \$250 million to purchase Chinasat-8, which has been in storage at manufacturer Space Systems/Loral's plant for several years. After transfer of ownership from China Telecommunications Broadcast Satellite Corporation on 5 January, Space Systems/Loral began refurbishing and modifying the ProtoStar satellite for a planned launch aboard an Ariane 5 ECA rocket in early 2008, to provide direct-broadcast television services from a geostationary-orbit slot at 98.5 degrees east longitude to customers in South and East Asia. The modified ProtoStar-1 will weigh 4.1 tonnes and carry 22 Ku-band and 38 C-band transponders.

Al Yah Satellite Communications Company (Yahsat, Abu Dhabi) placed a \$1.66 billion order with EADS Astrium (France) and Thales Alenia Space (France and Italy) on 8 August for two broadband spacecraft to be orbited in 2010. Comprising the first broadband satellite system in the middle east, Yahsat-1A and Yahsat-1B will each weigh 6 – 7 tonnes and will carry a mix of C-band, Ku-band, and Ka-band transponders. Yahsat-1A will be located in a geostationary-orbit slot at 52.5 degrees east longitude; the slot for Yahsat-1B will be announced later this year.

Broadcasting Satellite System Corporation's BSAT-3a (Japan) was launched in September from Kourou, French Guiana, by an ArianeSpace-5 ECA into B-SAT's geostationary-orbit slot at 110 degrees east Longitude. Built by Lockheed Martin Commercial Space Systems (USA) on the company's A-2100A platform, the direct broadcast satellite carries twelve 130-W Ku-band transponders to serve customers in Japan, and has a design life of 13 years.

China announced on 28 November 2006 that Sinosat-2, launched on 29 October 2006, had failed to deploy its solar arrays and large antennas and therefore had to be declared a total loss. The direct-broadcast satellite, built by the China Academy of Space Technology for operator Sino Satellite Communications Ltd. (Sinosat), was to broadcast television signals to 45-cm antennas and deliver television and digital broadband multimedia services to Hong Kong, Macau, Taiwan, and mainland China as far west as Tibet. It was to have provided television for the first time to rural Chinese customers without access to cable networks, and was slated as the mainstay for broadcasting the 2008 Beijing Olympic games. The \$190-million spacecraft, which was left in a quasi-geosynchronous orbit at 92.2 degrees east longitude, also heralded the first intended operational use of the Dongfanghong-4 (DFH-4) satellite bus, with 10 kW end-of-life power. It carried eighteen 36-MHz and four 54-MHz transponders, and had been expected to reach 100 million households by 2010, the equivalent of 300 – 400 million people. Some of its intended service will be assumed by Sinosat-3, launched subsequently in April, but that spacecraft, built on the mature but smaller and less capable DFH-3 bus, cannot carry the full load intended for Sinosat-2.

On 5 July a Chinese Long March-3B rocket launched ChinaSatCom's Chinasat-6B into its geostationary-orbit slot. The spacecraft was built by Thales Alenia Space (France and Italy).

India's 3-tonne Insat-4B was launched successfully by an Ariane-5 ECA rocket from ESA's Guiana Space Center on 11 March, along with the 4.7-tonne British Skynet-5A military communications satellite. Built by the Indian Space Research Organization (ISRO), Insat-4B carries 12 C-band and 12 Ku-band transponders, and is now serving the domestic Indian market for broadcast television from its geostationary-orbit slot at 93.5 degrees east longitude. Because of the loss of Insat-4C in July 2006 due to a Geostationary Space Launch Vehicle failure (see last year's report), all of Insat-4B's Ku-band transponders and 60% of its C-band transponders were sold prior to launch, at an annual lease price of about \$1 million each. Building Insat-4B cost ISRO about \$47 million, and its Ariane launch cost an additional \$52 million.

Malaysia's Measat-3 communications satellite was launched from the Baikonur Cosmodrome by an International Launch Services Proton-M rocket on 11 December 2006. The 4.7-tonne spacecraft, owned by Measat Satellite Systems Sdn Bhd (Malaysia), was built by Boeing Satellite Systems International (USA) on the company's 601HP bus. It carries 24 C-band and 24 Ku-band transponders, with three C-band beams providing television broadcast and communication services to 110 nations from Japan to Africa, and three Ku-band beams delivering direct-broadcast television to South Africa and Southeast Asia, including Indonesia and Malaysia. Following in-orbit checkout by Boeing, Measat-3 was turned over to Measat on 19 February, joining Measat-1 in a geostationary-orbit slot at 91.5 degrees east longitude.

Intelsat (Bermuda) provided backup communication services via satellite after the Taiwan earthquake of 26 December 2006 disrupted terrestrial communications networks

in Asia. Six major undersea fiber-optic cables were rendered inoperative by the earthquake, which registered 7.1 on the Richter scale. Intelsat's GlobalConnex Managed Networks Infrastructure was able to restore service for more than 20 telecommunications operators and broadcasters within hours of the earthquake.

On 16 March the Vietnam Post and Telecommunications Group (VNPT) signed a contract with Telesat Canada for technical oversight of the construction and launch of its Vinasat-1 spacecraft, being built by Lockheed Martin Commercial Space Systems (USA). The 2-tonne satellite, carrying 20 C-band and Ku-band transponders, is planned for launch in mid-2008 aboard an Ariane 5 rocket to a geostationary-orbit slot at 132 degrees east longitude. Vietnam's first domestic telecommunications satellite, which has a design life of 15 years, is costing VNPT \$270 million, including two ground-control stations in addition to spacecraft construction, launch, and insurance.

Nigeria's first communications satellite was launched to its geostationary-orbit slot over Somalia from the Xichang space launch center on 14 May by a Chinese Long March 3B rocket. The 5.16-tonne Nigcomsat-1 was also the first large satellite developed and launched by China for a non-Chinese customer. It carries 14 Ku-band transponders serving southern and western parts of Africa, C-band transponders for central, eastern, and southern parts of Africa, and an L-band system for navigation. Total cost of the spacecraft and launch was \$311 million. Nigcomsat-2, an Earth observation satellite, is being built by Surrey Satellite Technology Ltd. (UK; see below).

On 29 June PT Indosat Tbk (Indonesia) awarded a construction contract to Thales Alenia Space (France, Italy) for the 4.1-tonne Palapa-D satellite, planned for launch in late 2009 to Indosat's geostationary-orbit slot at 113 degrees east longitude. Built on Thales Alenia Space's 6-kW Spacebus 4000B3 platform, Palapa-D will carry 24 standard C-band transponders, 11 extended C-band transponders, and 5 Ku-band transponders. Because Thales Alenia Space has established a policy of excluding U.S.-built components (see prior reports), Indosat's contract provides for Palapa-D to be orbited by a Chinese Long March 3B rocket, which would not be permitted by U.S. export control regulations if any U.S. components were aboard.

Open Joint-Stock Company Sibertelecom (Russia) signed a contract on 26 June with Gilat Satellite Networks Ltd. (Israel) for a Very Small Aperture Terminal (VSAT) network to provide telephone and Internet connectivity services for remote Siberian communities via Gilat's SkyEdge system.

(2) Mobile Communication Systems

Inmarsat announced on 15 November 2006 that its first 5,500 customers for the mobile Broadband Global Area Network (BGAN) had subscribed to the service since 30 September 2006. The company is adding BGAN terminals at a rate of 350 per month, and has 12 BGAN distributors worldwide, including the Asia Cellular Satellite International Ltd. (ACeS) network, that Inmarsat purchased in September 2006 (see last year's report) to bolster its competitive position in service, using handheld terminals. On 27 November

2006, Inmarsat and BGAN service provider Telenor Satellite Services (Norway) began a three-stop campaign in Bangkok (Thailand), Manila (the Philippines), and Kumsan (South Korea) to persuade international communication service providers to integrate BGAN into their operations.

On 16 July Inmarsat inaugurated hand-held satellite telephone service aboard the company's Inmarsat 4 F1 spacecraft, located in a geostationary-orbit slot at 64 degrees east longitude. The service began immediately for Africa, Asia and the Middle East as well as backup service to ACeS customers using its Garuda-1 satellite, located at 123 degrees east longitude. The new IsatPhone service sells for about \$500, with voice communications costing less than \$1 per minute. Inmarsat plans near-global service by the end of 2008, using the Inmarsat 4 F2 satellite to provide service to the Americas, and will also add a maritime version to be called FleetPhone by the end of this year. The company has signed IsatPhone distribution agreements with eight companies: ACeS, Chinasat, Evosat, Fono, MCN, MVS, Satcom Global, and Stratos Global.

Globalstar (USA) and Alcatel Alenia Space (France and Italy; now Thales Alenia Space) signed an \$866-million contract on 30 November 2006 for 48 replacement Globalstar satellites. The new spacecraft will weigh 700 kg and will have a design lifetime of 15 years, while the original fleet was 450 kg in mass and had a 7-year lifetime. They will also transmit data at 144 kB/sec on a single channel, compared with the first-generation Globalstar satellites' data rate of 9.8 kB/sec. Thales Alenia Space plans to provide the first flight model by late 2009 (see last year's report), with the balance of the constellation following in two groups of 24 satellites each. The contract also includes pre-launch and post-launch support, and other services by Thales Alenia Space.

Meanwhile Globalstar launched four current-generation replacement satellites aboard a Starsem Soyuz-FG/Fregat rocket from the Baikonur Cosmodrome on 29 May. Another four were to have been launched on 29 July, but the launch from Baikonur was delayed until 22 October due to a suspected defect in the Soyuz launcher's Fregat upper stage, discovered after the successful 29-May launch. The successful 22-October launch lifted the four satellites to a 915-km orbit, from which onboard thrusters raised them to their operational 1400-km orbits and placed them in open orbital slots of Globalstar. While awaiting the launch, Globalstar on 5 September signed a \$210-million contract with Arianespace (France) to launch the first 24 of the new 700-kg replacement satellites aboard four Soyuz rockets from Kourou in 2009 and 2010, along with a commitment to launch the second group of 24 satellites between 2010 and 2014.

On 1 February Globalstar released its new GSP-1700 satellite telephone handset, weighing only 200 grams, which is half the weight and size of the company's previous model. Globalstar also re-introduced an E-Star Emergency rate plan costing \$30 per month, and on 8 February countered concerns about the degradation of its current fleet by announcing that the current constellation could maintain service until the launch of a new spacecraft in 2009.

ICO Global Communications (USA) announced on 2 May a major revision in its business plan, focusing in the future on two special services to mobile customers: interactive television and navigation. The primary customers are automobiles equipped with video-input slots, which will have access to 15 video channels at a price of \$15 - \$25 per month. Service will be provided by the fully financed ICO G1 satellite, built by Space Systems Loral (USA), to be launched by the end of this year aboard a Lockheed Martin Atlas-V rocket. G1 will be supplemented in the future by a second \$200 million satellite, contracted this summer. Both satellites will use the 2-GHz S-band with a network of Ancillary Terrestrial Components (ATCs) to boost the signals in mountainous areas, and in and near large cities. The ATC network is expected to cost ICO another \$250 million. The first field trials of the system are planned for early 2008 and will be overseen by Alcatel-Lucent (France), which has contracted with ICO to be the system 's network integrator.

After having been served notice by British regulators of impending renovation of its medium-orbit mobile satellite communication license without a demonstration of concrete steps to complete its constellation, ICO signed on 29 May a contract with International Launch Services (ILS, USA) to launch up to ten two-way mobile communication satellites between 2009 and 2011. The 2.75-tonne spacecraft, originally planned to be built by Boeing Satellite Systems International (BSSI, USA), are to be launched in pairs aboard ILS Proton rockets to their operating orbits at 10,390 km altitude. Pending resolution of a current lawsuit against BSSI, however, ICO may switch to a different spacecraft vendor.

On 21 February EchoStar Communications (USA) announced a two-pronged programme to deliver video programming of the 2008 Beijing Olympics to customers using hand-held devices. According to the announcement, EchoStar subsidiary China Mobile Broadcasting Satellite Ltd. (CMBSat) had obtained regulatory approval from China's State Administration of Radio, Film, and TV to deliver S-band video programming in China, using the CMBSat spacecraft being built by Space Systems/Loral. EchoStar also announced its investment of \$40 million in TU Media (South Korea), which currently delivers mobile S-band video to over a million customers in the region. On 11 March, the Indian Space Research Organization announced that India too will place an S-band mobile-video payload on an Insat satellite planned for launch next year. Its services are to be marketed by a new Indian company financed by U.S. venture capital.

Sirius Satellite Radio (USA) announced on 29 March an agreement with the Chrysler Group (USA) to deliver family-type television programming for children sitting in the rear seats of several models of the automaker's vehicles. The Backseat TV programmes will cost the consumer \$470, which includes the satellite-compatible television set and one year of service, as well as the cost of Chrysler's Rear Seat Entertainment System and Sirius Radio access. After the first year, service will amount to a total of \$20 per month, including subscription to the Sirius Radio.

On 13 June Continental Airlines (USA) issued a contract to Avionica, Inc. (USA) to install the company's satLINK Iridium satellite communications system aboard nine of Continental's Boeing 737-800 aircraft. The system, which provides voice and data communications to cockpits via the 66-satellite Iridium network, consists of a control panel, antenna, wiring, and structural elements.

The German Aerospace Center DLR began prototype testing in January of a satellite radio system using old communications satellites to broadcast radio programming to automobiles. The Ku-Mobil system uses Ku-band broadcast satellites whose north-south stationkeeping thrusters are turned off, allowing them to use the propellant thereby saved to continue operating for several more years. The resulting unstabilized orbit requires receivers to use active tracking antennas, and also to receive and store packets of programming for later use when the satellite link is unavailable. DLR's partners in the project are SES Astra, automobile firm BMW, and radio broadcast company Deutsche Welle. ESA's Artes communications research programme provided some funding for the demonstrations.

On 25 July the European Commission approved a joint venture by SES Global (Luxembourg) and Eutelsat (France) to develop and provide S-band mobile television and two-way telecommunication service to European customers via Eutelsat's W2A satellite, planned for launch in 2009 (see last year's report). The companies will share the \$180-million cost of building and integrating the S-band antenna for the two S-band transponders on the W2A spacecraft, along with other required modifications to the satellite's C-band and Ku-band transponder systems.

On 30 March Telespazio (Italy) and ESA announced an agreement with the regional government of Piedmont, Italy to conduct tests of Telespazio's Satellite Adaptor project, which uses an integrated communications system that enables first responders at a disaster site to maintain broadband data and voice contact with their operational centers regardless of the technical transmission standards used locally. Also involved in the project with the Piedmont regional civil protection agency are Thales Alenia Space (France and Italy), Indra (Spain), and Hispasat (Spain).

Following a long investigation, Thuraya Satellite Communications (United Arab Emirates) revealed on 4 April that the six-month-long jamming of the company's L-band mobile communications in 2006 had been caused by three sites within Libya, a shareholder in Thuraya, one of which was a military facility. According to Libya, the motive for the jamming action was to disrupt the operations of smugglers from Chad and Niger, who they believed were using satellite telephones. The jamming sites were finally discovered with the technical help of the Thuraya satellite's builder, Boeing Satellite Systems International (USA), who maneuvered the satellite so as to detect the location of the jamming signals.

On 9 October the United Nations' International Telecommunications Union (ITU) delivered 30 solar-powered satellite telephone terminals to Bangladesh to aid flood recovery efforts in the country. ITU purchased the terminals from Thuraya Satellite

Communications (United Arab Emirates), and covered the costs of training emergency crews in their installation and use.

On 11 June Telstra Corporation, an Australian telecommunications carrier, issued an eight-year contract worth \$3 million - \$3.5 million to Iridium Satellite LLC (USA) to add satellite capabilities to Beam Communications Pty Ltd.'s communications network, serving Australian Rail Track Corporation Ltd. The Iridium data and voice communications service will back up the existing terrestrial links that allow locomotive engineers on the 10,000-km rail network to communicate with station managers. This contract follows a \$4.2-million Telstra contract with Beam Communications Pty Ltd. to provide fixed and car-mounted Iridium telephones for Telstra's Universal Service Obligation programme.

(3) Navigation and Position Location

The U.S. Federal Aviation Administration (FAA) on 30 August selected a team, led by ITT Corporation (USA) to finance, develop, and build a nationwide network of terminals for the first satellite-based air traffic navigation and surveillance system, which will supersede the old radar surveillance and air traffic control systems. The system, called Automatic Dependent Surveillance-Broadcast (ADS-B), will process data-linked Global Positioning System (GPS) position reports from aircraft. Other bidders for the \$1.8-billion contract were Lockheed Martin and Raytheon (both USA). ITT will own the infrastructure and charge the FAA usage fees for ADS-B over several decades. The 18-year contract to ITT, of which the initial increment released on 30 August was \$207 million, is only the first part of a planned \$15-billion overhaul of U.S. air-traffic technology. The ITT team includes Thales (France), AT&T (USA) and thirteen smaller U.S. companies.

On 18 September the U.S. Air Force announced its final decision to remove the "selective availability" feature from the Global Positioning System (GPS). This feature, if implemented, would have allowed the U.S. military to degrade civil GPS signals. The U.S. had stopped using the selective availability capability in 2000, and it is not being incorporated into the next-generation GPS-3 system. The Air Force completed replacement on 14 September of the new GPS ground segment, which controls the system, determines the orbital position of the satellites, and keeps the system operational. Called the Architecture Evolution Plan, the upgrade replaces the legacy ground control segment that has been in place since the 1970s.

On 21 February Orbital Sciences (OSC, USA) announced a contract with public transportation provider Pierce Transit of Tacoma, Washington (USA) for a vehicle dispatch and locating system for the company's 391 buses. The \$6.2-million contract includes OSC's OrbCAD-XP dispatch and locating system and associated analytical tools.

Russia's Defense Minister announced on 13 November 2006 that all security restrictions limiting public access to the most accurate signal from Russia's Global

Navigation Satellite System (Glonass) would be removed as of 1 January 2007, to foster wider use of Glonass, that is also in the interest of increasing economic development in Russia. Three new Glonass satellites were launched in December 2006, raising the in-orbit complement to 13 spacecraft, with a 16-18-satellite constellation expected to be operational by January 2008, and the full 18-satellite fleet required for complete coverage of Russia planned to be in place by the end of 2008.

On 5 March ESA announced a contract with Surrey Satellite Technology Ltd (SSTL, UK) for a second Galileo navigation system satellite. Giove-A2, which is nearly identical to the Giove-A spacecraft built by SSTL and launched in December 2005, is planned as a backup for Giove-B, which has been delayed by about two years due to both technical and coordination problems among the subcontractors of a builder, the European Satellite Navigation Industries (formerly Galileo Industries). ESA stated on 6 March that Giove-A2 will be launched only in the event of a failure of Giove-B, which was delivered to ESA by builder Thales Alenia Space on 3 September and is now scheduled for launch in December. Giove-A2 will therefore assure the continuing use in orbit of the assigned frequencies, required by the United Nations' International Telecommunications Union's (ITU's) mandate that orbital slots expire if they are unused for two years. Giove-A2, like Giove-A, has a design lifetime of 27 months, and could be launched in the second half of 2008 if needed to "hold" the slot. Giove-A, whose first stage of testing was completed successfully in late August, is currently expected to last until at least early 2008. Giove-A2 is expected to cost between \$33 million and \$39 million, which ESA plans to draw from current programme reserves.

On 14 March, ESA announced that delivery of the four In-Orbit Validation (IOV) spacecraft for Galileo (see last year's report) will be delayed by at least eight months to late 2009 or early 2010, due to as-yet unresolved technical and management issues. Management concerns with the Galileo Operating Consortium (GOC), which was negotiating with the European Commission to be the operating entity that will deploy the 26 operational Galileo system satellites and run the system, also pushed the prospective service entry date back to at least 2012 – 2013.

On 16 May the European Commission (EC) proposed to remove these roadblocks by scrapping the public-private partnership (PPP) funding scheme and financing Galileo wholly with government funds. Under this proposal, Europe's governments would pay the entire \$4.7-billion cost of developing, building, and launching the system, leaving private investors to cover only the completed network's operation and the related wide-area augmentation system Egnos, which is due to begin service in 2008. At a meeting from 6 to 8 June, the European transport ministers accepted the EC's proposal and agreed to break off talks with the industry consortium bidding to deploy and operate Galileo, and to explore ways to replace private-sector financing with public money. They also agreed to consider different concepts for Galileo's operation and evaluate a new management structure and procurement policy for the project.

On 24 September the EC laid out a new policy making the European Parliament and the European Council responsible for Galileo's political and programme oversight,

the latter through a new European Global Navigation Satellite (GNSS) Program Committee. The EC would be the owner or sponsor of the project, under the supervision of the GNSS Program Committee, with ESA serving as prime contractor to the EC. ESA would be responsible for the IOV spacecraft, the 26 Full Operational Capability (FOC) satellites, and the related ground segment. The GNSS Supervisory Authority would be given responsibility for market services, accreditation and certification, and advising the EC. In November, the EU secured Galileo's future by allocating additional funds out of the EU's unused budget funds.

On 26 July the U.S. and Europe signed an agreement on a common civil signal for their future navigation and positioning satellite constellations. The agreement, which will apply to the U.S. GPS-3 L1C and Galileo L1F satellites when they begin operations in future years, will permit navigation terminal manufacturers to integrate both sets of signals into a single chipset, thereby providing the improved accuracy and signal reliability attainable by having more satellites in view at any one time. The Galileo L1F satellites are expected to begin operations in 2012; the GPS-3 L1C spacecraft in 2013.

Satamatics (UK) on 9 May announced the availability of its Personnel Tracker, a device that uses the GPS navigation signal, relayed by Inmarsat satellites, to monitor people operating in remote or dangerous areas not covered by mobile telephone or other radio service. The tracker, carried in a backpack or a vehicle, enables its user to send a panic alarm in case of an emergency.

On 6 November 2006 China released information about its Beidou experimental satellite navigation and positioning system. Plans call for a 35-satellite operational constellation, with five in geostationary orbit and the rest in medium-altitude orbits. The system, named Compass, will offer both civilian and military positioning services, with civilian-service signals providing position accuracies of 10 m, speed accuracies of 0.2 m/second, and 50-nanosecond timing precision. The fourth Beidou satellite was launched from the Xichang Satellite Launch Center on 2 February by a Long March 3A rocket to serve as in-orbit spare for the first Beidou spacecraft, which was launched to its geostationary orbit in 2000.

The first spacecraft of the operational Chinese system, Compass-1M, was launched by a Long March-3A rocket from the Xichang launch center on 14 April, and transmitted its first operational signal 570 seconds after liftoff. Three days later it was placed by the Xi'an Satellite Control Center in a 21,500-km medium-altitude orbit, similar to those of other navigational satellite systems GPS, Glonass, and the future Galileo system. Developed by the China Academy of Space Technology and the China Aerospace Science and Technology Corporation's Academy of Launch Vehicle Technology, the Compass satellites are planned to begin operational service in 2008.

At the meeting of the International Committee on Global Navigation Satellite Systems (ICG) in September, China announced it had started its project of a new global navigation satellite system Compass. The ICG was created on the recommendation by the United Nations Committee on the Peaceful Uses of Outer Space in 2005 as an informal

body to address the issues associated with coordinating the existing and planned satellite navigation systems of China, Europe, India, Japan, Russia, and the U.S.

On 23 May Japan's parliament enacted legislation that commits the government to fund the first satellite in the three-spacecraft Quasi-Zenith Satellite System for navigation and position location. Accordingly, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) will provide most of the \$619 million required to develop and launch the 4-tonne satellite no later than 31 March 2010. Planned to be built by the Japanese Aerospace Exploration Agency (JAXA), the spacecraft will use Mitsubishi Electric's DS2000 satellite platform and payloads supplied by NEC Toshiba Space Systems Ltd. A decision on the funding or development of the other two spacecraft has yet to be made. The constellation, in a highly elliptical orbit, is envisioned to have a positioning accuracy measured in centimeters and will also provide broadcast communications services.

B. Remote Sensing

(1) Earth Observations

At a commemoration of the 50 years since the launch of Sputnik-1 that heralded the beginning of the Space Age, organized by the IAF on 21 March, the world's space agencies signed an agreement with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) to use their space assets to support the protection of UNESCO natural and cultural sites. The 830 sites on UNESCO's World Heritage List include Australia's Great Barrier Reef, the Great Wall of China, the Copan ruins in Honduras, the Pueblo de Taos in New Mexico, USA, and the Mahabodhi Temple complex in Bodh Gaya, India where Buddha received enlightenment.

On 15 January the U.S. National Academy of Sciences released its report, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond." The report suggests that the U.S. government funds 17 Earth observing satellites between 2010 and 2020 in order to rebuild the nation's aging network of environmental spacecraft; otherwise the number of U.S. climate-monitoring satellites would drop from today's 29 to only seven by 2017. Implementing this suggestion would require NASA to return its annual investment in Earth science from the current level of \$1.5 billion to the 2002 level of \$2 billion (in constant 2007 dollars), and also would mandate a constant annual investment of \$1 billion by the National Oceanic and Atmospheric Administration (NOAA), which was charged with undertaking two of the 17 new missions identified by the report.

Four companies - Ball Aerospace, General Dynamics Advanced Information Systems, Orbital Sciences Corporation, and Space Systems/Loral - received four-month, \$600,000 contracts from NASA on 22 May to provide advise on how their products could best accommodate the Landsat Data Continuity Mission (LDCM). All four companies are spacecraft catalogue-type suppliers to NASA's Rapid Spacecraft Development Office at the Goddard Space Flight Center. A \$180-million contract for the primary Landsat instrument, the Operational Land Imager, was subsequently issued on 16 July to Ball

Aerospace and Technologies Corporation (USA), and in August the Agency issued a request for proposals from the four companies on the satellite bus. The mission is planned for launch no sooner than July 2011.

DigitalGlobe's 2.3-tonne Worldview-1 satellite was launched from Vandenberg Air Force Base by a United Launch Alliance Delta-2 on 18 September. The 0.5-m-resolution spacecraft, developed by DigitalGlobe, Ball Aerospace, and ITT (all USA), was the first satellite launched under the U.S. National Geospace-Intelligence Agency's \$500-million NextView award (see prior reports), but most of its high-resolution black-and-white images are being made available commercially as well as to the U.S. government during its 7-year design lifetime. It was the highest-resolution commercial satellite launched to date. The other company receiving a \$500-million NextView award, GeoEye (USA), plans to launch its 0.5-m-resolution multispectral imager early next year.

Data from NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites on water storage trends in over 50 river basins worldwide, released on 12 December 2006, showed significant drying over the past five years in a number of African river basins, including the Congo, Nile, and Zambezi, contrasted with increases in the U.S. Mississippi and Colorado river basins. The data are being used to make more informed water management decisions.

NASA announced on 15 May that data from the agency's Quick Scatterometer (QuikScat) indicated significant melting of large regions of Antarctic snow cover in January 2005. It was the largest-scale Antarctic snowmelt detected by satellite over the past 30 years. The early melting occurred in several regions that together cover an area about the size of the U.S. state of California. The January 2005 snowmelt could presage larger-scale melting of Antarctic snow sheets, which up to now have escaped any major impact by global warming except on the Antarctic Peninsula.

OrbView-3 (OV-3), built by Orbital Sciences Corporation (USA) and owned by GeoEye Inc. (USA) suffered loss of imagery quality on 4 March due to electronic problems with the spacecraft's camera, built by Northrop Grumman (USA). OV-3, launched in 2003 with a design lifetime of five years, does not have a backup camera. On 19 March it was declared a total loss by GeoEye and subject to a \$40-million insurance claim. OV-3's successor, GeoEye-1, was equipped with redundant cameras by the sensor manufacturer, ITT Industries. The 1,890-kg satellite, to be launched early next year, was built for GeoEye by General Dynamics Advanced Information Systems.

On 19 April GeoEye announced a partnership with the East Dawn Group (China) to distribute satellite imagery and value-added products in China. East Dawn formed a new company, Beijing Earth Observation (BEO), to be GeoEye's exclusive master reseller in China, and to have access to GeoEye's archive of over 278 million square km of map-accurate satellite imagery. GeoEye appointed two members of BEO's Board of Directors.

On 25 May China launched the Yaogan-2 remote-sensing satellite from Jiuquan aboard a Long March-2B rocket into a near-polar Sun-synchronous orbit, along with a small microelectronics research spacecraft. On 19 September China launched the new China/Brazil Earth Resources Spacecraft (CBERS-2B) aboard a Long March 4B rocket from Taiyuan into a 750-km near-polar Sun-synchronous orbit. With 2.7-m resolution, the 1,450-kg CBERS-2B provides China with the capability for dual-use, high-resolution, near-real-time digital image transmission. The Brazilian space agency INPE accessed the satellite's first signals shortly after it was placed in orbit. Brazil's Opt Electronics is prime contractor to INPE for the cameras to be used on the next two CBERS satellites.

Surrey Satellite Technology Ltd (SSTL, UK) announced on 6 November 2006 that it had received a contract from Nigeria's National Space Research and Development Agency to build Nigeriasat-2, an optical Earth observation satellite. The 300-kg spacecraft, to be launched into a 700-km polar orbit in 2009, will carry two imagers, one with 2.5-m black-and-white resolution and 5-m four-color resolution with a swath width of 20 km; the other, for wide-area coverage, with 32-m resolution and a swath width of 300 km. It will carry a solid-state data recorder with 16 GB memory, from which it will be able to download data at up to 210 MB/sec. As part of the contract, SSTL will host 25 Nigerian engineers to observe the satellite's construction and to build their own training model. Nigeriasat-1, a communications satellite, was built by the China Academy of Space Technology.

On 27 March SSTL also announced a contract with the Federal State Unitary Enterprise - the Russian Research and Production Enterprise Pan-Russian Research Institute for Electromechanics to provide avionics equipment, software, and assistance with satellite assembly for Russia's Kanopus Earth observation satellite, planned for launch in 2008. SSTL expects this contract to open the door for cooperation with Russia on future small satellite projects.

The first of Germany's five SAR-Lupe radar-imaging satellites, SAR-Lupe-1, was launched from the Plesetsk Cosmodrome into a 500-km polar orbit by a Kosmos-3M rocket on 19 December 2006. The 720-kg, 250-W SAR-Lupe spacecraft, to be launched at 4-6 month intervals during the next two years, will operate in three quasi-polar orbits during their 10-year design lifetime, providing over 30 images daily with better than 1-m resolution (down to 0.5 m) over a swath width of 5 km per satellite at latitudes between 80 degrees north and 80 degrees south. The \$240 - \$300-million network, built by OHB System (Germany), began operations in January with SAR-Lupe-1, which was tested and declared fully functional on 19 January. The satellites are equipped with crosslinks that enable them to relay commands to each other. Thales Alenia Space (France and Italy) is the prime contractor for SAR-Lupe radar sensors, and other payload subsystems are being built by Saab Space (Sweden), Tesat-Spacecom (Germany), and Thales Group (France). Astrium Satellites, which competed with OHB-System for the SAR-Lupe prime contract, is prime contractor for the system's ground segment. SAR-Lupe-2 was launched by a Russian Cosmos-3M rocket from the Plesetsk Cosmodrome on 2 July and entered service a month later. SAR-Lupe-3 was launched from Plesetsk by another Cosmos-3M rocket on 3 November, and the remaining two satellites in the constellation will be

launched in 2008.

Germany's 1.35-tonne TerraSAR-X radar satellite (see last year's report) arrived at the Baikonur Cosmodrome on 27 February and was launched into its 514-km near-polar orbit by an ISC Kosmotros Dnepr rocket on 15 June, following a delay due to a Russian-Kazakh dispute over responsibility for debris caused by a July 2006 Dnepr failure. The 1-m resolution spacecraft, which also carries a laser communications payload built by Tesat Spacecom (Germany) and a tracking, occultation, and ranging experiment built by GFZ Earth Observation Center (Germany), is a joint venture between the German Aerospace Center DLR and EADS Space subsidiary Infoterra GmbH, who are marketing the radar data commercially. The spacecraft was built by Astrium Satellites (Germany) for \$174 million including the launch; ground facilities and five years of operations added another \$74 million.

The first of Italy's four CosmoSkyMed radar-satellite constellation was launched by a United Launch Alliance Delta-2 from Vandenberg Air Force Base on 7 June, and its first images were released by the Italian government on 4 October. Along with TerraSAR-X, the CosmoSkyMed constellation will be an integral part of Europe's Global Monitoring for Environment and Security (GMES) system, which in turn is a cornerstone of the international Global Earth Observation System of Systems (GEOSS). The next two spacecraft slated for GMES are Germany's hyperspectral EnMap and Italy's 400-kg hyperspectral Prisma, planned to enter full-scale development early next year. The first dedicated GMES satellite contract, issued by ESA on 18 June to CosmoSkyMed-1's builder Thales Alenia Space, was for Sentinel-1, a 2.3-tonne C-band synthetic-aperture radar satellite with 5-25-m spatial resolution, to be built on CosmoSkyMed's Prisma bus at a cost of \$310 million. ESA has allocated an additional \$1.3 billion for Sentinel-2, which will provide optical land imagery, and Sentinel-3, providing ocean altimetry, color, and temperature data. Contracts for the latter two were issued later in the year.

The German space agency DLR signed a contract with Kayser-Threde GmbH (Germany) on 15 November 2006 for the design of a hyperspectral Earth observation satellite named EnMap (Environmental Mapping and Analysis Programme). Cost of the spacecraft, planned for launch in 2011, is estimated at \$115 million, including the launch and ground segment. OHB Technology (Germany) will build the bus, with Kayser-Threde responsible for the payload and overall management of the mission. The 700 – 800-kg EnMap will be the first non-experimental satellite to use high-quality hyperspectral imagery, which up to now has been employed operationally only by aircraft. It will have about 200 spectral channels – at least twice the number in existing multispectral satellites – over a range of 420 – 2,450 nanometers, with a spectral resolution of about 30 m over a 30-km swath. Onboard storage will be 512 GB, with a downlink data rate of 100 – 300 MB/sec.

On 24 February Japan's H-2A rocket launched a radar-imaging satellite and an optical-sensor demonstration spacecraft from the Tanegashima Space Center into a 400 – 600-km polar orbit. The radar satellite completed the four-satellite constellation of Japan's initial Information Gathering Satellite (IGS) system, which consists of two 1-3

m-resolution radar-imaging and two 1-m-resolution optical-imaging spacecraft. The secondary payload of the 24 February launch carried an experimental optical sensor with resolution reported as 0.6-m, to demonstrate technologies never before tested by Japan. Both the IGS system and the demonstration satellite are managed by Japan's Cabinet Satellite Center.

Japan's Daichi Advanced Land Observing Satellite, launched in January 2006 (see last year's report), measured a land-surface rise of up to 45 cm in an 80-km diameter area around the city of Wajima following the Noto Peninsula offshore earthquake of 25 March. The measurement was based on data from the spacecraft's Phased Array L-band Synthetic Aperture Radar (Palsar) on 23 February, before the earthquake, and on 10 April, after it.

Cartosat-2, the twelfth in India's remote-sensing satellite series, was successfully launched on 10 January into its 639-km polar orbit by a Polar Satellite Launch Vehicle (PSLV) from the Satish Dhawan Space Centre, along with three other spacecraft. Cartosat-2 carries a panchromatic camera with a ground resolution better than 1 m and a swath of 9.6 km. Its data are being received and processed by India's National Remote Sensing Agency for use in cartographic applications, urban and rural infrastructure development and management, and in India's Land Management System and Geographical Information System.

One of the four satellites launched by India's PSLV on 10 January was the 55-kg Lapan-Tubsat, a cooperative Earth-observation venture between the Indonesian Space Agency Lapan and the Technical University of Berlin (Germany). Lapan-Tubsat carries two charge-coupled-device (CCD) cameras with ground resolutions of 5 and 200 m.

On 26 September, at the International Astronautical Congress (IAC) in Hyderabad, India, the African Union announced the establishment of the African Resources Management (ARM) network, a constellation of microsatellites to monitor water and land use, agriculture, forestry, and other sustainable development parameters. The four nations involved initially in the ARM network, Algeria, Kenya, Nigeria, and South Africa, will each contribute its own space and ground segment, at an estimated cost of \$1-\$4 million per country, and share data with the others. The network will be open to other countries; Egypt and Morocco have expressed interest, as have Canada and Germany.

The ARM space segment will consist of the Nigerian and Algerian satellites currently in orbit plus two on order, one by Nigeria from Surrey Satellite Technology Limited (SSTL, UK) and one by Algeria from EADS Astrium (France and Italy). The ARM plan is to have three levels of imaging capability: 20-30-m wide swath, 3-5-m multispectral resolution, and 0.5-0.75 panchromatic resolution. The four-satellite constellation would permit one revisit every two days, necessary for land and agriculture measurement.

With the proliferation of new small-satellite designs, new satellites are expected to cost the network no more than \$12-\$25 million each, not only from SSTL and EADS Astrium, but also from Thales Alenia Space (France and Italy), who revealed a new design at the Congress based on France's Myriade and Proteus buses and Italy's Prima platform. Satrec Initiative (South Korea) has also sold 10-m imagers for Turkey's Rasat and Singapore's Xsat, planned for launch in 2008-2009, as well as 2.5-m imagers for the United Arab Emirates' DubaiSat and Malaysia's Razaksat, due for launch next year.

The Indian Space Research Organization (ISRO) announced on 28 September that they plan to launch a remote-sensing satellite in January 2008 that will provide free imagery to universities and research organizations in developing countries worldwide. The 100-kg Third World Satellite (TWSAT), orbiting at 630 km, will carry two cameras, one with a resolution of about 36 m, the other with a ground swath of 128 km and a resolution of 500 m. The only cost to participating nations will be the purchase of a 3.7-m dish antenna to receive the data. TWSAT is the first of a planned five-year series of microsatellites, weighing about 100 kg and carrying 30-kg payloads powered at 20 W, and minisatellites, weighing about 450 kg and carrying 200-kg payloads with 200 W available power.

(2) Atmosphere and Ocean Observations

The full complement of instruments aboard Europe's Metop-A polar-orbiting satellite, launched in October 2006 (see last year's report), began routine level-2 operation in May. The spacecraft's first set of comprehensive data, initiated early in March, prior to the full-complement routine startup, were atmospheric ozone and nitrogen dioxide concentrations, measured by the German Aerospace Center DLR using the satellite's Gome-2 spectrometer. The data were released via Eumetsat's ozone satellite application facility, which generates, validates, archives, and distributes records and predictions on atmospheric ozone, trace gases, and aerosols, as well as surface ultraviolet radiation. Metop-A's main instrument, the Infrared Atmospheric Sounding Interferometer (IASI), began delivering data on 31 May to weather services and research institutes. The IASI is expected to account for half the scientific output of the satellite. However, another key instrument, the Advanced High-Resolution Picture Transmission payload, failed in July, and has not yet been restored to service. Its function has been taken over by the U.S. NOAA-17.

Operation of the French/U.S. Jason-1 oceanography satellite, launched in 2001 for a nominal 3-year mission, was extended to another five years in December 2006. Initial performance checks of the follow-on Jason-2 were completed in July, mechanical testing was done in August, and acoustic tests run in October. Thermal vacuum testing and final performance checks are planned for November and December, with launch scheduled for 15 June 2008. The 525-kg Jason-2, which is the first of the Topex-Poseidon/Jason series to be designated operational (the others were experimental), differs from Jason-1 in several ways: its design life is 5 years in comparison to Jason-1's three years; the U.S. National Oceanic and Atmospheric Administration (NOAA) is sharing the \$450-million cost this time with Jason-1 sponsors CNES and NASA; it carries three experimental

auxiliary payloads: a CNES and a JAXA radiation monitor and a CNES ground-clock; it has a digital elevation unit to provide real-time coverage of coastal and inland waters and sea ice as well as ocean coverage; and it carries a diode assembly that affords real-time orbit determination in less than 0.5 seconds.

Late in June the Committee on Earth Observation Satellites (CEOS), meeting at an International Astronautical Federation seminar in Paris, identified 26 essential climate variables that needed to be monitored in order for the world's nations to address climate issues effectively. They expressed concern that insufficient coordination among the various national and regional Earth observation systems is leading to costly duplication and, perhaps even more important, environmentally damaging policy mistakes due to lack of essential climate information by the world's decision makers. The 26 essential climate variables include upper-air temperatures, changes in carbon-dioxide concentration, and soil moisture.

ESA's Goce Gravity-Field and Steady-State Ocean-Circulation Explorer satellite was shipped for testing to the agency's Estec center in Noordwijk, the Netherlands from prime contractor Thales Alenia Space (Italy) on 20 August. The 1,100-kg satellite is scheduled for launch by Eurockot Launch Vehicles GmbH (Germany and Russia) aboard a Russian Rockot vehicle in March 2008. Its gradiometer gravity-field instrument uses three pairs of accelerometers designed by Onera (France), claimed to be sufficiently sensitive to detect the force of a 200-mg snowflake landing on a million-tonne oil tanker. The spacecraft has no moving parts; it carries 40 kg of xenon propellant for the ion thruster that will overcome perturbations due to drag in its extremely low orbit of 250 km. Despite technically imposed delays of about two years, the mission, including launch and 20 months of operations, is expected to end up costing only about 10% more than its original budget of \$372 million.

On 28 November 2006 the Chinese Meteorological Administration (CMA) and the U.S. National Oceanic and Atmospheric Administration (NOAA) agreed to adopt Europe's Eumetcast model for broadcasting meteorological information via commercial satellites to small satellite dishes similar to those used for direct-to-home television broadcasts. China will expand its current FengyunCast system, which employs Chinese weather satellites and data from three NOAA satellites plus NASA's Terra and Aqua, to provide communications over Asia, and NOAA will involve the twenty-odd agencies that produce and process environmental data in the U.S. The new Geonetcast global network, expected to be operational by late this year, will extend from Pakistan to New Zealand via Chinese leases of commercial spacecraft capacity, and throughout North and South America via NOAA leases. The Russian Mitro system, which uses Russia's Yamal and Express communication satellites, is expected to join Geonetcast.

Meanwhile on 8 December 2006 China launched its newest weather satellite, FengYun-2D, aboard a Long March 3A rocket from the Xichang Satellite Launch Center into a geostationary-orbit slot at 86.5 degrees east longitude, where it will serve as a backup to FengYun-3C in its geostationary-orbit slot at 105 degrees east longitude. FengYun-2D was declared operational in early January, beginning to transmit images to

the ground every half-hour. It is scheduled to help forecast weather for the 2008 Olympic Games in Beijing. On 11 April China launched its new Haiyung-1B oceanographic spacecraft into a Sun-synchronous orbit aboard a Long March 2C rocket from Taiyuan. It was China's 54th straight launch success since 1996.

The Indian National Remote Sensing Agency (INRSA) signed an agreement with the U.S. National Oceanic and Atmospheric Administration (NOAA) on 15 December 2006 that will allow NOAA to place a ground station in India for the next-generation U.S. National Polar-Orbiting Operational Environmental Satellite System (NPOESS) planned for launch beginning in 2013. The station will be hosted by INRSA and the Indian Space Research Organization (ISRO), and the its key hardware will be built by the Raytheon Company (USA).

IV. HUMANS IN EARTH ORBIT

A. International Space Station Deployment and Operations

Space Shuttle Discovery arrived at the International Space Station (ISS) on 11 December 2006 following its night launch from the Kennedy Space Center on 9 December. The Shuttle crew conducted four spacewalks during which they retracted the port wings of the space station's top-mounted solar array, switched the station to a new electrical configuration, activated the ammonia cooling loops, and with great difficulty, including an extra spacewalk by Shuttle astronaut Robert Curbeam that delayed the Shuttle landing by one day, finally managed to retract and stow the old Port 6 (P6) solar array so that the newly delivered Port 5 array could be deployed and rotated to follow the Sun. Curbeam was assisted by the first Swedish astronaut Crister Fugelsang (ESA), who had flown to the ISS on Discovery, and Shuttle astronauts Joan Higgenbotham and Sunita Williams. Discovery brought Sunita Williams to the ISS to replace ESA astronaut Thomas Reiter, who returned to Earth aboard the Shuttle on 22 December, and also delivered to the ISS 21 kg of nitrogen and 2,180 kg of hardware, returning 2,230 kg of excess hardware from the ISS to Earth.

A Russian Soyuz delivered the Progress 24 supply capsule to the ISS on 19 January, bringing over 2 tonnes of supplies including 780 kg of propellant and 50 kg of oxygen.

Two members of the ISS Expedition-14 crew, Commander Michael Lopez-Alegria and Flight Engineer Sunita Williams, conducted three spacewalks on 31 January, 4 February, and 8 February to reconfigure the ISS cooling system for long-term operations, replacing the temporary radiators on the P6 truss with the permanent ones on the P4/P5 truss and jettisoning several thermal blankets, which re-entered the atmosphere and were destroyed. The spacewalks set three records: the longest extra-vehicular time logged by astronauts or cosmonauts without a Shuttle docked to the station, the longest extravehicular time logged by a female astronaut (Sunita Williams): 29 hours, 17 minutes, and the longest space-walk time logged by a U.S. astronaut (Michael Lopez-Alegria): 61 hours, 22 minutes. A fourth spacewalk, lasting 6 hours, 18 minutes, was

conducted on 22 February by Lopez-Alegria and the third Expedition-14 crewmember, Flight Engineer Mikhail Tyurin, to retract manually the rendezvous antenna on Progress 23, which had failed to retract automatically when it had approached the ISS on 23 October 2006, to allow Progress 23 to undock from the Zvezda service module in April.

On 7 April Expedition-15 cosmonaut crewmembers Fyodor Yurchikhin, commander, and Oleg Kotov, flight engineer, were launched aboard a Russian Soyuz TMA-10 spacecraft from the Baikonur Cosmodrome, along with space tourist Charles Simonyi (see last year's report), arriving at the ISS on 9 April. Simonyi, a software expert who led the teams that developed Microsoft Word and Excel, spent his 12-day ISS tour participating in ESA biomedical experiments aimed at better understanding of anemia, the muscular changes that affect lower back pain, and the effects of space radiation on white blood cells. Simonyi also made many radio and video broadcasts to students on Earth to spur interest in spaceflight, science, and technology. He then returned to Kazakhstan on 21 April with Expedition-14 crewmembers cosmonaut Mikhail Tyurin and astronaut Michael Lopez-Alegria. The price for his trip, which was brokered by Space Adventures (USA) for the Russian space agency Roskosmos, was between \$20 million and \$25 million.

Queen Elizabeth II of the United Kingdom heard about ISS activities from all three members of the Expedition 15 crew during her visit to NASA's Goddard Space Flight Center on 8 May. She was on a visit to the U.S. to commemorate the 400th anniversary of the British settlement of Jamestown.

On 6 June Cosmonauts Yurchikhin and Kotov conducted a 5-1/2 hour spacewalk to complete the installation of 17 aluminum panels designed to protect the Zvezda service module from micrometeoroid orbital debris, completing the task they had started on 30 May. They also rerouted and repaired cables to assist the docking of ESA's Automated Transfer Vehicle early next year and to prepare for software upgrades during the summer, and installed canisters of biological samples for the Biorisk space-exposure experiment.

Space Shuttle Atlantis was launched to the ISS on 8 June after a 7-week delay caused by possible hailstorm damage. Prior to its arrival on 10 June, the orbiter's thermal protection system was examined for possible damage during launch, using the Shuttle's robotic Canadarm and the 15-m Orbiter Boom Sensor System extension, and was again checked on arrival at the ISS by the ISS crew, using high-resolution digital photography. After docking with the ISS, the ISS and the Shuttle crews joined forces to extract the \$367-million combined S3/S4 starboard truss elements from the Shuttle payload bay, hand them over from the Shuttle Canadarm to the ISS robotic arm, and park the combined unit near the station.

The S3 truss segment carries the 3.2-m diameter Solar Alpha Rotary Joint that will keep the starboard solar array at its optimum position for maximum power; the S4 truss carries the solar arrays in their "solar blanket boxes," plus switching units, converters, and radiators. The combined truss units span 13.6 m and weigh 16.2 tonnes, the heaviest payload ever orbited by a space Shuttle. After they were bolted in place on

the starboard end of the station truss, Shuttle astronauts John Olivas and Jim Reilly connected power cables, pulled off the launch restraints, and rotated the solar blanket boxes 90 degrees to allow the solar array wings to unfold. The combined crews then unfurled the arrays and unlocked the Solar Alpha Rotary Joint, after which Shuttle astronauts Patrick Forrester and Steven Swanson began the process of folding and stowing the old starboard array on the P6 panel, which would have blocked the full rotation of the new starboard solar array wings. That task was completed by astronauts Jim Reilly and John Olivas on a subsequent spacewalk. The deployed new solar wings, spanning a total of 73 m, provided the ISS with net additional power of 14 kW, enabling the station to operate the ESA Columbus module and Japan's Kibo module after their delivery to the ISS.

On 13 June during the stowing of the 7-year-old old P6 solar panels, which continued to prove difficult to accomplish, the station's critical command and navigation system computers failed. These computers, built in Germany and located on the Russian side of the ISS, operate the reaction-control thrusters which are needed for attitude control when the station's control moment gyros are not operating. Moscow's Mission Control Center managed to restart one channel of the three redundant data paths to the Russian Service Module Terminal Computer early on 14 June, enabling them to route power from the U.S. solar arrays to the underpowered Zarya and Zvezda modules and restart their critical life-support units, but after 7 minutes the computers crashed again and were not able to be restarted. The problem was eventually traced to the failure of redundant surge-protector circuits in the computers, and a temporary fix was made by using jumper cables to bypass the fault. However, the cause of the circuit failure was not determined.

A final space walk was conducted by Olivas and Reilly to install a hydrogen vent on the Destiny module, allowing startup of the U.S. Oxygen Generation System later in the year. The Shuttle's departure was delayed by two days to enable an assessment of the repair procedure for a small, 10-cm x 16-cm tear in the corner of the Flexible Reusable Surface Insulation (thermal blanket) on the craft's left Orbital Maneuvering System pod. The tear had resulted from lifting of the blanket corner by aerodynamic forces about 61 seconds after Atlantis's launch. Following ground simulation of several alternative approaches, the blanket was successfully repaired during a 15 June spacewalk by Shuttle astronauts Jim Reilly and Pat Oliver, who used surgical staples and metal wires to seal it to the adjoining thermal tiles and blankets. On 19 June the Shuttle undocked from the ISS for a final flyaround inspection of its thermal protection system and to photograph the now-symmetrical station configuration. Thundershowers postponed Atlantis's two landing attempts at the Kennedy Space Center in Florida on 21 June, forcing a landing on 22 June at the alternate facility, Edwards Air Force Base in California. Atlantis returned Expedition-14 crewmember Sunita Williams, who was replaced on the ISS by astronaut Clayton Anderson.

On 23 July the ISS Expedition-15 crewmembers Clay Anderson and Fyodor Yurchikhin conducted a 7-hour, 41-minute spacewalk to jettison a 640-kg ammonia tank and a 96-kg support for a video stanchion. Crewmember Kotov, inside the U.S. Destiny

module, operated the Canadarm-2 robotic arm, from which Anderson deployed the surplus hardware in a retrograde direction that precluded any chance of collision with the ISS. For extra safety, the station was then boosted to a higher-altitude orbit.

Russia's Progress-26 robotic resupply vehicle was sent to the ISS from the Baikonur Cosmodrome by a Soyuz rocket on 3 August, and docked uneventfully with the station two days later. It replaced Progress-24, which had departed the ISS with a load of trash on 1 August. Besides 2,300 kg of food, propellant, water, and other supplies, Progress-26 also brought to the Expedition 15 crew the replacements for the six failed command and navigation system computers.

Shuttle Endeavour was launched to the ISS on 8 August, carrying the short 2.3-tonne S5 "spacer" for the starboard end of the main station truss and the final commercial Spacehab module with about 2,300 kg of supplies. This was the first Shuttle mission to use the Station-to-Shuttle Power Transfer System (SSPTS), which enables the docked Shuttle to use power from the station's two new solar power arrays. Availability of ISS power via four channels, each delivering about 2 kW, conserves the hydrogen and oxygen used by the Shuttle's fuel cells, allowing extended Shuttle missions to the ISS. Endeavour's mission was extended by 3 days to 14 days, using only two of the four available SSPTS channels, all of which were tested on this mission. Future Shuttle missions could be extended by up to six days. Motivation for the SSPTS was to accelerate completion of ISS construction by permitting more work periods for the Shuttle crews. One of the first tasks completed by Endeavour's crew after docking with the ISS was to activate Endeavour's Boeing Power Transfer Units that convert ISS power to the Shuttle's 24-volt level, and to configure the solar arrays to handle the added load.

During the mission, besides installing the 3.3-m long S5 truss spacer element the Shuttle astronauts also replaced a failed 270-kg control moment gyro, installed a third 3.4-tonne External Stowage Platform on the P3 truss element, and relocated two Crew and Equipment Translation Aid carts from the port to the starboard side of the Mobile Transporter. These activities cleared the truss rail line to allow the transporter to carry the old P6 truss element and its folded solar arrays to the port end of the truss for final deployment during the Shuttle mission in October.

Endeavour also brought mission specialist Barbara Morgan to the ISS, where she conducted several 20-minute teaching sessions for schoolchildren in the U.S. She was the backup "Teacher in Space" for Christa McAuliffe, who lost her life in the Shuttle Challenger explosion in January 1986. It was decided by NASA that an on-orbit repair of a gouge in the craft's thermal protection tiles would not be carried out, so Endeavour landed at Cape Canaveral on 22 August, after a record 10-day stay at the ISS.

Working from inside the ISS, on 30 August the Expedition 15 crew moved the old docking port, Pressurized Mating Adapter-3, from its port-side location on NASA's Unity module to an Earth-facing berth, clearing space for the new Harmony node to be delivered in October. The new node will be used to install ESA's Columbus module and Japan's Kibo module when they are transported to the ISS.

The ISS Expedition-16 crew was launched from the Baikonur Cosmodrome on 10 October aboard a Soyuz TMA-11 spacecraft, and arrived uneventfully on 12 October. The vehicle carried new ISS crew members Peggy Whitson, the first woman to command an ISS crew, and Yuri Malenchenko, along with Malaysian cosmonaut Sheikh Muszaphar Shukor. Shukor, an orthopedic surgeon and Malaysia's first astronaut, conducted research and physiological experiments for Malaysia and ESA during his 12-day stay on the ISS. He and backup Malaysian astronaut, dental surgeon Faiz Khalid, were selected from among 11,000 applicants. He returned safely to Kazakhstan on 21 October with Expedition-15 crewmembers Yurchikhin and Kotov, although the Soyuz return vehicle had suffered an unintended ballistic return trajectory before finally setting down about 350 km short of the intended landing site, where the cosmonauts were picked up 20 minutes later by Russian helicopters. The third Expedition-15 crewmember, Clayton Anderson, remained aboard the station with the Expedition-16 crew (see below).

On 23 October Space Shuttle Discovery was launched to the ISS for a 14-day mission, carrying the 14.3-tonne Harmony module, on which Europe's Columbus module and Japan's Kibo module will be mounted when they are launched in December and early next year, respectively. Harmony will also serve as the docking berth for Japan's H-2 Transfer Vehicle, future Shuttles, and Europe's Multi-Purpose Logistics Module. Harmony, also designated Node 2, was built by Thales Alenia Space (Italy) under supervision of the Italian Space Agency, and will serve the ISS as a nexus for communications, water and air supply, and electric power distribution. It cost \$425 million, and holds another \$280 million worth of equipment.

After arriving at the ISS on 25 October, Discovery's astronauts worked with the ISS Expedition-16 crew in conducting four spacewalks to berth Harmony in its temporary location on Unity (Node 1) and activate it, and in using the ISS's robotic arm to move the 16-tonne P6 truss and solar array to their permanent location at the end of the main station truss. Discovery's commander, Pamela Melroy, was the first female Shuttle commander to be greeted by a female ISS crew commander, Peggy Whitson. ESA astronaut Paolo Angelo Nespoli (Italy) directed the outfitting of the Harmony module, as well as conducting the Esperia experiment for ESA.

The space-walk schedule was adjusted on 28 October to allow astronaut Dan Tani to inspect the starboard solar alpha rotary joint (SARJ), which operates the starboard solar panels, after it was observed to draw excessive power to operate. Tani found ferrous shavings inside the joint, apparently from its steel components. Another spacewalk was then scheduled on 30 October to inspect the port rotary joint, which was found to be clean and working properly.

Despite the already complex nature of the mission, it was decided to conduct another unscheduled spacewalk to repair a torn solar panel on the outermost solar array, 27 meters from the bottom. It had been torn during its deployment on 30 October, and if not repaired it would have prevented full deployment of the array, prejudicing the activation of the Columbus and Kibo modules planned for delivery on succeeding

missions. On 3 November, therefore, Shuttle astronaut Scott Parazynski conducted a 7-hour, 19-minute spacewalk, including a 45-minute journey on the station's robot arm to the site of the tear, to clip the frayed wire stays and install five hand-made "cuff links" to patch the gap in the array. His trip was monitored by astronaut Doug Wheeler, who made sure the robot-arm operators did not bump Parazynski into the delicate array. The repair was successful, and the array was fully deployed.

The ISS Expedition-15 crewmember Clayton Anderson joined Discovery's crew in their return to Earth on completion of their mission, leaving astronaut Daniel Tani, who flew to the ISS on Discovery, to replace him on the ISS Expedition 16 crew. Discovery landed at the Kennedy Space Center on 7 November.

On 9 April NASA announced a \$719-million contract modification with the Russian Federal Space Agency Roskosmos to extend the provision of space-station crew and cargo transportation services through 2011. The contract extension calls for Roskosmos Soyuz vehicles to deliver six crew members to the ISS in 2009, six in 2010, and three in 2011, and also for Progress vehicles to deliver and remove a total of 5.6 tonnes of ISS cargo during the same period. NASA Administrator Michael Griffin stated on 12 April that this agreement with Roskosmos would not affect the Agency's intent to use commercial space vehicles to deliver and retrieve payloads during the same period under NASA's Commercial Orbital Transportation Services (COTS) programme (see above and last year's report).

Late in June, in response to a Congressional mandate to employ the space station as a national laboratory, NASA announced the availability to the research community of eleven refrigerator-sized experiment racks and four exterior sites aboard the ISS, after station construction is completed in 2010. Although there will be no fee charged by NASA for access to the experiment sites, the users will have to cover all costs of their research and payload devices. They will also have to arrange their own transportation to the ISS, since the Shuttle will not be available after 2010. Possible transporters include Russian Soyuz and Progress capsules, ESA's ATV, Japan's H-2 Transfer Vehicle, and the companies that will have access to the ISS via NASA's Commercial Orbital Transportation System (COTS) programme. The pressurized experiment racks are located in the U.S. Destiny module, the European Columbus module, and Japan's Kibo module.

South Korea's Ministry of Science and Technology on 5 September released the name of the nation's first astronaut, 30-year-old robotics expert Ko San, from the Samsung Advanced Institute of Technology. He will fly to the ISS in April 2008 aboard a Russian Soyuz capsule. Ko San was selected over Yi Soo-yeon, a 29-year-old woman, based on performance and other tests during their training in Russia

B. Other Earth-Orbital Flight Operations

A sudden hailstorm at the Kennedy Space Center on 26 February damaged Shuttle Atlantis's external propellant tank, forcing postponement of Atlantis's mission to the ISS

from its planned 15 March date to 8 June. The extent of the damage caused by sheets of 3 – 4-cm diameter hailstones driven by 100 km/hr winds was such that the tank was repairable. If the damage to the tank’s foam insulation by the 7,000 divots and blemishes caused by hailstone impacts had been found to have been sufficiently severe that “patching” would not suffice, the tank would have had to have been replaced. NASA also checked what appeared to be “cosmetic” damage to the Orbiter’s thermal protection system, both the tiles that cover the craft’s lower surface and the reinforced carbon-carbon protective material on the Orbiter’s nose and wing leading edges. Atlantis was finally cleared for launch on 8 June, and docked with the ISS two days later (see above).

After Space Shuttle Endeavour docked with the International Space Station following its launch on 8 August, an inspection of the orbiter’s belly using laser sensors on the Orbiter Boom Sensing System (OBSS) found a divot gouged out of two insulating tiles, 8.8 cm long, 5.9 cm wide, and at least 2.8 cm deep. It was believed that the gouge resulted from an impact by a piece of external-tank insulation, probably mixed with ice that had formed on one of the brackets that hold the 43-cm liquid oxygen propellant feed line, 58 seconds after Endeavour’s launch from Cape Canaveral. NASA decided after extensive analyses and simulations by a number of engineering teams that the gouge was not sufficiently risky to require incurring the nontrivial risk of an on-orbit repair, although the Shuttle crew had the capability and materials to do so.

Inspection following Endeavour’s uneventful landing on 22 August revealed no further development of the small gouge. Nevertheless, following X-ray inspections of next-to-fly Shuttle Discovery’s tank brackets, which revealed small cracks in the super-lightweight ablator under the foam insulation on four of the five aluminum brackets holding the oxygen feed line, NASA decided to remove the ablator material from all five brackets and recoat them with only the foam insulation. The aluminum brackets are slated to be replaced by titanium ones, which are less prone to ice formation, in 2008.

A train carrying eight solid-propellant Shuttle booster rocket segments from the ATK plant in Utah to NASA’s Kennedy Space Center derailed on 2 May, disqualifying four of the segments that had been travelling on flatcars near the head of the train that left the tracks. Sensors on these boosters indicated acceleration data outside acceptable limits. The four segments that were riding near the back of the train were on cars that did not derail and were not affected; i.e., their accelerometer readings were within guideline limits. The four disqualified segments were returned to Utah for use in ground testing or for full refurbishment. The four undamaged segments continued, after careful inspection, on to the Kennedy Space Center for use on an upcoming Shuttle mission.

On 11 April Bigelow Aerospace (USA) released its business plan for developing, launching, and operating private-sector space stations based on the use of inflatable modules, building on the Genesis-1 subscale prototype module launched to orbit in 2006 (see last year’s report). The first step in Bigelow’s plan was the launching of Genesis-2 on 28 June to a 480-km orbit by an ISC Kosmotras Russian/Ukrainian Dnepr rocket from Kosmotras’ Yasny Launch Base in the Orenburg region of Russia, after which the spacecraft deployed its solar panels and was powered up. Although the same 4.5 x 2.4-m

size as Genesis-1, with the same 8-panel solar-array design, Genesis-2 has more mature systems, including upgrades to vehicle controls and sensors, a multitank inflation system, 22 exterior and interior cameras, additional layers on the module's outer shielding, and an exterior projection system to display images on the module's outer surface. As a demonstration of future advertising capability, this system on Genesis-2 projects a sign reading, "Blair," the name of Bigelow's granddaughter. Genesis-2 also carries a number of personal items, a "Space Bingo" game, and a "Biobox" containing a California red harvester ant farm, South African flat-rock scorpions, and Madagascar hissing cockroaches. Genesis-2 transmits data to more ground sites than Genesis-1's sole contact with Bigelow's space control center in Las Vegas, Nevada.

The next phase of Bigelow's plan calls for the launching in late 2008 of a Galaxy module, twice as big as Genesis, followed in 2010 by a 9-tonne Sundancer design equipped with life-support facilities for three astronauts. It will measure 8.6 x 6.2 m, with a volume of 175 cubic meters. The operational space outposts, each consisting of a BA 330 habitation module with a volume of 330 cubic meters, would be launched in 2012 and 2013, followed in 2015 by a station composed of two BA 330 inflatable modules. Each outpost would be dedicated to a specific use; e.g., one with minimal astronaut activity that would be used for microgravity experiments; one in a high-inclination orbit for Earth observations, etc.

Bigelow also outlined plans for transportation to its outpost that involve a number of potential launch vehicles and launch sites, such as SpaceX's Falcon-9, Rocketplane Kistler, Russia's Soyuz, China's Long March, Ukraine's Zenit, and Lockheed Martin's Atlas-V, launched from Cape Canaveral, the Baikonur Cosmodrome, Woomera, and others. The company envisions three flights a month to its outposts after 2015. Bigelow's payment plan for customers will be much more liberal than current "tourist" schedules, including innovative concepts such as escrow accounts to hold refundable payments until the company achieves specified milestones for transfer to nonrefundable payments. For nations who wish to send astronauts to Bigelow's outposts, the company will charge \$14.9 million (in 2012 U.S. dollars) for four weeks, plus \$2.95 million for a four-week extension. Up to the launch of Genesis-2, Bigelow had invested \$95 million in the company.

On 22 June Space Adventures (USA) announced that they had booked a passenger for a trip around the Moon, and were in negotiation with several other potential space tourists. Their flight plan involves use of a Russian Soyuz vehicle, which had originally been designed for circumlunar missions, although not with human passengers or crew. With some communications upgrades and a bigger window, they claim, the Soyuz could carry two passengers and a crew of one around the Moon following an Earth-orbit rendezvous, with a kick stage to provide the necessary velocity increment. The price for the trip would be \$100 million per passenger. Space Adventures has also received conditional approval from the Russian space agency to provide a space-walk experience from the International Space Station for a tourist who would first receive extensive training. Approval by NASA would still be required.

Part of the \$205-million increase in India's space budget for Fiscal Year 2008 (beginning on 1 April 2007), announced on 28 February, is \$11.3 million for "developing a fully autonomous orbital vehicle to carry a two-member crew to low Earth orbit and safely return them to Earth." The Indian Space Research Organization's (ISRO's) Space Capsule Recovery Experiment (SRE-1), launched and recovered in January after 12 days in orbit (see below), demonstrated a critical enabling capability for India's essay into human space flight.

C. Life Sciences

NASA's Extreme Environment Mission Operations 12 (NEEMO-12) took place on 7–18 May in the U.S. National Oceanic and Atmospheric Administration's (NOAA's) Aquarius Underwater Laboratory. It was the first such exercise to include a NASA flight surgeon, Dr. Josef Schmid, who worked with two astronauts and a physician from the University of Cincinnati to refine and demonstrate telerobotic surgery procedures that address the time-delay issues to be encountered on future trips to Mars by humans. The team also practiced procedures planned for use in Moon-walking and geological sampling during upcoming manned lunar missions, and built an undersea structure using a remotely controlled vehicle. Subsequently the NEEMO-13 crew, comprising U.S. astronauts Richard Arnold and Nicholas Patrick, Japanese astronaut Satoshi Furukawa, and NASA systems integration engineer Christopher Gerty, occupied the Aquarius Laboratory for 10 days beginning 6 August to simulate Moon walks, erect a communications tower, practice sample collection, and check out potential lunar spacesuit designs.

On 19 June ESA called for applications by volunteers for a simulated trip to Mars, in which six "astronauts" will spend 17 months in an isolation tank on Earth. The purpose of the experiment is to gain experience about the psychological challenges a crew will face on a trip to Mars. Their "spaceship" will be a series of interlocked modules comprising about 550 cubic meters at Russia's Institute of Biomedical Problems in Moscow. Communications with "mission control" and family members will be by radio link with a 40-minute delay, simulating the actual time for transmissions between Earth and Mars, and food will be the same type as that eaten on the ISS. A precursor 105-day study is planned to begin in mid-2008, possibly followed by a second one, before the full 520-day "mission" begins in late 2008 or early 2009. Four of the crew will be Russians; two will be from ESA member countries. They will be paid \$158 per day. As of 19 June Russia had already received about 150 applications, of which only 19 were female applicants.

V. SPACE STUDIES AND EXPLORATION

The Global Exploration Strategy (GES) was signed on 31 May as a voluntary, non-binding, open-ended forum for sharing cooperation plans and supporting exploration activities of participating nations (see Chapter IX.).

On 18 October the European Space Agency's Space Science Advisory Committee selected nine mission proposals out of fifty that had been received in March for Europe's Cosmic Vision 2015 – 2025 programme. After two years of study for technical and financial feasibility, the nine mission proposals will be narrowed down to two medium-class (\$425-million) and two large-class (\$925-million) missions in October 2011, and subsequently to one mission in each class for launch in 2017 and 2018.

The nine selected missions include four in astrophysics, four in solar-system exploration, and the Laser Interferometry Space Antenna (Lisa) mission, which had been approved previously (see prior reports) but is now being reconsidered, depending on results of the upcoming Lisa Pathfinder mission (see prior reports). One of the astrophysics mission concepts is Xeus, two spacecraft flying in formation that together constitute a large X-ray observatory to examine supermassive black holes, cosmic feedback, and other current topics of astrophysical interest, which ESA hopes will involve an international partner from China, Japan or the U.S. The second astrophysics concept will be a dark-energy mission conducted in cooperation with NASA, to be chosen from two separate proposals: Dune, which would employ a wide-field imager, and Space, a near-infrared all-sky surveyor. The third, in cooperation with Japan's JAXA, is Spica, which will use a large-aperture cryogenic telescope to conduct wide-field, high-sensitivity photometric mapping at high spatial resolution. The fourth is Plato, a photometric planet-finder, like Corot (see last year's report) able to observe rocky Earth-like planets, but around brighter and better-characterized stars.

In the space exploration category, one prospect is Laplace, a proposal to deploy three orbiters to visit Jupiter and its moons with primary focus on Europa, and to conduct studies of Jupiter's magnetosphere, atmosphere, and interior. Laplace would be cosponsored by NASA and JAXA. The second is Tandem, a joint mission with NASA to revisit Saturnian moons Enceladus and Titan. It would consist of an orbiter and a carrier spacecraft that would deliver a balloon and three probes to Titan. The third exploration proposal, Marco Polo, is for a near-Earth-asteroid sample-return mission cosponsored by JAXA, consisting of a mother spacecraft, a lander, a sampling system, an instrument payload, and a re-entry capsule. The fourth, also cosponsored by JAXA, is Cross-Scale, a constellation of 12 satellites to measure plasma characteristics in different near-Earth space regions to study the acceleration and heating effects of shock waves and the relation between magnetic reconnection phenomena and energy generation and conversion.

A. Astronomy and Astrophysics

Failure of the backup power system of the Hubble telescope's Advanced Camera for Surveys (ACS) on 27 January caused the entire telescope to shut down and go into its "safe mode." Controllers returned the telescope to service on 28 January, continuing observations with its other instruments. The ACS's primary power supply had failed during the summer of 2006 (see last year's report). The ACS, which was designed to operate in three channels covering the frequency range from the far ultraviolet to infrared, continued after the failure to operate in only one channel, the far ultraviolet. NASA

announced on 7 June that the fifth and final repair mission for the telescope is scheduled for 10 September 2008, when Space Shuttle Atlantis will carry a 7-person crew to conduct the repairs and upgrades during an 11-day mission.

That mission should enable Hubble telescope operation through 2013, when the James Webb follow-on telescope is scheduled to be launched. On 18 June NASA and ESA signed a cooperation accord on the Webb telescope, calling for it to be launched by an Ariane 5 ECA rocket as part of ESA's contribution to the telescope project. The two agencies will share instrument development, with NASA supplying the Near-Infrared Camera and ESA the Near-Infrared Spectrograph, using NASA detectors and microshutters. NASA and ESA will join with several European national institutions in joint development of the Mid-Infrared Instrument, and Canada will develop and build the telescope's Fine Guidance Sensor/Tunable Filter Imager. Under the agreement, Europe will fund 15% - 20% of the Webb's \$4.5-billion cost, plus about \$200 million for the launch and another \$270 million in engineering and payload coordination costs.

The 630-kg Corot astronomy satellite was launched from the Baikonur Cosmodrome into an 827-km orbit by an upgraded Soyuz 2-1-b rocket on 27 December 2006. Developed by the French space agency CNES and built by Alcatel Alenia Space (France and Italy; now Thales Alenia Space) on the CNES-designed Proteus bus, the \$200-million Corot spacecraft project also involves participation by Austria, Belgium, Brazil, Germany, Spain and ESA, with ground stations located in Brazil, France, French Guiana, South Africa, and Sweden. It was activated in orbit on 2 January, and on 18 January detected its first light from stars in the constellation Monoceros, the Unicorn, near Orion. From its 900-km polar orbit, the \$45-million Corot mission is studying the vibrations of 100 bright stars to determine their internal structure, age, and composition. By observing another 120,000 faint stars, Corot is also collecting data that can be used to seek new planets, especially telluric bodies with physical properties comparable to those of the Solar System's rocky planets. The spacecraft will perform five 150-day surveys and five shorter (20 – 30-day) surveys over its 30-month design lifetime, during which it is expected to find at least 40 terrestrial-type planets and hundreds of thousands of gaseous ones. Corot found its first planet on 3 May, a hot gas giant named Corot-exo-1b about twice the size and 1.3 times the mass of Jupiter, orbiting a yellow dwarf star similar to the Sun located about 1,500 light-years away in Monoceros.

On 6 January NASA's Goddard Spaceflight Center released data on a unique gamma-ray burst that were collected on 14 June 2006 by the Swift gamma-ray telescope (see last year's report). The observed burst differed from typical short (e.g., 2-second) bursts, which result from the collision of two neutron stars that create a black hole, and from typical long bursts, caused by the explosions of massive stars that also create black holes. The 14 June 2006 data indicate a long (102-second) burst, but suggest that their source was either the collapse of a star into a black hole, leaving no visible residue, or a collision between a neutron star and a black hole.

NASA Goddard Space Flight Center's Far Ultraviolet Spectroscopic Explorer (FUSE), launched in 1999, suffered a breakdown in December 2006, when two of its four

reaction control wheels failed, rendering the spacecraft inoperable. However, in April controllers uploaded new flight software for FUSE's attitude control, instrument data, and fine-error sensor-processing systems and activated a local electric field in the satellite's magnetic torque bars. This allowed them to control the spacecraft's attitude by varying the electric current, since the electric field's interaction with the Earth's magnetic field provided a controllable torque to supplement that of the two remaining control wheels. As a consequence, FUSE's original five-year mission was extended for the third time, and the satellite subsequently imaged one of the most massive pairs of binary stars ever discovered, classified as LH54-425. Finally, however, although its scientific instruments were still usable, NASA shut FUSE down on 18 October, when all its control functions ceased operation.

On 23 May NASA announced four grants to universities totaling \$4.2 million for research in astrophysics and heliophysics using sounding-rocket payloads to be launched from the Wallops Flight Facility. The University of Wisconsin and the University of Colorado are developing astronomy payloads employing far-ultraviolet spectroscopy; Dartmouth College will study substorm-related solar aurorae and their variations; and the University of California, Los Angeles will test a new photoelectron focusing system for solar observations.

NASA announced on 11 July that the agency's Spitzer infrared telescope had discovered evidence of water on an exo-solar planet: HD 189733b, in the Vulpecula constellation about 63 light-years away. Observations were made of the planet as it crossed in front of its star; the presence of water was deduced from the different amounts of light absorbed at three different infrared wavelengths, a property unique to the water molecule. It was the first evidence of water found on a planet outside the Solar System.

Spitzer also found traces of sand, glass, marble, rubies, and sapphires in the neighborhood of a massive black hole embedded in the quasar PG2112+059, about 8 billion light-years from Earth. Researchers from the University of Manchester (UK), reporting these results in October's *Astrophysical Journal*, suggested that such material from black holes and supernovas could have been the main source of the dust in the early universe from which the first generation of stars were derived.

Late in September NASA reinstated the Nuclear Spectroscopic Telescope Array (Nustar). A \$120-million Small Explorer class mission, Nustar had been terminated in 2006 due to a shortage of funds, but is now back on track for a planned 2011 launch into an equatorial orbit. Its focusing hard-X-ray detector, consisting of three aligned grazing-incidence mirrors kept in proper configuration by laser metrology, will count black holes and track material in the remnants of young supernovae with 500 times the sensitivity to hard X-rays of any previous instrument.

Japan's Akari infrared astronomy satellite, launched into its 700-km Sun-synchronous orbit in February 2006, completed its first all-sky observation in November 2006. Subsequent surveys, comprising the first all-sky infrared census since NASA's Infrared Astronomical Satellite mission in 1983, conducted over 3,500 detailed "pointed

observations” during Akari’s first year of operations and covered 90% of the sky twice, including the disk of the Milky Way galaxy. Akari’s 69-cm reflector telescope took images at wavelengths of 9, 18, 65, 90, 140, and 190 microns. Observations in the mid-infrared and far infrared spectra ended on 26 August with the depletion of the spacecraft’s liquid helium coolant.

Brazil’s National Space Research Institute (INPE) made substantial progress this year in developing the X-ray astronomy satellite mission MIRAX (Monitor and Imager of X-rays). MIRAX will be a wide-field X-ray monitor of the central Galactic plane. The three cameras on board will cover a field-of-view of 58 x 23 degrees in the 2-200 keV energy range with an angular resolution of 5 arc minutes. This will allow for an unprecedented coverage by virtue of very long continuous observation of a large X-ray source sample. MIRAX will be able to study in exquisite detail the behavior of transient systems related to neutron stars and black holes.

B. Plasma and Atmospheric Physics

Five small satellites of NASA’s Time History of Events and Macroscale Interactions During Substorms (Themis) mission were launched from Cape Canaveral Air Force Station on 17 February into a 2,000 x 187,000-km elliptical orbit by a United Launch Alliance Delta-2 rocket with nine strap-on solid-propellant boosters. The launch marked the first collaboration between NASA and the United Launch Alliance. The \$180-million mission to resolve competing theories about the aurora borealis is being managed by NASA’s Goddard Space Flight Center, with extensive Canadian involvement. The five identical 128-kg satellites, each carrying 11 instruments, 3 propellant tanks, and 8 deployable booms extending up to 40 m, were built by Swales Aerospace (USA) and the University of California at Berkeley. The Composites Optics Division of ATK Space Systems (USA) and Spectrolab (USA) were responsible for building the specialized body-mounted solar arrays designed for non-interference with the instruments’ precision scientific electrical and magnetic measurements.

Following launch the apogees of two of the spacecraft were reduced to about 60,000 km. Themis’s measurements, coordinated with a line of 20 ground-based imaging systems spread across Canada to Alaska and instrument stations in 10 rural U.S. schools, are aimed at resolving a 30-year debate about two competing theories on the transfer of magnetic energy into kinetic energy that creates the aurora’s dynamic displays and triggers magnetic storms in the Van Allen radiation belts. The Reconnection Theory holds that the magnetosphere on the night side of Earth, at an altitude of about 80,000 km, is like two rubber-bands that stretch, snap, and then reconnect into U-shaped bands that release their energy much like a slingshot. The Current Disruption Theory says that at the onset of a magnetic storm, higher-frequency instabilities are excited, inducing the plasma and electromagnetic field to form a turbulent state in the Van Allen belt about 150,000 km above the equator, which then short-circuits the current, forcing it directly into the Earth’s atmosphere.

The two NASA Stereo spacecraft launched on 25 October 2006 (see last year's report) are now returning images of solar coronal mass ejections. One of the twin spacecraft entered a heliocentric orbit ahead of the Earth on 15 December 2006; the other used a lunar gravity-assist maneuver to place it in its heliocentric orbit behind the Earth on 21 January. Three-dimensional observations of the solar corona by the Stereo mission began on 24 April, when the spacecraft were separated by 4 degrees of their heliocentric orbit. Since then, they have been slowly separating by about one degree per week, broadening their three-dimensional perspective of potentially damaging solar coronal mass ejections. The twin spacecraft were built by the Johns Hopkins University Applied Physics Laboratory (USA), and the mission is being managed by NASA's Goddard Space Flight Center.

NASA's 195-kg Aeronomy of Ice in the Stratosphere (AIM) satellite was launched from Vandenberg Air Force Base on 25 April by an Orbital Sciences Pegasus XL vehicle. Built by Orbital Sciences Corporation, the \$140-million mission is the most recent addition to NASA's 16-spacecraft Heliospherical Observatory studying the Sun's influence and interactions with Earth and the rest of the Solar System. AIM is designed to find and study noctilucent (night-shining) clouds consisting of ice crystals that form near the edge of space about 80 km above the Earth's poles, high enough to reflect sunlight after sunset. AIM's first images of such clouds suggest a connection with global change in the lower atmosphere, and may provide early warnings of changes in Earth's environment.

Japan's Solar-B spacecraft, launched on 22 September 2006 (see last year's report) and now renamed Hinode ("Sunrise"), began in December 2006 to return very detailed images of the Sun's outer atmosphere from its Sun-synchronous orbit, identifying the precursor events to massive solar storms. A joint effort by NASA, ESA, and the Japanese space agency JAXA to study how changes in the solar magnetic field propagate outward from the Sun's surface, Hinode carries three instruments that provide comprehensive three-dimensional profiles of the Sun from its surface through its outer atmosphere: an X-ray telescope, a solar optical telescope, and an extreme-ultraviolet imaging spectrometer. On 22 March JAXA released spectacular images taken by Hinode of a gigantic flare on 13 December 2006 that ejected solar material at a speed of 700 km/sec and gave rise to a magnetic storm accompanied by auroral activity that was visible as far south as Japan's Hokkaido island.

ESA announced on 16 November 2006 that the joint European-Chinese Double Star programme was being extended by nine months, to September 2007, at a cost of \$675,000. Since their launches in December 2003 and July 2004, the TC-1 and TC-2 satellites have been studying the Earth's magnetic field and its interaction with the Sun, alongside ESA's four Cluster satellites, and coordinating their data with NASA's Stereo and Themis solar-terrestrial missions. TC-1 was retired on 14 October and was subsequently guided to a destructive re-entry.

On 23 April an Indian Polar Satellite Launch Vehicle (PSLV) placed Italy's Agile satellite in a 550-km circular orbit inclined at 2.5 degrees to the Equator following its

launch from the Indian Space Research Organization's (ISRO's) Satish Dhawan Space Center at Sriharikota. It was India's first dedicated launch of a foreign payload, although Indian rockets had previously launched foreign satellites weighing up to 100 kg as secondary payloads.

The 365-kg Agile, built for the Italian Space Agency and the Italian Institutes of Astrophysics and Nuclear Physics by Carlo Gavazzi Space at a cost of less than \$82 million, is equipped with a 100-kg payload containing four instruments to study high-energy astrophysics phenomena, including X-rays and gamma radiation. They are a 30-bar cesium-iodine mini-calorimeter, a 12-layer silicon-tungsten tracker, an anti-coincidence system of segmented plastic scintillators to filter out unwanted cosmic particles, and SuperAgile, an assembly of four silicon detector quadrants and a collimator equipped with a tungsten codified mask designed for hard X-ray monitoring. Its instruments allow Agile to detect hard X-rays in the 15-60 keV range and gamma rays in the 30-MeV – 30 GeV range. Thales Alenia Space (France and Italy) and Telespazio (Italy) were responsible for payload integration and the ground segment. Agile is now investigating black holes, gamma-ray bursts, pulsars, supernova remnants, active galactic nuclei, and other phenomena.

The contract for Agile's launch, signed in January 2004 with OHB Technology subsidiary Cosmos International (Germany), was for \$11 million; it was ISRO's first commercially procured launch vehicle since the PSLV was first offered on the global market. Agile did not require any of the PSLV's six liquid-propellant strap-on boosters which are normally used for payload masses closer to the rocket's rated capacity of 1,300 kg.

C. Space Exploration

On 9 November 2006 the Indian Space Research Organization (ISRO) announced its intent to initiate a human space exploration programme, with the first flight to take place in 2014 and a planned landing of an Indian astronaut on the Moon in 2020. This is a new development in India's traditional policy of using space technology primarily for national development needs such as communications, health care, education, and Earth resource development and monitoring. ISRO presented this new development as based on two factors: the importance of humans in space exploration, which is one of ISRO's current goals, and India's booming economy, which will now permit the high expenditures required for human space flight. Initial funding of the programme began in April and is expected to require from \$2.5 billion to \$3 billion annually.

Similarly, a recommendation issued to the British National Space Council (BNSC) on 13 September by the U.K. Space Exploration Group would end Britain's long-standing opposition to all programmes involving astronauts and make the U.K. a full participant in the emerging global space exploration strategy for missions to the Moon and Mars. The Group's report notes that although it is now too late for Britain to become active in ESA's current International Space Station activities, participation in the human exploration of the Moon (and later of Mars) is a valid and important objective for the

U.K., and future U.K. exploration strategy should acknowledge this. The BNSC plans to incorporate the Group's conclusions into a reassessment of Britain's civil space strategy, which, if accepted by the government, would require new human space flight funding mechanisms that go beyond the U.K.'s space science budget.

On 4 December 2006 NASA's Jet Propulsion Laboratory (USA) released images taken by the MARS Reconnaissance Orbiter of the two Viking spacecraft landers that were launched in 1975. The images provide an idea of the environmental conditions the landers have endured over the thirty years since they arrived on the Martian surface. For example, one surprise finding was that a parachute still remained attached to one of the landers.

NASA's 10-year-old Mars Global Surveyor (MGS) experienced failure on 2 November 2006, ascribed to improperly coded software transmitted to the spacecraft in June 2006. The error caused MGS to point its heat-shedding radiator toward the sun, resulting in overheating and subsequent failure of the spacecraft's battery.

According to a NASA statement released on 6 December 2006, recent images of Mars compared with images recorded during the past seven years indicate that liquid water has flowed in at least two sites during that period and may still be seeping out in short bursts from crater walls. The key images were obtained from the now-silent Mars Global Surveyor's Mars Orbital Camera. The two areas of interest are Terra Sirenum and a crater in the Centauri Montes region.

The detectors in the High-Resolution Imaging System (HiRise) on NASA's Mars Reconnaissance Orbiter (MRO) began to degrade early in February, forcing managers to reduce the number of images transmitted per week from 80 to 40, at least until they could determine that imaging frequency was not causing the problem. Other causes could be thermal, electrical, or other factors. The 40 weekly images that continued to be transmitted retained the high-resolution character consistent with MRO's data capabilities.

Observations from NASA's Mars Odyssey during March revealed seven dark spots on Mars near the volcano Arisa Mons that appear to be caves, with openings measuring from 100 to 250 m across and one of them appearing to be about 130 m deep. Detected by the spacecraft's Thermal Emission Imaging System (Themis), they were designated Seven Sisters and assigned individual names of the wives or companions of the researchers who discovered them. An Earth-Mars Cave Detection Programme was subsequently created by researchers from NASA, Northern Arizona University, and the U.S. Geological Survey to study caves on Earth in geographical areas similar to those on Mars (e.g., the Mojave Desert in the U.S., the Atacama Desert in Chile, Antarctica, and Iceland) to develop observation techniques for Themis using these "Mars analogues," to get more information on the newly discovered Mars caves.

According to a NASA announcement on 23 July, both of the agency's Mars rovers, Spirit and Opportunity, successfully survived a major sandstorm on Mars, when

they were over 9,000 km apart. They escaped without significant permanent loss of power, because although the sand and dust would have obscured their solar arrays, the storm's high winds apparently cleared them. However, dust in the atmosphere did create variable power conditions for both rovers, which required suspension of stationary operations on 30 June and affected the planning of their missions. Nevertheless, on 29 August Opportunity made its initial 30-m trek to the rim of the 730-m-diameter, 70-m-deep Victoria Crater, and on 13 September proceeded 6 m down inside the crater.

On 8 January NASA selected two competing proposals under the agency's Mars Scout programme to send an orbiter to Mars in 2011 to study the planet's atmosphere evolution. The University of Colorado proposed the Mars Atmosphere and Evolution Mission (Maven), to address key questions about Mars climate and habitability, and improve understanding of the dynamic processes in the upper Martian atmosphere and ionosphere, and the Southwest Research Institute proposed the Great Escape mission, to directly determine the basic processes in Martian atmosphere evolution by measuring the structure and dynamics of the upper atmosphere. Each proposer received a \$2 million contract to refine its studies; the winner will get up to \$475 million to launch its mission by 2011. Partners in the Maven mission are Lockheed Martin Space Systems, which would build the spacecraft, the University of Michigan, the University of California at Berkeley, and the NASA Goddard Space Flight Center. The Great Escape team includes the Johns Hopkins University's Applied Physics Laboratory, Orbital Sciences Corporation, the University of Michigan, and others.

Radar data from ESA's Mars Express orbiter, released on 14 March, indicate massive deposits of water ice under Mars' south pole. The spacecraft's Mars Advanced Radar for Subsurface and Ionospheric Sounding instrument (MARSIS), using a radar echo sounding technique that could penetrate down to about 4 km below the planet's surface, revealed water ice deposits of sufficient magnitude that, if melted, would cover the entire planet with an 11-m deep water ocean. The radar data indicate that 90% or more of the frozen polar deposit is pure water ice, sprinkled with dust particles. MARSIS was subsequently trained on Mars' north pole, where prior observations had also indicated massive but as yet unquantified deposits of ice.

On 30 January researchers at the University College of London (UK) released their report of a study on the radiation doses to which Mars had been exposed from both solar and cosmic sources. Their results indicate that only life forms buried more than 7.5 m below the Martian surface could have survived for long periods of time, although in some regions where denser rock material had been blasted to the surface by meteor strikes it was possible that living cells could have survived at subsurface depths of only 2 m. Survival, however, is complicated by the inability of living cells to repair radiation damage due to the frigid Mars temperatures, limiting predicted cell lifetimes to only 450,000 years, with only one in a million cells able to live that long.

Data from a soil analysis by the German alpha-particle X-ray spectrometer aboard NASA's Spirit Mars rover indicate a very high concentration of silica (90%). This is strong evidence that the Gusev Crater, from which the sample was extracted in mid-May,

would have probably required the long-term presence of water in the ancient past and therefore could possibly have been habitable by microbial life forms. Spirit's miniature thermal emission spectrometer also observed silica in the same patch of Mars' surface.

During the first week in February Thales Laser (France) completed shock-resistance tests on Diva, a rock analysis tool for use on NASA's Mars Surface Laboratory (MSL) 2009 mission. The 2,000-g testing provided the confidence that Diva can withstand the launch acceleration and landing loads to be imposed on it. Thermal vacuum tests on the 20 cm x 5 cm, 0.6-kg instrument in July demonstrated Diva's ability to operate through the temperature range +30/-30 Celsius in the harsh Mars radiation environment. As the active element in MSL's ChemCam, Diva's 30-mJ pulses will create plasmas on rock surfaces for subsequent analysis. This Laser Induced Breakdown Spectroscopy technology has been used in the laboratory, but never before in a space mission. Diva was delivered to NASA in July for integration in the MSL spacecraft.

NASA's 1500-kg Phoenix Mars lander was launched on 4 August from Cape Canaveral on a United Launch Alliance Delta-II rocket. Following course correction maneuvers on 10 August and in October (the first two of the six such maneuvers planned), the \$420-million mission will land on Mars on 25 May 2008 to retrieve soil and ice samples in Mars' north polar region. The spacecraft's landing mass of 525 kg and span of 1.8 x 1.5 m are too large to use the airbag landing technique that was employed for the Spirit and Opportunity rovers, so Phoenix will use 12 hydrazine-powered rocket engines, built by Aerojet (USA), to set Phoenix down, following separation from the spacecraft's parachute at 570 m altitude. After landing, Phoenix will use its 2.4-m arm to dig trenches up to 90 cm deep to image subsurface layers and retrieve samples. The mission carries equipment from Canada, Denmark, Finland, Germany, and Switzerland, and is cosponsored by the Canadian Space Agency, whose laser instrument will search Martian clouds after the spacecraft lands.

Phoenix's main objectives are to search the Martian soil for organics, which have yet to be discovered on Mars, and to test ice and water samples for acidity and the potential to hold food sources for life. Phoenix carries eight ovens to bake samples for organic analysis in its Thermal and Evolved Gas Analyzer and four wet chemistry bays to assess soil acidity. The project is led by the University of Arizona, with NASA's Jet Propulsion Laboratory responsible for spacecraft development and operations.

As the first step in the U.S. "Vision for Space Exploration," (see last year's report), on 4 December 2006 NASA laid out its plan for establishing an outpost on the Moon. Based on last year's series of international meetings under the umbrella "Global Exploration Strategy" (see last year's report and below), the lunar programme architecture is aimed at establishing an outpost on the Moon: "an enduring, sustainable human and robotic presence that will open up vastly greater opportunities for science, research, and technological development."

The plan calls for an open lunar architecture that other nations and commercial interests could add to "in order to evolve and allow the journey to continue to Mars and

other destinations.” Scientists from Europe, India, Japan and Russia had already begun teaming with U.S. scientists on instruments for the U.S. Lunar Reconnaissance Orbiter, and are working together to set up calibration standards for locating observation targets on the Moon. The U.S. announced on 8 January that the forthcoming missions to the Moon will use only the International System of Units (i.e., the metric system), rather than the dual metric-English units often used on NASA missions, including the ISS. NASA also sees opportunities for international and commercial partners in spectrum management, establishing common hardware interfaces, communications gear, robotics, habitation development, surface mobility technologies and systems, and resource utilization.

NASA’s notional plan would establish the lunar base at the Shackleton crater at the Moon’s south pole, and would enable six-month stays within five years of the first landing by leaving a piece of critical infrastructure on the Moon with each landing. Following the opinion by planetary scientists of the U.S. National Research Council on the importance of diversity in lunar sampling, NASA stated that its lunar mission architecture was being designed with the capability for sorties to any point on the Moon. Initial planning of the space transportation system, which aims at maximizing the payload delivered to the Moon, envisions a capability for placing 6 tonnes on the lunar surface. The planned Shackleton Crater base location, which is exposed to sunlight 75% of the time, makes it practical to consider a solar powerplant.

Subsequently, in September NASA unveiled a new modular lunar architecture based on large, movable habitats and small pressurized rovers, which would facilitate early occupancy and long-distance mobility, and would offer the flexibility and autonomy that would support collaboration with international partners. The prospects for such collaboration blossomed at the International Astronautical Congress (IAC) in Hyderabad, India in late September, fueled by the current lunar exploration programmes of China, India, Japan and the U.S., and future plans for human and robotic exploration of both the Moon and Mars revealed at the IAC by Canada, Germany, Russia, the U.K., ESA, and others.

The Japanese Aerospace Exploration Agency (JAXA) launched the agency’s \$480-million Selenological and Engineering Explorer (Selene) mission to the Moon from the Tanegashima Space Center on 14 September aboard an H-2A-2022 rocket. The 3-tonne spacecraft carried 14 instruments, a high-definition television camera, and two 50-kg subsatellites named VRAD and Relay. One purpose of the year-long mission, which has the spacecraft circling the Moon at an orbital altitude of about 100 km, is to use its wide-area sensors to produce data to cue the finer-grain sensors of NASA’s Lunar Reconnaissance Orbiter (LRO) planned for launch next year (see above and last year’s report), and to use its gamma-ray spectrometer to detect hydrogen for further study by the LRO.

A second goal for the Selene mission is to use the main spacecraft and its two spin-stabilized subsatellites, in elliptical orbits around the Moon, to map lunar gravity by using Doppler ranging to measure changes in the main spacecraft’s orbit. The first whole-

Moon gravity map they will produce is expected to have a precision of one meter or better. Selene's instrument suite is also collecting data on surface chemistry and mineralogy, surface and subsurface structure to a depth of 5 km, terrain mapping with a resolution of 5 m, the remnants of the Moon's magnetic field (about 1/10,000th as strong as Earth's), and charged and neutral particles in the lunar environment, along with a lunar perspective on Earth's plasmasphere and aurorae. Total data return, at 10 MB/s, is expected to comprise 4.3 terabytes of raw data and 25.6 terabytes of high-level data. Selene is also broadcasting high-definition video of the moon via Japan's public broadcast company NHK. Selene, subsequently named Kaguya after Kaguye-hime, a Moon princess in a well-known Japanese folk tale, was the heaviest spacecraft launched to the Moon since the U.S. Apollo programme.

After taking a number of high-definition images of Earth, on 5 October Kaguya was inserted in a trajectory that subsequently brought it into its 96-km lunar orbit. Its first images of the Moon were recorded on 8 October, when Kaguya also deployed the first of its small subsatellites, Relay, also called Rstar. The second 1-m sub-satellite, VRAD, was deployed on 14 October. Selene is the first of a series of four advanced lunar missions, followed on 24 October by China's Chang'e-1, on 9 April 2008 by India's Chandrayaan-1, and on 31 October 2008 by NASA's LRO.

On 28 September, at the International Astronautical Congress in Hyderabad India, China revealed government-approved plans for follow-on projects to Chang'e-1, which was launched to the Moon by a Long March rocket on 24 October to construct a three-dimensional map of the lunar surface, measure the thickness of the lunar regolith, identify and map up to 14 chemical elements on the Moon's surface, and study the space environment between the Earth and the Moon. The 2.35-tonne spacecraft carries an optical imaging system, a stereo camera, an interferometric spectrometer imager, a laser altimeter, gamma and X-ray spectrometers, a microwave detector, a system for monitoring the space environment, a high-energy solar particle detector, and a low-energy ion detector. After spending six days in Earth orbit, Chang'e-1 departed for the Moon on 31 October and was subsequently placed in a circular 200-km lunar orbit. The mission was supported by ESA, who provided detailed information to assist the Chinese in the key functions of telemetry, tracking, and control, which were made difficult by China's lack of a deep-space network.

The Chinese follow-on lunar projects announced at the IAF Congress will include a 1,300-kg lander on the Moon in 2015-2017 to serve as a testbed for a sample-return mission in 2020. The testbed lander, weighing 4 tonnes when launched by a Long March-3B rocket, would be sent directly to a lunar transfer orbit and then placed in a 100-km lunar orbit, from which it would descend to about 15-km altitude. A throttleable engine would then lower the lander to a point 4 m above the surface, from which it would drop unpowered to a landing cushioned by either a crushable honeycomb material or a hydraulic system in the four landing struts. The lander would be equipped with a rover, robotic arms, and a drill, to serve its function as a testbed for the follow-on sample-return mission. Its 90-day tour on the lunar surface would be powered first by a solar array and then by a radioisotope thermoelectric generator (RTG) fueled by plutonium-238. China

had already conducted a full-scale drop test of the lander's descent, which caused some structural damage to the test article due to a design flaw and excessive weight of the test rig.

On 3 August NASA selected four Moon-based experiments for further study. Two proposals, one by the University of Maryland and one by NASA's Goddard Space Flight Center (GSFC), would place suitcase-sized instruments at various locations on the Moon containing laser ranging arrays able to measure the Earth-Moon distance to submillimeter accuracy. Their goal would be to permit precise tests of Einstein's general theory of relativity, as well as to improve our understanding of the Moon's structure and Earth-Moon interactions. A second proposal by GSFC would measure X-ray emissions caused by the solar wind and its interaction with Earth's magnetosphere. The fourth proposal, by the U.S. Naval Research Laboratory, would place a small radio telescope on the Moon to study particle acceleration in the solar corona and celestial objects such as supernovas and quasars, and to serve as a pathfinder for a large radio astronomy telescope to be placed on the far side of the Moon.

The X-Prize Foundation announced the competitors for the 2007 Northrop Grumman Lunar Lander Challenge on 21 June. The \$2-million award is sponsored by NASA's Centennial Challenges Programme (see prior reports) to accelerate commercial development of technology for cargo- and crew-carrying lunar-surface-to-lunar-orbit ferries. The seven remaining competitors (two dropped out late in August) are Acuity Technologies, Armadillo Aerospace, Bon Nova, Maston Space Systems, Paragon Laboratories, SpeedUp, and Unreasonable Rocket.

On 13 September Google, Inc. and the X-Prize Foundation (USA) announced the \$30-million Lunar X-Prize, to be sponsored by Google. Goal of the competition is to place a privately funded robot rover on the Moon and have it complete several mission objectives, including a 500-m traverse on the lunar surface and transmitting at least a gigabyte of video, images, and data back to Earth. Qualification for the grand prize of \$20 million needs to be completed by 31 December 2012, after which the prize drops to \$15 million for missions completed before 31 December 2014. There is also a \$5-million second prize for a team that can land successfully on the Moon, rove for an unspecified distance, and transmit data back to Earth, and a \$5-million bonus to the team that can achieve a number of specified tasks; e.g., imaging artifacts such as the remains of the Apollo landing vehicles or astronauts' footprints, discovering water ice, surviving a full lunar night, or roving on the lunar surface for more than 5 km. Space-X (USA) has offered competing teams a 10% discount on a Falcon rocket launch, and the SETI Institute (USA) has offered its Allen Telescope Array as a communications downlink from the Moon at no cost to the teams. The St. Louis Science Center (USA) will coordinate a worldwide network of museums and science centers to participate in the contest, and the International Space University (France) will conduct international team outreach and help guide the formation of a judging committee.

NASA's 455-kg New Horizons probe to Pluto, launched on 19 January 2006 (see last year's report), made its closest approach to Jupiter on 28 February at 2.3-million km,

for a gravity boost of over 14,000 km/hr, bringing its speed away from the Sun up to 83,600 km/hr. While in the vicinity of the giant planet, New Horizons' instruments were used to make about 700 observations of Jupiter's atmosphere and magnetosphere, and of the composition and topography of moons Io, Europa, Ganymede, and Callisto, transmitting over 40 GB of data by the end of April. Besides revealing significant new details of Jupiter's atmosphere by the spacecraft's Linear Etalon Imaging Spectral Array (LEISA), New Horizons' measurements also served to verify performance of the spacecraft's instruments that will be required when it reaches its target in 2015.

Among the data collected by New Horizons during its Jupiter encounter were the first close-up scans of the Little Red Spot, Jupiter's second largest storm (about half the size of the Great Red Spot and about 70% of Earth's diameter), which had first turned red in color about a year before the New Horizons encounter; detailed images of the small satellites Metis and Adrastea herding dust and boulders through Jupiter's faint rings; volcanic eruptions on Io (including a 320-km-high plume from the volcano Tvashtar); and circular troughs on the surface of Europa.

During the summer New Horizons also made an unprecedented traverse down most of Jupiter's 160-million-km long magnetotail. As reported in *Science* on 9 October, the spacecraft found large bobbing bubbles of plasma in the magnetotail. These plasmoids are thought to derive from the material ejected by the moon Io at a rate of about a tonne per second, which is then ionized by Jupiter's powerful magnetic field to form the plasmoids. Much of the material in the magnetotail apparently also comes from Jupiter's own atmosphere, with some from the solarwind.

NASA's Messenger mission to Mercury, launched in August 2004, received its second gravity assist from Venus on 5 June, following previous encounters with Earth in August 2005 and Venus in October 2006 (see prior reports). The June maneuver, which brought the spacecraft within 320 km of the planet's surface while travelling at a relative speed of 48,000 km/hr, gave Messenger its biggest boost of the mission, a velocity increment of 24,000 km/hr.

During the flyby, Messenger's seven instruments gathered about 6 GB of data and took over 630 images, many of the upper cloud layers in both visible and near infrared wavelengths for comparison with observations by previous missions. Magnetic field and charged-particle measurements were taken to characterize solar-wind interactions and find solar-wind pickup ions. Upper-atmosphere composition was measured via ultraviolet, visible, and X-ray spectrometry, and Messenger searched for lightning on Venus's night side. During the encounter, the spacecraft's instruments conducted joint observations of the planet's environment with ESA's Venus Express. Messenger's next events are Mercury swingbys in January and October 2008 and September 2009. These gravity assists will enable orbital injection around Mercury in March 2011, when the spacecraft will begin its year-long mission.

NASA's \$446-million Dawn mission to explore protoplanet Vesta and dwarf planet Ceres (formerly designated the two largest known asteroids) was launched by a

United Launch Alliance Delta-2 Heavy rocket from Cape Canaveral on 27 September, following delays for a number of reasons from the previously planned June date. The spacecraft's most unique feature is its three-engine solar-electric ion propulsion system, which provides Dawn with more propulsion capability than any previous spacecraft. Its 425 kg of xenon propellant will accelerate the 1,218-kg spacecraft by about 11 km/sec during the course of its mission to orbit 520-km-diameter Vesta in 2011 and 960-km-diameter Ceres in 2015. The purpose of the mission is to shed light on the transition from the Solar System's inner planets, which have similar solid surfaces, to the gas-giant outer planets and their icy moons. Vesta has an Earth-like surface, while Ceres is much like the outer-planets' icy moons. The spacecraft's ion propulsion system was tested satisfactorily on 6 October through 5 different throttle levels, consuming only 280 g of its xenon propellant

Dawn was built by Orbital Sciences Corporation (USA) for NASA's Jet Propulsion Laboratory (JPL). It will be the first spacecraft to orbit two celestial bodies. Its three ion engines, which will operate separately (for redundancy) for an unprecedented 2,000 days during the course of the mission, were developed by JPL in conjunction with Boeing Electron Dynamics Inc. (USA) and L-3 Communications (USA). The 10-kW solar arrays, which span about 20 m and are the largest ever launched on a NASA planetary spacecraft, were built by the Dutch Space unit of EADS Astrium. Dawn's three primary instruments are twin German cameras to map the targets' surfaces, an Italian Space Agency visible/infrared spectrometer to map mineral distribution, and Los Alamos National Laboratory (USA) gamma-ray and neutron detectors to map elemental composition. Following a gravity assist from Mars in February 2009 and an exploration of the asteroid belt between Mars and Jupiter, Dawn will study the protoplanets from a series of orbit altitudes ranging down to 200-km orbit at Vesta and 700 km at Ceres, where planetary protection considerations preclude getting closer.

The spacecraft that were employed for NASA's 2004 Stardust and 2005 Deep Impact missions (see prior reports) are being re-used for additional missions, according to a NASA statement released early in July. The Stardust spacecraft, in a mission called The New Exploration of Tempel-1, will revisit comet Tempel-1 in February 2011 to observe changes that have occurred in the comet since its close approach to the Sun. This first mission to revisit a comet will also study the 20-m-deep crater left by Deep Impact in 2005. The Extrasolar Planet Observation and Characterization (Epoch) mission will use the Deep Impact spacecraft to observe known exosolar planets as they pass in front of their stars. The goal is to use Deep Impact's imaging infrared spectrometer and 30-cm reflecting telescope to characterize giant planets orbiting several nearby bright stars and determine if they have moons, rings, or companion Earth-sized planets. The Deep Impact Extended Investigation mission will then study comet Boethin during a flyby on 5 December 2008.

The Cassini-Huygens spacecraft currently exploring Saturn and its moons (see prior reports) flew by the tiny (508-km) moon Enceladus on 28 June at a distance of 88,000 km. Enceladus is notable in that geysers of liquid water issuing from its surface

were observed on a previous Cassini flyby in December 2005, despite a mean surface temperature of -200 C (see last year's report). The geysers came not from the moon's equator but from the south pole, dumping about a tonne of water, nitrogen, carbon, carbon dioxide, and hydrocarbons methane, propane, and acetylene every eight seconds. They issue from an underground source apparently close to a very young surface feature called "tiger stripes," whose temperature is slightly higher than Enceladus's average surface temperature. Age of the "tiger stripes" was estimated at 10 - 1,000 years. Several theories as to the source of the energy heating the geysers have been suggested but none appear to be conclusive at this time. Meanwhile Enceladus has become an important research target, since all three of the characteristics generally deemed necessary for life are there: water, organic carbon compounds, and an energy source. Late in the year plans were laid to send Cassini to within 30-100 km of Enceladus in March 2008 to collect and analyze samples of the moon's geysers and study its unique surface features more closely.

High-resolution infrared images of the Saturnian moon Iapetus taken during a close encounter by the Cassini spacecraft in September, suggested an explanation for the moon's unusual feature: the sharp contrast between its leading side, which is almost jet black, and its trailing side, which is as white as snow. The new data suggest that as it travels around Saturn the leading face of the satellite accumulates a thin coating of light-absorbing dark material on Iapetus's icy crust, which then warms the surface ice layer enough to cause it to evaporate. It then recondenses on the colder trailing side of the moon, thereby whitening the trailing side and leaving the leading surface even blacker.

On 2 and 3 January ESA's Rosetta comet-chaser explorer, launched in March 2004 (see prior reports), took preliminary images of asteroid 21-Lutetia, one of its targets on the way to its ultimate goal, comet 67P-Churyumov-Gerasimenko. The 100-km asteroid was observed by Rosetta's Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) from a distance of about 250 million km. Rosetta received a gravity assist from Mars on 25 February and another from Earth in November, slinging it toward close encounters with asteroid 2867-Steins (from only 1,700 km away) in September 2008 and with Lutetia again (this time from a distance of 3,000 km) in July 2010. During the Mars swingby, the Philae lander's Imaging System (CIVA) took close-up images of the red planet's Syrtis region from only 1,000 km away, operating totally autonomously and thereby verifying Philae's operating mode when it reaches its target.

On 31 January ESA approved \$426-million contracts for the BepiColombo Mercury Planetary Orbiter, a two-satellite mission to be launched in 2013 in cooperation with the Japanese space agency JAXA. Prime contractor is Astrium GmbH (Germany); co-primes are Astrium Ltd (UK) and Thales Alenia Space (France and Italy). The second satellite, the Mercury Magnetospheric Orbiter, is to be developed and built by JAXA. Total mission cost, including launch by a Soyuz rocket and operation of the seven-year mission, is expected to be \$860 million.

Japan's Hayabusa asteroid sample return mission (see last year's report) began its return to Earth on 25 April, but suffered from the malfunction of three of its four ion

thrusters and two of its three reaction control wheels. One of the ion thrusters was able to be restarted in July and another can be restarted if mission safety standards can be relaxed. Among them the three operational ion thrusters should be able to provide the thousands of hours of operating life required to complete the return trip.

VI. TECHNOLOGY ADVANCEMENT

A. Propulsion

(1) Earth to Orbit

On 16 November 2006, NASA and ATK (USA) ran a 120-second hot-fire test of the space shuttle reusable solid-propellant rocket motor, gathering information on the light available from the rocket exhaust for night-time Shuttle launches and on the performance of the first stage of the Ares-1 launch vehicle for the Orion crew exploration vehicle (see above and last year's report). The test had 58 objectives applicable to these goals.

The first firing of the P-80 engine, the first stage of Europe's Vega launcher (see above and prior reports), was conducted successfully on 30 November 2006 at the Guiana Space Center. The 10.5-m long filament-wound composite motor burned 88 tonnes of propellant during the 115-second test run, developing an average thrust of 1.9 MN, a peak thrust of 2.5 MN, and generating a pressure of about 90 bars. The \$173-million project, funded by Italy (52%), France (34%), Belgium, and the Netherlands, is being managed by prime contractor Avio (Italy) and the Italian space agency ASI, with Europropulsion (France and Italy) responsible for development and production and the French space agency CNES managing development and testing.

On 28 March the Zefiro-9 upper-stage engine of the Vega launcher, designed and manufactured by Avio SpA (Italy), failed during a test firing in Sardinia, Italy. The engine's pressure dropped suddenly, 35 seconds after ignition of the 10-tonne propellant grain, and remained at below-normal levels for the remainder of the test. There was some damage to the engine's nozzle. The failure was subsequently traced to a production defect that allowed gases to infiltrate the internal nozzle structure. Activities are in progress to modify the nozzle and the motor configuration, with minor effect on the Vega development program.

Italy, in its studies for possible future Vega evolutions, has awarded Vega prime contractor ELV (an Avio and ASI company) a study contract for a demonstrator engine which in the future could replace the Vega's Avum liquid-propellant fourth stage with a new liquid oxygen-methane engine named Mira.

ESA signed a contract with Snecma (France) on 22 December 2006 for design, production, and testing of the new cryogenic Vinci upper-stage engine for the Ariane 5 launch vehicle, including long-duration and re-ignition tests. The Vinci is Europe's first engine to use the expander cycle rather than the gas-generator cycle, enabling mid-flight restarts. It will also boost the Ariane 5 ECA's payload capability from 10 tonnes to 12

tonnes. Funding is being provided by ESA's Future Launcher Preparatory Programme (FLPP; see prior reports).

An intended long-duration firing of the Indian Space Research Organization's (ISRO's) upper-stage cryogenic rocket engine was terminated on 19 January a few seconds after ignition, but was repeated successfully for the full planned duration of 720 seconds three weeks later, after the minor anomaly causing the abort (false sensor readings) was corrected. The aborted test will not delay the first planned use of the engine, whose development cost \$76 million, on a Geostationary-orbit Satellite Launch Vehicle (GSLV) mission in March 2008.

A \$54-million international joint hypersonic research effort, announced on 3 January, teams Australia's Defence Science and Technology Organization and the Boeing Company's Phantom Works (USA) with team leader U.S. Air Force Research Laboratory. The Hypersonic International Flight Research Experimentation (HIFiRE) programme will conduct ten flight tests over a five-year period at South Australia's Woomera Test Facility. The first launch is planned for the end of this year. Boeing is handling design and engineering for the three tests to be conducted in 2009, 2010, and 2011, with those functions for the remaining flights to be competed among the three partners.

The tests will involve a supersonic-combustion ramjet (scramjet) engine mounted atop a 12.7-m long Terrier-Orion sounding rocket that will boost the test engine up 250-km altitude and then dive to reach the scramjet operating speeds of Mach 4 to Mach 8. The Woomera test site allows recovery of the vehicles after their flights. The first flight of a scramjet engine with an inward-turning inlet (promising higher efficiency than previous 2-dimensional inlets), conducted on 15 June, reached Mach 10 and an altitude of 530 km following a three-second firing after its sounding-rocket launch.

In addition to a number of NASA, U.S. Air Force, and industry test facilities and laboratories in the U.S., the project is being supported by the Australian Hypersonics Consortium, with the Australian universities of Queensland and New South Wales conducting extensive research on hypersonic phenomena. A goal of the programme is to collect data that will help develop the technologies needed for lighter, higher-thrust scramjet engines that could provide affordable access to space. HIFiRE will support the technology base for Boeing's X-51 scramjet demonstrator aircraft, which is co-sponsored by NASA and the U.S. Air Force. X-51 flights at Mach number 6 – 7 are expected to begin by 2009, and will then operate in parallel with the balance of the HIFiRE tests, which are planned to run for a total of 6 to 8 years.

The Montana Aerospace Development Association (MADA) recently received approval and funding from the U.S. Air Force Research Laboratory to proceed with the development of the Air-breathing Engine and Rocket Operational Test and Evaluation Center (AEROTEC), to be located in Butte, Montana, USA. This unique test facility will provide responsive and moderate-cost ground-testing services for advanced propulsion technologies, both air-breathing and rocket. The AEROTEC organization was started by

MSE Technology Applications, Inc. (MSE, USA) and Spath Engineering (USA) for the purpose of developing the Mass Injection Pre-Compressor Cooling (MIPCC) supersonic turbine engine test bench for the U.S. Defense Advanced Research Projects Agency (DARPA). The AEROTEC facility is expected to be operational in 2008. Space Propulsion Group (SPG, USA) is currently in negotiations with MADA to be the AEROTEC facility's first customer with a 90-kN thrust liquid oxygen-paraffin hybrid rocket.

A 5-month series of wind-tunnel tests of the Pratt & Whitney Rocketdyne (PWR, USA) X-1 demonstrator engine for the X-51 "Waverider," completed at NASA's Langley Research Center in April, met all U.S. Air Force and PWR performance predictions. The SJX61-1 nickel-alloy demonstrator engine was operated in an X-51A vehicle forebody/inlet through 35 thermal cycles for a total of 15 minutes at Mach numbers 4.6 and 5.0. The tests on the demonstrator were considered so successful that the X-2 flight engine is being readied for X-51B flights in 2009 without any major modifications to the original design. The engine is built of Inconel, uses many off-the-shelf components, and burns JP-7 hydrocarbon fuel.

On 18 September Aerojet (USA) completed data analysis of wind-tunnel testing conducted on 14 June of an experimental hypersonic Dual-Combustion Ramjet (DCR) at a simulated speed of Mach 6. The 240-second test validated the engine's durability under hypersonic conditions and paved the way for flight testing of the engine, which is planned for use by Boeing on the DARPA - U.S. Navy HyFly programme

China released details of its scramjet research programme at the Joint Propulsion Conference in late August. Most notable was the Hypersonic Propulsion Test Facility at Beijing's Laboratory of High-Temperature Gasdynamics, which features a hydrogen/air and oxygen replenishment combustion heater with a flow rate of 3.5 kg/sec that can generate velocities up to Mach 5.6 at stagnation temperatures of 2,000 K. Other data released included the aerodynamic performance of waverider designs featuring airframe-scramjet integration; computational fluid dynamic codes for coupled ramjet/scramjet inlet flowfields; designs for a controllable hypersonic inlet; scramjet combustion mode translation studies; hydrogen injection and scramjet ignition testing; thermal and structure studies; and numerical simulation of combustion instability.

During April and May TGV Rockets Inc. (USA) conducted its first phase of test firings on a 133-kN variable-thrust rocket engine at NASA's Stennis Space Center. Funded by the U.S. Naval Research Laboratory, the TGV engine, planned for use in operationally responsive launch-and-landing vehicles, burns standard jet fuel. The Phase-1 tests demonstrated stable combustion throughout the engine's operating range and consistent ignition down to 20% of full power.

Space Propulsion Group, Inc. (USA) continued work on paraffin-based hybrid rocket fuels this year, with development of processing techniques and the modeling of the structural and combustion behavior. Nine tests of 27 – 30 kN thrust liquid oxygen-paraffin 28-cm-diameter hybrid rocket motors were conducted.

(2) Orbit Transfer and Stationkeeping

On 6 December 2006 Aerojet (USA) secured the rights to market Russian Hall-effect plasma thrusters in the U.S., South America, and Japan. The thrusters are built by the Fakel Design Bureau (Russia), and began to be shipped to Aerojet early this year. Plasma thrusters are used for deep-space propulsion, orbit transfer, and stationkeeping of both commercial and scientific spacecraft. Aerojet delivered four 4.5-kW Hall thruster systems for the first Advanced-EHF spacecraft, scheduled for launch in 2008. The thruster qualification test programme included a total demonstrated life of 6,750 hours.

NASA's Evolutionary Xenon Thruster (NEXT) ion propulsion system project, managed by NASA's Glenn Research Center, successfully completed qualification-level vibration testing of the thruster gimbal and environmental testing of the propellant management system on the prototype model, built by Aerojet. The engineering model thruster has completed over 10,000 hours of testing at full power.

In early 2007 Aerojet completed developmental testing of an innovative cryogenic oxygen-methane reaction control engine (RCE) that simplifies system complexity, reducing cost and schedule risk for a key component of NASA's lunar exploration program. Aerojet completed over 135 tests of the RCE for NASA's Propulsion Cryogenic Advanced Development (PCAD) project, exceeding project goals for control engine technology critical to the Lunar Surface Access module (LSAM).

In December 2006, the Roll Control Thruster (MRCT) programme conducted by Aerojet for NASA's Marshall Space Flight Center demonstrated pulse-mode operation of 1.8- and 2.7-kN thrust monopropellant engines over a representative Ares 1 first-stage mission profile. The MRCT engine is based on the original Aerojet MR-80, which flew successfully on the Viking programme. This engine is also being qualified for the 2009 Mars Science Laboratory Mission as the Mars Lander Engine (MLE). Based on these tests, NASA selected Aerojet to provide developmental engines for the Ares 1 launch vehicle's first-stage roll control system.

Pratt & Whitney Rocketdyne (PWR, USA) conducted a series of tests in April on their RL-10 liquid hydrogen – liquid oxygen upper-stage engine to determine whether it could qualify for the descent stage of NASA's planned lunar lander. Goal of the tests was to evaluate the effectiveness of a new "fix" employing a bypass valve to route hydrogen around the main turbopump and thereby slowing the turbomachinery, enabling the engine to be throttled to as low as 10% of its rated 58-kN thrust. The current test series is aimed at assessing the prospects of using different propellant mixture ratios to avoid the combustion instability that marred prior testing of the RL-10 at these low thrust levels.

XCOR Aerospace (USA) completed a series of six test firings of its 3.3-kN 5M15 methane-oxygen prototype rocket engine from 12 to 21 December 2006. Technology of the uncooled engine prototype, funded by a \$3.3-million subcontract from Alliant Techsystems (USA) under Alliant's \$10.4-million contract from NASA Glenn Research

Center, is expected to support design and development of a cooled flight-weight methane-oxygen engine slated for extensive ground-testing by NASA. The first firing of the 33-kN-thrust fully regeneratively cooled design was conducted on 2 April.

A new liquid-propellant rocket engine design that eliminates the need for regeneratively cooled thrust chambers was successfully test-fired on 25 April by Orbitec Technologies Corp. (USA). The subscale 4.45-kN thrust propane-oxygen engine, named Forward-1, employs an oxygen injector to generate a pair of coaxial vortices in the combustion chamber. The outer vortex is composed of cold oxygen that protects the chamber-wall surfaces; the hot combustion gases are confined to the inner vortex. The elimination of external chamber-wall cooling and complex injectors is claimed to reduce the cost and improve the reliability of rocket engines employing this design. The vortex principle and injector design had been previously verified by Orbitec in over 200 firings of a 220-N thrust methane-oxygen engine and several tests of a 1-kN thrust hydrogen-oxygen engine. Orbitec plans future testing of 45-kN and 135-kN propane-oxygen designs beginning next year.

On 28 September the U.S. Defense Advanced Projects Agency (DARPA) signed a contract with SpaceDev (USA) to initiate the demonstration of a solar-thermal propulsion system for orbital maneuvering of a small spacecraft. The High Delta-V Experiment (HiDVE) will utilize a 15-kg satellite platform, to be designed by a SpaceDev-led team along with the solar-thermal propulsion system under the initial 6-month, \$3.75-million contract. Subsequent funding for ground testing and spacecraft development could follow, culminating in a 2010 flight demonstration.

The third hot-fire test of Rocket Propulsion Engineering Corporation's (RP's, USA) 20-kN thrust prototype kerosene-liquid oxygen rocket engine was conducted successfully on 3 April. The fuel-film-cooled thrust chamber ran for 3.7 seconds, generating a thrust of 19.7 kN. It is planned to serve as the upper-stage engine for RP's C-50 vehicle, designed for payloads up to 180 kg. The test programme is supported by \$1 million in funding from the U.S. Defense Advanced Research Projects Agency (DARPA).

On 4 August the Indian Space Research Organization (ISRO) conducted a successful 8-minute firing of its liquid hydrogen-liquid oxygen upper stage for the Geosynchronous Satellite Launch Vehicle (GSLV). The test, at ISRO's Mahendragiri rocket engine test facility in Tamil Nadu, concluded 6,000 seconds of total firing time for the indigenously developed cryogenic stage. It is scheduled for use in a GSLV launch early next year, superseding the Russian cryogenic upper stages used on all previous GSLV missions.

B. Power

On 11 March a team led by General Atomics (USA) tested a magnetohydrodynamic generator operating on the exhaust of a hypersonic scramjet combustor running at a simulated flight Mach number of 8. Peak power production of 15

kW was reached during a series of test runs at varying magnetic field intensities and power levels. Goal of the tests is to develop the technology for a flight-weight high-power generator system.

NASA awarded a \$600,000 Phase-2 contract on 24 May to Entech, Inc., a U.S. small business firm, for development of a stretched-lens solar array (SLA). The SLA technology produces electric power with a specific power five times that of current arrays, and is claimed to be able to reach 8 times the power per kg of today's arrays. Plans for the new contract include testing a 60-volt array powering a Hall-effect electric thruster in Auburn University's large vacuum facility.

On 20 September NASA issued a request for proposals on studies of missions using nuclear radioisotope power systems for a new programme element, "Discovery and Scout Mission Capabilities Expansion." The studies were to focus on the breadth of small planetary missions that could be enabled with Advanced Stirling Radioisotope Generators (ASRGs) of the type currently being developed by Lockheed Martin under the U.S. Department of Energy sponsorship, with technical support by NASA's Glenn Research Center. These ASRGs operate at four times the efficiency of the radioisotope thermoelectric generators (RTGs), that are currently used on the Cassini and New Horizons spacecraft. Proposals were due by 30 November, and NASA plans to issue six to nine 6-month study contracts of about \$1.8 million each.

An extensive 75-page assessment of the current status of space-based solar power systems (SBSPS) for terrestrial use was released on 10 October by the U.S. National Security Space Office (NSSO). The report, entitled "Space-Based Solar Power as an Opportunity for Strategic Security," did not claim that an SBSPS could be implemented in the very near future. However, the report stated that the U.S. military would derive a number of significant national-security benefits from an SBSPS and would be willing to pay a substantially higher price for electric power than commercial power customers. The report claimed that with the military as an "anchor tenant," a sizable demonstration project could be launched within a decade; e.g., a geostationary-orbit platform capable of beaming 5-10 MW of power to a ground receiver. Such a project would substantially reduce the risk of mounting a full-scale system financed by either industry or government agencies other than the U.S. Department of Defense. The assessment concluded that while the "business case" for SBSPS still doesn't close, it is now closer than ever before. Space transportation still remains the key barrier issue.

C. Spacecraft Design, Technology, and Development

On 8 March a United Launch Alliance Atlas-5 rocket launched the six payloads of the U.S. Air Force's Space Test Programme-1 (STP-1) mission from Cape Canaveral Air Force Station into a 490-km orbit inclined at 46 degrees. The two main spacecraft were the \$267-million Orbital Express mission, funded by the U.S. Defense Advanced Projects Agency (DARPA) and managed by DARPA and NASA's Marshall Space Flight Center. The mission's goal was to demonstrate autonomous servicing, refueling, and repair of orbiting satellites (see last year's report). It consisted of an Autonomous

Space Transport Robotic Operations (ASTRO) vehicle, built by Boeing Advanced Systems (also the system integrator), and a prototype modular next-generation serviceable satellite (NEXTSat), built by Ball Aerospace. The mission was launched with an unusual “spacecraft transponder abnormality” in the ASTRO vehicle, a tendency to toggle between a locked and unlocked state, that could interfere with the essential data link to NASA’s Tracking and Data Relay Satellites (TDRSS) and hence may have caused some loss of data from the mission. The cause of the problem was traced to the incorrect installation of a pitch momentum wheel on ASTRO.

Despite this anomaly, however, the initial demonstration of the mission (designated Scenario 0-1) was accomplished successfully on 1 and 2 April, when ASTRO transferred 14 kg of hydrazine propellant into NEXTSat’s tank. NEXTSat then returned the hydrazine to ASTRO on 4 April, and on 12 April ASTRO transferred a battery to its companion spacecraft. Rendezvous and capture operations of the mission began on 17 April with separation of the two spacecraft using ASTRO’s robotic arm, jettisoning of the separation ring that had joined them together, and remating them again by use of the robotic arm and ASTRO’s capture mechanism. It was the first fully automatic docking ever conducted by the U.S.

However, on 11 May a second attempt at rendezvous and docking was aborted when the main computer on ASTRO malfunctioned. Controllers moved the two spacecraft apart to avoid a collision and activated the backup computer. Almost eight days later, after the two spacecraft had orbited at distances up to 6 km apart, controllers successfully remated the satellites on 19 May. The two satellites completed another rendezvous and capture maneuver on 29 June. The mission then demonstrated the ASTRO spacecraft’s ability to remove and re-insert a spare flight computer with its robotic arm, after which the U.S. Air Force declared the Orbital Express mission to be complete. A final set of maneuvers was begun on 16 July to gather sensitivity data on Astro’s navigation sensors, after which decommissioning of the two spacecraft was carried out by dumping their remaining propellant. NextSat is expected to decay and burn up in the atmosphere in 3 to 5 years, and Astro will follow in 12 to 15 years.

The success of the Orbital Express mission apparently motivated an agreement announced on 3 September between Arabsat (Saudi Arabia) and Kosmos GEO-Ring Services (Germany and Greece) to investigate the prospects for extending the service lives of existing and future satellites and restoring inoperative satellites to service. The system involves a 250-300-kg teleoperated servicing vehicle equipped with a robotic arm and a quick-disconnect coupling that connects to new spacecraft for on-orbit refueling. Arabsat has agreed to install the coupling on two Arabsat-5 satellites ordered earlier this year.

The Atlas-5 that launched Orbital Express also placed into the same orbit the 116-kg MidStar-1 microsatellite, built by midshipmen at the U.S. Naval Academy and carrying two experimental computer payloads, the Eclipse experiment to study electrochemical membranes in space for NASA and Eclipse Energy Systems, and a prototype microdensitometer for the National Space Biological Research Institute. The

other three payloads aboard STP-1, all launched by a second Centaur upper-stage burn into a 557-km orbit inclined at 35 degrees, were the 156-kg STPsat-1, built by AeroAstro and carrying two experiments to collect atmospheric data and demonstrate several spacecraft technologies; the 159-kg Cibola Flight Experiment (CfeSat) to evaluate new spacecraft technologies for the Los Alamos National Laboratory; and the 54-kg FalconSat-3, built by cadets at the U.S. Air Force Academy to conduct five experiments on the near-Earth plasma environment, new space hardware, and a micropropulsion attitude-control system.

The Japan Aerospace Exploration Agency's (JAXA's) Engineering Test Satellite 8 (ETS-8) was launched by an H-2A rocket from the Tanegashima Space Center on 18 December, 2006. It was then moved to its geostationary-orbit slot at 146 degrees east longitude, where it underwent on-orbit checkout until mid-April. Renamed Kiku-8, the 3-tonne spacecraft carries two Large Deployable Antenna Reflectors (LDARs), one of which, at 40 x 40 m, makes Kiku one of the world's biggest geostationary-orbit satellites. Kiku-8 was developed by Japan's National Institute of Information and Communications Technology and Nippon Telegraph and Telephone Corporation to learn more about how to deal with the increasing demand for digital communications, especially by mobile telephones and other mobile communication devices.

Late in January, during pre-operational checkout, it was found that a number of Kiku-8's 32 Low Noise Amplifiers (LNAs) could not be switched on, apparently due to a problem in the harness that connects the LNAs to their power supply. The problem was resolved by disconnecting the fuse serving the one bank of four LNAs that contained the faulty circuit, and operating the spacecraft with the remaining 28 units.

D. Materials and Structures

The Elastic Composite Hinge Experiment was launched to the International Space Station on 16 December 2006 to evaluate the robustness of low-mass composite hinges for solar arrays, antennas, and other deployable spacecraft systems in a microgravity environment. The 18-month experiment, funded by the U.S. Air Force, involved a proprietary material called Tembo that employs carbon-fiber reinforcement of shape-memory polymers. The six test hinges were fabricated by Composite Technology Development Inc. (USA), who also designed and built the experiment hardware.

NASA and DuPont (USA) signed a Space Act agreement on 11 July covering development of a Kevlar-fiber-reinforced urethane foam insulation. Potential applications include the space station, for meteoroid protection, and the new Ares-1 crew launch vehicle. Kevlar fibers are currently used in body armor.

On 4 September Nanotailor (USA) licensed through NASA's Innovative Partnerships Programme a process for making single-walled carbon nanotubes that was developed by the agency's Goddard Space Flight Center. With a thickness of one carbon atom, the single-walled nanotubes are stronger, less costly, and easier to manufacture than the more conventional multi-wall tubes. The technology can be used in a number of

potential commercial applications including micromechanical devices and eventually in such advanced concepts as the space elevator.

On 11 April Japan's Kobe Steel company announced the invention of the world's strongest aluminum alloy, with a strength of 780 megapascals and a strain capability of 14%, as compared with the previous record of 710 megapascals and 5% strain capability of Lockheed Martin's Weldalite, the material used in space Shuttle external propellant tanks. Ingots of up to 240 kg are expected to be available commercially in 2008 – 2009.

E. Information Technology

The first tests of laser transmission between an aircraft and a geostationary-orbiting satellite were initiated in early December 2006 by the French arms procurement agency DGA. The first field operations of the \$66-million Airborne Laser Optical Link (Lola) project were successfully concluded in six links between a Lola terminal mounted on a Dassault Mystere business jet aircraft and ESA's Artemis satellite. The plane was flown at a speed of 300 km/hour at altitudes between 6 and 10 km, under cloud-free conditions, although one test was conducted with light cloud cover. Data transmission speeds were limited by the Artemis laser terminal's capacity of 50 MB/sec. Astrium Satellites (France) was the prime contractor for the project, which continued through May.

In another project to increase satellite data rates, the German Aerospace Center DLR issued a \$20-million contract on 24 November 2006 to Tesat, a subsidiary of EADS Astrium, to develop a geostationary-orbit-based Laser Communications Terminal (LCT) to serve as a relay for low-Earth-orbit satellites. Current relay systems such as the U.S. Tracking and Data Relay System (TDRS) and the Silex terminal on ESA's Artemis use low-data-rate radio spectra. Tesat's LCT will operate at 2.8 GB/second, in comparison to Artemis's 50 MB/second. The primary application for the LCT is visualized to be remote-sensing satellites, allowing them to download data at high rates continuously instead of being limited to line-of-sight orbit periods. The first test of the LCT will be on Germany's TanDem-X a commercial X-band remote-sensing satellite planned for launch in 2009 (see last year's report).

Argentina's 6-kg nanosatellite PehuenSat-1 was launched into a 635-km polar orbit by India's Polar Satellite Launch Vehicle on 10 January, along with India's Cartosat-2 and SRE-1, and Lapan-Tubsat. PehuenSat-1, developed by the University of Comahue, the Amateur Satellite Association of Argentina, and the Argentina Association for Space Technology, serves as a platform for conducting amateur radio experiments between colleges and universities in Argentina.

F. Automation and Robotics

On 20 July NASA announced a demonstration of autonomous rovers conducted in the Arctic's Houghton Crater (Canada) that closely simulated the conditions in craters on the Moon and Mars. The 74-kg rovers, developed by NASA's Ames Research Center,

navigated via a combination of Global Positioning System (GPS) data, stereo cameras, a three-dimensional scanner, and Sun trackers, powered by automated solar panels that followed the Sun. The four-wheel-drive rovers, named K10 Black and K10 Red, were equipped with surveying scanners that provided three-dimensional images with 5-mm resolution and could collect subsurface structural data at depths up to 5 m with their radar instrument. They conducted their surveys autonomously without relying on the controller commands required by the current Mars rovers Spirit and Opportunity.

Eurobot, an ambulating robot with three arms designed by ESA and being developed by Thales Alenia Space (France and Italy), completed a set of tests during July in the neutral buoyancy tank at the European Astronaut Center, Cologne, Germany. The robot is planned for use assisting astronauts in space-walks and for mundane tasks associated with extra-vehicular activity. Each arm will have seven joints, an “end-effector” or hand, and a camera, and is being designed to be able to handle very small objects.

G. Guidance, Navigation, and Control

NASA’s \$10-million Inertial Stellar Compass (ISC), funded under the Agency’s New Millennium programme for the development of innovative space technologies, was orbited as part of the U.S. Air Force Research Laboratory’s TacSat-2 payload launched aboard an Orbital Sciences Minotaur-1 rocket on 18 December 2006. Built by the Draper Laboratories (USA), the 2.9-kg, 3.6-W ISC employs miniaturized components that can reduce the mass of navigation sensor systems by more than 10 kg and cut their power requirements by over 30 W, making ISC designs of particular interest in the development of new classes of small satellites for exploration missions to comets and asteroids. The ISC is the first complete spacecraft attitude control system to use a microelectromechanical system (MEMS) gyroscope.

H. Space Research Facilities

On 29 June NASA announced the shutdown on 31 August of the NASA Institute for Advanced Concepts (NIAC), which the Agency had created in 1998 to support and provide “seed money” for revolutionary concepts in space science and exploration. Established and operated by the Universities Space Research Association (USA) on an annual budget of about \$4.4 million, NIAC focused on projects that pushed the boundaries of space science and technology and that would not be expected to come to fruition for ten to forty years.

Spacehab (USA) announced on 10 April the creation of a new division that will explore in-space manufacturing opportunities in life sciences and materials. The company claims that products will be based on research that has already been largely completed, and therefore will not require prolonged research and development to achieve marketability status in two to three years. Potential products cited include pure substrates for next-generation microchips and life-saving pharmaceuticals using processes that cannot be carried out on Earth.

Astrium Satellites reopened its UK satellite test facilities on 12 October following an 18-month overhaul that cost \$2.04 million. The Triton Range facility is equipped with an anechoic chamber to test for interference among satellite electronic payloads, and enables on-site testing of Astrium's full range of Earth observation and communications satellites. On 9 October Astrium and the British government also established the UK Centre for Earth Observation Instrumentation to study future Earth observation sensor technologies. The Centre's initial 15 months of operation were co-financed at \$3.06 million by the two founders. Its first study, by Scotland's University of Edinburgh, is on the use of space-based lasers to assess vegetation cover and its evolution over time.

On 10 January India's Polar Satellite Launch Vehicle orbited the Indian Space Research Organization's (ISRO's) 550-kg Space Capsule Recovery Experiment (SRE-1), along with Cartosat-2 and two other small satellites (see above). After being placed in its 639 x 485-km polar orbit, SRE-1 was used to demonstrate the technology of an orbiting platform for experiments in microgravity conditions. Its two experiments were an Isothermal Heating Furnace and a biomimetic experiment, Biomineralization of Inorganic Materials. SRE-1 was tracked and monitored cooperatively by several ground stations, in Bangalore (India), Lucknow (Mauritius), Biak (Indonesia), Bearslake (Russia), Saskatoon (Canada), Svalbard and Tromso (Norway). The capsule was returned to Earth on 22 January, using parachutes to slow it and deposit it in the Bay of Bengal about 140 km east of the Sriharikota Island launch site, where a flotation system was used to keep it afloat for recovery by Indian navy and coast guard vessels.

Russia's Foton-M3 was launched into a 275-km orbit from the Baikonur Cosmodrome by a Soyuz-U rocket on 14 September, carrying a 400-kg payload with over 40 experiments by European, Chinese, and Russian scientists. The experiments included studies of fluid physics, bone tissue cells, radiation exposure, exobiology, protein crystals, butterfly pupae, snails, newts, and gecko lizards. The mission, which lasted for 12 days and was recovered on 26 September, also carried an ESA student-built "space-mail" delivery system (see below).

I. Environmental Effects of Space Flight

(1) Space Debris

The launch of a U.S. Air Force meteorological satellite (DMSP-17) by a Boeing Delta-4 rocket on 4 November 2006 left an unusually large trail of debris from the vehicle's upper stage. Sixty-two trackable pieces of debris left the stage between release of the DMSP-17 spacecraft into its 850-km polar orbit and a unique upper-stage maneuver whose purpose was to deorbit the 3-tonne upper stage and send it into a destructive re-entry trajectory so that it would pose no future debris hazard. A camera mounted on the rocket detected only the normal 12-piece ejection of graphite-epoxy stiffeners used to extend the nozzle on the stage's Pratt & Whitney-Rocketdyne RL10B-2 engine, but ground-based U.S. Surveillance Network radar spotted the additional 50 pieces of debris.

NASA's Orbital Debris Programme Office reported in January that they had recorded eight breakups of orbiting satellites and spent rocket stages during the last eight months of 2006, until this year (see below) more than in any year since 1993. The largest number of pieces tracked came from the intentional destruction of a 7-tonne Russian Resurs Earth-observation satellite on 28 November 2006, leaving a trail of debris from the spacecraft's low orbit (200 – 350 km) up to over 850 km. Most of this debris, in addition to that from the other seven observed breakups, deorbited and was destroyed, but some will remain in orbit for years.

On 11 January a medium-range ballistic missile launched from Xichang, China destroyed an obsolete Chinese FengYun-1C weather satellite launched in 1999 and placed in an 863-km near-polar Sun-synchronous orbit. The non-explosive impact ejected a cloud of debris in all directions at speeds of 1100 – 2200 km/hr. The debris was expelled in two main clusters, one at sufficiently low altitude (down to 200 km) so that most of the pieces re-entered the atmosphere soon after the event and pose no future hazard; the other ranging from 863 to 3,800 km, with the bulk of debris between 900 and 1,700 km. Early estimates placed the number of trackable pieces (>10 cm) remaining in orbit at over 900 and the entire orbiting debris cloud (>1 cm) at about 35,000 objects. The previous record was established in 1996, when an exploding rocket propellant tank created 713 trackable pieces.

Because the bulk of the debris is concentrated in a near-polar orbit at a commonly used altitude, it could endanger many spacecraft in various Earth orbits that regularly pass through the polar plane, possibly including manned vehicles such as the International Space Station, the Space Shuttle, and the Soyuz ferries to and from the ISS. However, the lowering of the ISS orbit by 60 km in December 2006, to 340 km, in order to facilitate the delivery of heavy components such as the truss segments and the European and Japanese modules Columbus and Kibo, has significantly reduced the danger of impact by debris from the higher-orbit Chinese test.

Nevertheless, on 22 June NASA had to fire the thruster of the Agency's Terra satellite for 1.3 seconds, boosting its orbit by 1.3 km, in order to reduce to zero the 7% probability of a collision with a 40-cm Fengyun-1C debris fragment. Despite the 11 January weapons test, China is an active member of the Inter-Agency Space Debris Coordinating Committee (IADC).

Four other debris-creating events occurred shortly after the Chinese test. On 14 February an auxiliary engine on a Russian SL-12 missile exploded over Finland, and on the same day the upper stage of a Proton rocket used to launch a Russian government Coupon communications satellite in 1997 broke into 60 observable pieces while in a 260-km by 14,160-km elliptical orbit. The retired China-Brazil Earth Resources Satellite-1 (CBERS-1) broke into about 25 pieces on 18 February while in an orbit between 770 and 780 km. On 19 February the explosion of a Russian Breeze-M stage, which was involved in the failed Proton launch of Arabsat-4A on 28 February 2006 (see last year's report), left an amount of debris of the same order of magnitude as the Chinese test in an elliptical

orbit with an apogee of 15,000 km and a perigee of 500 km. The five major debris events occurring in the first two months of the year are in contrast with only eight such events in all of last year, which were the most since 1993.

At the July Inter-Agency Space Debris Coordination Committee meeting, held in Toulouse, France, China announced a wide series of measures aimed at mitigating space debris hazards. Most of the measures were focused on Chinese launch vehicles and spacecraft; e.g., emptying upper-stage propellant tanks and re-orbiting retired satellites or redirecting them into re-entry trajectories. China will also conduct space debris surveillance using two ground-based telescopes.

(2) Near-Earth Objects

On 8 March NASA reported to the U.S. Congress that its current \$4.1-million annual budget for detecting and tracking near-Earth objects (NEOs --asteroids and comets) that could collide with Earth was not sufficient to meet the Congress's suggested goal of detecting 90% of all NEOs greater than 1 km in diameter by 2020. The system of dedicated space-based infrared spacecraft and multiple shared ground-based observatories needed to meet that goal was estimated to cost about \$1 billion, whereas a less costly approach using existing spacecraft and ground-based telescopes might be able to survey 83% of 1-km NEOs by 2020. The report also concluded that to deflect any impending collisions with Earth, nuclear standoff explosions would be 10 – 100 times more effective than non-nuclear alternatives such as kinetic impactors, lasers, or asteroid "tugs."

VII. EDUCATION

A. Teaching Programmes

On 6 December 2006 Orbital Sciences Corporation (OSC, USA) announced that the company is donating a small 10-cm Cubesat satellite kit to student members of the Excelsior Aerospace Club at Thomas Jefferson High School in Annandale, Virginia (USA). The kit provides the students with the information and material to design, build, and operate their satellite, called TJ-Sat-1. OSC will also provide testing facilities and make about 20 technical advisors available to the students. The Club will seek additional financial support from companies in the area. Launch of TJ-Sat-1 is planned for 2009.

NASA announced on 7 March that the International Space University (ISU) will hold its summer session programme for 2009 at the Agency's Ames Research Center in Mountain View, California. The nine-week session for about 120 postgraduate students and young professionals will run from mid-June through August, covering engineering, life sciences, the physical sciences, satellite applications, space policy, management, and the humanities. It is the first ISU session to be held at a NASA center.

On 19 March the new state agency Space Florida and Zero Gravity Corporation jointly created the Florida Microgravity Education and Research Center to facilitate space

education and research opportunities for Florida teachers and students. Its goal is to reach 8,000 teachers and 80,000 students annually through microgravity flights and workshops, online curricula, downloadable educational materials, and professional development programmes.

Students from Florida's Embry-Riddle Aeronautical University (USA) set a new altitude record for student-built rockets on 22 March, when their 4.8-m Icarus two-stage sounding rocket reached a height of 60.48 km after its launch from NASA's Wallops Flight Facility in Virginia. The students were members of Future Space Explorers and the Development Society at Embry Riddle.

On 2 April a student team from Cornell University (USA) won the two-year Nanosat-4 Phase 1 design competition sponsored by the American Institute of Aeronautics and Astronautics and the U.S. Air Force, and began construction of their nanosat. Designs by the eleven U.S. university entrants in the competition were graded on technical competence, maturity, spaceflight qualifications, and educational impact by a panel of expert judges from Jackson and Tull, Lockheed Martin, the Massachusetts Institute of Technology, Northrop Grumman, and Orbital Sciences.

On 9 October five astronomy students at the University of Washington (USA) reported the discovery of over 1,300 new asteroids during the past two years. They used the 2.5-m Sloan Telescope in New Mexico, along with computer software to analyze the data. Their findings were verified by the Minor Planet Center at Harvard University (USA). The students will each get to name up to 260 of the asteroids they found, which constitute about 1/250th of the known objects in the Solar System.

The 2007 Team America Rocketry Challenge (see prior reports) was won on 19 May by the Newark Memorial High School (California) team, who launched and recovered a raw hen's egg to within a fraction of a meter of the specified altitude goal of 257.58 m and to within a second of the flight-time goal of 45 seconds. The second prize went to the Madison West High School Team 2 (Wisconsin), and the third place was won by the W.G. Enloe High School of Raleigh (North Carolina). The three winning teams shared over \$60,000 in scholarships and prize money donated by the Challenge sponsors, the Aerospace Industries Association and Lockheed Martin, and the top team attended the Paris Air Show in June by courtesy of the Raytheon Company.

The first-ever flyoff of the UK Aerospace Youth Rocketry Challenge was held on the grounds of the Charterhouse School, Surrey (UK) on 13 April. As in the abovementioned Team America Challenge, the mission requirement was to design, build, and launch a rocket that carries a raw egg (unbroken) to an altitude of exactly 257 m with a total flight duration of exactly 45 seconds. The competition was won by Buttershaw Enterprise College from Bradford, West Yorkshire, whose craft flew to 264 m with a flight duration of 48.2 seconds. Second and third places went to Crofton School from Portsmouth and Royal Liberty School from Essex, respectively. The event was organized by Tripolus, UKRA, and Space Connections, with support from the Royal Aeronautical Society.

On 14 September the Young Engineers Satellite 2 (YES-2) was launched as a “piggyback” payload aboard a Russian Foton-M3 capsule from the Baikonur Cosmodrome. The satellite’s 5.5-kg Fotino payload was deployed downward 30 m from the Foton capsule by a Dyneema tether, like a pendulum on a swing. At its nadir, the tether was cut and the Fotino dropped to Earth, where it parachuted to the ground in Kazakhstan. The “space mail” experiment, which involved 450 students worldwide for five years, was sponsored by ESA.

Gilat Satellite Networks Inc. (Israel) announced on 4 December 2006 that they have signed contracts with Alef Soluciones Intergrales (Mexico) and Corporative Lanix (Mexico) to provide a Very Small Aperture Terminal (VSAT) network to 4,400 sites serving 7,700 Mexican middle-school classrooms. The system will eventually be extended via Gilat’s SkyEdge network to 41,000 classrooms in Mexico. Deployment of the network, which was contracted to the two Mexican distributors by the Mexican Ministry of Education’s Enciclomedia programme, began in December 2006.

On 3 April the Indian Space Research Organization (ISRO) announced the creation of a new institute for space science and technology “to generate the high-quality manpower customized to meet requirements of the space programme.” The goal of the institute, which began operations in June at Thiruvananthapuram in India’s southern state of Kerala, is to eventually supply at least half of ISRO’s technical and scientific workforce. Budgeted at \$17 million for the fiscal year 2007 – 2008, the new institute is expected to make up the shortfall of ISRO workforce sources from the Indian Institutes of Technology at Mumbai, Kanpur, Kharagpur and Chennai, the Indian Institute of Science in Bangalore, and the University of Pune, many of whose graduates, along with young ISRO employees, seek employment at higher-paying multinational companies.

B. Public Awareness

The Planetary Society (USA) announced on 1 December 2006 an opportunity for the general public to send wishes to space aboard one of the three spacecraft in the Japanese Aerospace Exploration Agency’s (JAXA’s) Selenological and Engineering Explorer Mission (Selene), which was launched on 14 September. The messages were limited to 30 characters or less, and had to be submitted to the website of the Planetary Society by 31 January.

On 18 December 2006, NASA announced a Space Act Agreement with Google (USA) that will make NASA data, already available on the Internet, accessible to massively distributed computer and better human-computer interfaces, including the Google Earth feature. Typical of the information to be disseminated under the new agreement are real-time weather visualization; high-resolution, three-dimensional maps of the Moon and Mars; real-time tracking of the International Space Station operations in orbit; and real-time tracking of Space Shuttle launches and operations.

VIII. GLOBAL SPACE MARKET ISSUES AND OPPORTUNITIES

A. Government Programmes

On 2 May the U.S. General Services Administration (GSA) announced a new \$750-million five-year procurement programme for U.S. government civil and military communications using both fixed and mobile satellite services. These will be awarded via indefinite-delivery, indefinite-quantity (IDIQ) contracts for specific business opportunities over the life of the programme. The bid solicitation went to about 25 companies, including Americom Government Services, Arrowhead Global Solutions, Artel, Inc., Intelsat General Corporation, Stratos Global, Telenor Satellite Services, and Viasat Inc.

In a decree issued on 3 February by the President of the Russian Federation, four Russian launch vehicle and spacecraft manufacturers were consolidated under the control of the Khrunichev Space Center, following up the rocket and space industry integration strategy formulated in July 2006 (see last year's report). The four companies now integrated into the new M.V. Khrunichev Space Research and Production Center were the Voronezh Mechanical Plant, the A.M. Isaev Chemical Engineering Design Bureau ("Khim mash"), the Moscow Enterprise for Equipment Configuration ("Dlina"), and Production Association Polyot.

The new Center is responsible for the development, production, and operation of small and heavy-lift launch vehicles; development and manufacturing of space systems for remote sensing and telecommunications; and modules for manned space stations. On 11 February Khrunichev invested over \$190 million in the four newly acquired units, which will help the company produce an expected \$1 billion worth of launch vehicles and other equipment in 2008.

On 7 February a report issued by the French Parliamentary Office for the Evaluation of Scientific and Technical Choices cited 50 proposals to invigorate Europe's civil and military space policies in the face of growing space competition by the U.S., China, India, and Russia. The civil space policy proposals included the following: (1) Sanctions should be imposed on any European government that fails to give preference to European launch vehicles for its government satellites; (2) France should begin preparing nuclear-powered spacecraft for deep-space exploration; (3) The heavy-lift Ariane rocket should be made capable of launching humans within five years; (4) Managers of the Galileo satellite-navigation project should negotiate with the North Atlantic Treaty Organization (NATO) on the use and protection methods for Galileo's encrypted governments-only signal; (5) France and other European countries should assist companies proposing to develop suborbital flight systems designed to create a space tourism industry.

B. Commercial Enterprises

“The Space Report: The Guide to Global Space Activity,” issued by the Space Foundation (USA) on 15 November 2006, placed the total 2005 revenues of the space industry at \$180 billion. Of that total, commercial revenues were \$110 billion and \$70 billion came from government purchases of goods and services for both civil and military space programmes. Reported revenues, according to the Space Foundation, included only those that could be “conservatively and absolutely” proven. The most rapid growth was in the commercial sector, from satellite television, satellite radio, and especially Global Positioning System (GPS) applications.

Space News’ annual “Launch and Satellite Review and Forecast, “ issued on 8 January, reported that 27 commercial geostationary-orbit satellites had been ordered in 2006, a substantial gain over 2005’s total of nineteen. Space Systems/Loral (USA) and Astrium Satellites (France) led the manufacturers in orders with seven each, followed by Thales Alenia Space (France and Italy) with five and Khrunichev State Research and Production Center (Russia) with three. Boeing Satellite Systems International (USA) had two orders, and China Aerospace Corporation, Lockheed Martin Commercial Space Systems (USA), and Orbital Sciences Corporation (USA) one each.

The same review reported that the three major commercial launch service providers, Arianespace (France), International Launch Services (ILS, Russia), and Sea Launch (USA), each conducted five launches in 2006. Arianespace booked 9 more during the year; ILS signed four launch contracts in 2006; and Sea Launch booked four for the heavy-lift Sea Launch rocket during 2006 plus five for the lighter-lift Land Launch vehicles.

Space News’ report on 25 June listed the growth of the five top providers of fixed satellite services as follows (in millions of U.S. dollars):

<u>Company</u>	<u>2006 Revenue</u>	<u>2005 Revenue</u>
Intelsat (Bermuda)	\$ 2,100	\$ 2,030
SES (Luxembourg)	1,900	1,720
Eutelsat (France)	1,050	885
Telesat (Canada)	411	407.3
JSAT (Japan)	326	373

Euroconsult’s (France) forecast for the satellite and launch business through 2016, released on 1 February, predicts an increase of 32% in the number of government-ordered satellites, both civil and military, over the decade ending in 2016, and a corresponding growth of 5.5% in the number of commercial satellite orders. The average satellite mass will increase by 11% to 1.91 tonnes, and the cost of launches will decrease by 5%, to \$22,130 per payload kg. The average satellite cost, adjusted for non-market economies such as China’s, is predicted to be \$109 million.

According to a Eutelsat report released on 3 September, the unit cost of transponder capacity has plummeted by 80% since the mid-1990s, due primarily to the influx of larger, higher-capacity, higher-power spacecraft and longer service lives, plus the relative insensitivity of launch costs to satellite capacity. SES Global confirmed this trend, citing reduction of unit costs by a factor of three since the mid-1990s.

The annual report by the Satellite Industry Association (USA), released on 7 June, cited 2006 global satellite industry revenues of \$106.1 billion, up 19.5% over 2005, nearly double the rate of increase over the past five years. Satellite service revenues, the biggest single sector, grew by 19% to \$62 billion. Transponder use in 2006 was up to 70% vs 58% in 2004, and demand is forecasted (by Futron, USA) to outstrip supply by 2014. The new market in high-definition television (HDTV) carried by satellites leaped from 67 channels at the end of 2005 to 471 by the end of 2006, although HDTV still accounted for only 2% of total satellite television channels. Satellite manufacturing sales in 2006 were \$12 billion, up over 50%, and satellite ground equipment revenues grew by 14% to \$28.8 billion. Launch service revenue dropped by 10% to \$2.7 billion.

United Launch Alliance (ULA), a joint enterprise of Boeing and Lockheed Martin (see last year's report), initiated operations on 1 December 2006. ULA combines the manufacturing and U.S. government marketing of Boeing's Delta and Lockheed Martin's Atlas rockets. Full consolidation of Delta and Atlas launches, expected to take about two years, is claimed to offer the U.S. government savings of \$100 million to \$150 million annually over the cost of supporting two separate launch vehicle operations. The first Atlas-5 launch by ULA took place on 8 March.

On 14 February GE Capital (USA) and SES Global (Luxembourg) announced an agreement to sell GE's 19.5% share of SES for \$846 million in SES assets and \$735 million in cash. The SES assets transferred to GE include 19.99% of Brazil's fleet operator Star One, 34% of Hong Kong's AsiaSat, 5.5% of Orbcomm (USA), the Satlynx broadband communications business (see last year's report), and the AMC-23 satellite, launched in December 2005 into a geostationary-orbit slot over the Pacific Ocean at 172 degrees east longitude. GE Capital has placed these assets and the cash into a new company, SES International Holdings Inc. The purchase closed on 30 March. On 12 March SES also transferred to its newly acquired subsidiary New Skies Satellites (NSS) two of its spacecraft, AMC-12/Astra-4A, now renamed NSS-10, and AAP-1, renamed NSS-11. Both are in a geostationary-orbit slot at 108.2 degrees east longitude. NSS also took over the marketing of eight transponders on the West African beam from Astra-2B at 28.2 degrees east longitude. These transfers increased NSS capacity by 48%, to 318 transponders and seven spacecraft.

Once this transaction was approved by U.S. and Luxembourg regulatory agencies, GE Capital and the Chinese-government-owned CITIC group proposed on 13 February to purchase all of AsiaSat's publicly traded shares for \$2.34 per share, and said that they will not accept any competing offers for AsiaSat. However, on 21 April the U.S. Department of State refused to approve the plan by GE Capital and CITIC to withdraw AsiaSat from the Hong Kong and New York stock exchanges, pay off existing

shareholders, and eventually share ownership of the company on an equal 50-50 basis. The rationale for the State Department's right to veto the deal was AsiaSat's use of U.S.-built satellites, but the Department did not explain the basis for its decision or suggest how GE Capital and CITIC might modify their plans to win U.S. approval.

On 21 June BC Partners (Europe) announced their purchase of 76% of Intelsat (Bermuda) for \$5.03 billion plus assumption of \$11.4 billion of Intelsat's debt. Former owners Apax, Apollo, Madison Dearborn, and Permira (see last year's report) will retain the other 24%. BC stated that they had no plans to reduce Intelsat's 2007 capital spending of \$615 million, announced in March, nor to change current management personnel. The deal is expected to close early in 2008.

DataPath, Inc. (USA), a manufacturer of satellite terminals with antennas 1.8 m in diameter and larger, purchased SWE-Dish Satellite Systems AB (Sweden) on 12 July for \$56 million in cash. SWE-Dish, which builds portable (suitcase-sized) satellite communications terminals, reported sales of \$43 million in 2006. DataPath's revenues in 2005 were \$237 million, of which 84% came from the U.S. Department of Defense.

On 6 September Apax Partners (France) completed the purchase of Telenor Satellite Services (Norway) and merged it into Apax's Vizada company (France), the former France Telecom mobile satellite service business. The new acquisition gives Vizada annual revenues of \$586 million. Between them, Vizada and Stratos Global (USA) represent over 75% of annual sales by Inmarsat (UK), the world's largest distributor of mobile satellite services. Inmarsat agreed this year to finance the purchase of Stratos by CIP Canada, which is expected to close in 2009.

India's Ministry of Communications struck satellite communications a major blow on 19 January by eliminating satellite C-band users' rights to the upper end of C-band, from 3.7 to 4.2 GHz, in favor of terrestrial broadband wireless users, including WiMax systems. The order stated that all concerned users should shift their operations to other suitable bands within six weeks, after which interference would have to be accepted. The problem with the order, which was appealed but reaffirmed by the Ministry on 1 March, is that any broadband wireless access to a portion of C-band will wipe out satellite reception not only in that portion, but everywhere else in C-band. Tests have confirmed that a broadband wireless transmitter located within 30 – 50 km of a C-band receive-only satellite antenna wipes out the entire C-band satellite link, from 3.7 to 4.2 GHz. There are about 160 satellites currently in orbit that depend on C-band availability, constituting approximately half of in-orbit satellite communications capability.

The debate between satellite and terrestrial C-band users was the primary issue discussed at the United Nations' International Telecommunication Union 2007 World Radiocommunication Conference (WRC-07) held in Geneva, Switzerland from 22 October to 16 November. Supporters of the satellite sector are the U.S. and most of the Americas, Russia, China, most of Southeast Asia, as well as the satellite fleet operators, space-launch service companies, and nonprofit satellite industry associations. Backers of the terrestrial broadband wireless companies include the European Union, Japan, South

Korea, and the world's cellular telephone operators and manufacturers. The African nations are divided, and India remained undecided going into the WRC.

XM Satellite Radio (USA) announced on 5 January that its subscriber roster had reached 7.63 million by the end of 2006, a growth of 442,000 during the fourth quarter and 1.7 million for the year, and that for the first time the company had achieved positive cash flow during the last quarter. To strengthen its balance sheet, on 14 February XM sold the XM-4 satellite's transponders to a specially created trust, Satellite Leasing LLC, for \$288.5 million. XM will lease the transponders from the trust, which is managed by Wells Fargo (USA), for at least 5 years with an option to extend the lease to 9 years and then re-purchase the satellite, which was launched in October 2006 and began operations in January. On 26 July XM reported a 22% increase in second-quarter revenue, to \$277 million, and a 16% growth in subscribers, to 8.25 million, in comparison to the corresponding numbers for 2006. During the year ending in June the company signed agreements with Acura, General Motors, Harley-Davidson, Honda, Hyundai, and Lexus to install XM-compatible radios in their new vehicles.

Competitor Sirius Satellite Radio reported on 3 January that it had 6.02 million satellite radio subscribers at the end of 2006, with an increase of 910,000 in the fourth quarter that more than doubled XM's growth rate. Subscriber growth continued into this year, with 7.14 million reported by Sirius on 31 July. Revenues during the second quarter also jumped by 51% in comparison to the second quarter of 2006, reaching the record revenue of \$226 million.

Satellite mobile data-services provider Orbcomm (USA) doubled its subscriber base in 2006, ending the year with 225,000 customers. Satellite television broadcaster EchoStar (USA) added 2 million customers in 2006, bringing its year-end total to over 13 million; competitor DirecTV (USA) had 15 million subscribers at the end of 2006.

On 19 February XM Satellite Radio and Sirius Satellite Radio announced their intent to merge into a single \$11.4-billion entity. Although they face formidable technical issues; e.g., different types of satellite constellations, incompatible ground receivers, and different automobile radios, there are potential, although difficult, solutions to these problems. The major hurdle, however, will be obtaining regulatory approval due to current U.S. Federal Communications Commission (FCC) policy, which explicitly prohibits such a merger, as well as the precedent set when antitrust regulators blocked a comparable merger in 2002 of DirecTV and EchoStar.

On 18 December 2006, Loral Space & Communications (USA) and Bell Canada affiliate BCE signed an agreement to purchase Telesat Canada for \$3.16 billion, including assumption of a \$167-million debt. Loral will hold 64% of a new company retaining the name Telesat, but only 33% of the voting stock. Canada's Public Sector Pension Investment Board (PSP Investments) will hold 36%, along with two-thirds of the voting stock in association with other Canadian investors, as required by Canadian regulations. Resident Canadians will comprise 70% of the Board members. The purchase was approved by Industry Canada, the cognizant regulatory authority, on 19 September,

and by the U.S. Federal Communications Commission on 5 October, clearing the way for closure of the acquisition on 31 October.

Headquartered in Ottawa, the new company is the fourth-largest communications satellite operator worldwide, with a backlog on 30 September 2006 of \$4.9 billion and a fleet of 11 satellites, with five more on order. Not surprisingly, Telesat Canada selected Space Systems/Loral on 4 January to build Telesat's Nimiq-5 direct-broadcast satellite (see above). Loral stated on 15 March that the merger will save the new Telesat \$60 million in operating costs and \$38 million in overhead.

Less than a month later, Telesat Canada BCE sold its minority share of Mobile Satellite Ventures LP (MSV, USA) to the majority owner of MSV, SkyTerra Communications, Inc. (USA). MSV had three satellites on order from Boeing Satellite Systems International since January 2006, two for North American markets and one for South America, but cancelled the South American spacecraft late in 2006.

On 5 April Alliant Techsystems (ATK, USA) announced its purchase of Swales Aerospace (USA) for \$100 million. The purchase, which was approved by Swales shareholders and U.S. regulatory authorities in May, provides ATK's new Space Division a capability in microsatellite technology and construction, as well as Swales' expertise in spacecraft thermal management and systems engineering. The acquisition boosts ATK's \$3.5-billion annual revenues by about \$100 million.

Northrop Grumman purchased Scaled Composites (both USA) on 5 July, increasing its holdings in the company that is building SpaceShip-2 vehicles for Virgin Galactic from 40% to 100%. Scaled Composites employs about 250 people in its Mojave, California facilities, from which Virgin Galactic plans to begin commercial tourist-flight operations in 2009. Northrop Grumman stated its intention of retaining the full complement of Scaled Composites people and making no changes in the company's management or in its participation with Virgin Galactic in The Spaceship Company (see last year's report). The fatal accident at Scaled Composites on 26 July did not affect the terms of the purchase. Following regulatory approval by the U.S. Department of Justice, the transaction closed on 24 August.

On 28 August the Center for Space Resources at the Colorado School of Mines (USA) announced the formation of the Eighth Continent Project, a new effort to integrate space business into the global economy. Its goal is to connect government, industry, and academia with entrepreneurs and venture capitalists to promote the development of potentially profitable space technologies. Besides the Colorado School of Mines, other sponsors of the initiative include the University of Colorado's Leeds School of Business, the Colorado state governor's Office of Economic Development, DigitalGlobe, the Keiretsu Forum, Broadreach, CTEK, and Townsend & Townsend & Crew (all USA).

A Wildblue Communications, Inc. order to ViaSat, Inc. (USA) for 500,000 Ka-band consumer-broadband terminals was issued on 14 May. The \$200-million contract included support services and improvements to the Wildblue network, and could grow

beyond the initial 500,000 SurfBeam terminals. The terminals are being used with the Wildblue-1 satellite, which was launched in December 2006 and was declared operational in March.

The Qinetiq Group (UK) acquired the Analex Corporation (USA) in March for \$173 million, shortly after a Qinetiq-led team won a \$31-billion 25-year-long defense training infrastructure programme from the British Defense Ministry. Analex's 1,100 employees at 11 U.S. locations provide high-technology professional services such as space-launch integration, testing, and evaluation to U.S. government agencies.

Contraves Space (Switzerland) completed its purchase of the solar-array drive system business of Safran (France) on 30 November 2006. The purchase, which added annual revenues of about \$6.6 million to Contraves's annual income of \$74.5 million, has made Contraves the biggest European builder of solar-array drives, a business that is currently growing by 20% annually.

The application for approval of the acquisition by Thales (France) of Alcatel's 67% share of Alcatel Alenia Space and its 33% share of Telespazio, filed with the European Commission (EC) in October 2006 (see last year's report), was delayed until April by the EC, pending a full-scale inquiry into potential market dominance resulting from combining the manufacture and sales of Thales's travelling-wave tubes with those of related Alcatel components and subsystems. This action delayed completion of Alcatel's \$11.8-billion merger with Lucent Technologies (USA), which was approved by the U.S. Administration in late November 2006.

Thales' acquisition, which created a new company called Thales Alenia Space, was finally approved by the EC on 4 April and closed on 6 April. The final terms and conditions were slightly different from those of the original agreement; i.e., Thales' cash payment for the purchase was increased from \$900 million to \$950 million and Alcatel-Lucent received 25 million newly issued shares of Thales, increasing its ownership from 9.46% to 20.95%. The French government still holds 27.29% of Thales, which is also a defense contractor.

On 29 June, OHB Technology (Germany) announced its purchase of Kayser-Threde (Germany), ostensibly to eliminate potential future competition for full satellite integration contracts, which Kayser-Threde had demonstrated by its successful bid for Germany's hyperspectral Enmap Earth imaging satellite. OHB paid \$8 million plus the assumption of about \$14 million Kayser-Threde debt for the company, whose 2006 revenues were about \$51 million. OHB's 2006 revenues were about \$250 million. The purchase was completed in mid-July. OHB subsequently purchased 19% of SpaceDev Inc. (USA) on 19 September for \$4.4 million. SpaceDev's 2006 revenues were \$33 million.

EMS Technologies (USA) announced its purchase of DSpace (Australia) on 25 June for \$5.7 million. The purchase, which closed in July, provided EMS's Satcom Division with DSpace's satellite radio for Inmarsat's Broadband Global Area Network

satellite service that features a software system, providing easy upgrades to accommodate new technology advances.

On 2 December 2006, Arabsat (Saudi Arabia) and Nilesat (Egypt) created a strategic partnership allowing an Arabsat ground station to be located in Nilesat's tax-free zone in Cairo. The Arabsat gateway will provide convenient satellite access to the company's Egyptian television broadcast customers. The agreement is considered by the two companies to be "a critical first step toward a further constructive and mutually beneficial cooperation."

Astro All Asia Networks PLC (Malaysia) announced on 5 April that it had bought 20% of Sun Direct TV Private Ltd (India) for \$166 million. The transaction had received Indian government regulatory approval on 2 March. Maran Group (India) holds the remaining 80%, as required by Indian law restricting foreign ownership of domestic direct-to-home (DTH) television providers to 20%. Sun Direct TV had received a license in August 2006 to provide DTH television services in India. The company plans to invest \$670 million over the next five years to deploy its service, which employs the Insat 4B satellite that was launched in March. India's current market consists of 118 million television households, of which 65 million are pay-television customers, expected to grow to over 150 million in the next decade.

IX. INTERNATIONAL COOPERATION AND SPACE LAW

A. Global developments and organizations

(1) Status of UN Treaties

Since 1987, the International Institute of Space Law (IISL) has compiled 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 of the current year.

In 2007, the following accessions to, and/or ratifications of space treaties took place:

- Algeria has ratified the 1972 Liability Convention and the 1975 Registration Convention;
- Lebanon has acceded to the 1975 Registration Convention and to the 1979 Moon Agreement;
- Montenegro has ratified the 1975 Registration Convention and the 1974 Brussels Convention Relating to the Distribution of Programme-carrying Signals Transmitted by Satellite; and
- Turkey has ratified the 1973 Rescue Agreement and the 1975 Registration Convention.

At the national level:

- Brazil established a national registry of space objects in 2006, to be maintained by the Brazilian Space Agency (AEB);
- Indonesia established a national registry of space objects in 2006, to be maintained by the National Institute of Aeronautics and Space (LAPAN);
- Kazakhstan established a national registry of space objects in 2006; and registered its first national geostationary communication satellite, KazSat, under the UN Register of Objects Launched into Outer Space.

The Global Exploration Strategy

The Global Exploration Strategy (GES) was signed on 31 May following a three-day workshop in Italy. The workshop was the third in a series that started in Washington DC (USA) in 2005 (see prior reports). The strategy involves space exploration activities in the U.S. (NASA's "Vision for Space Exploration"), in Europe (Aurora), and similar initiatives in China, India Japan and Russia. The GES is not a stand-alone programme to which the participants commit resources and schedules, but a voluntary, non-binding, open-ended forum for sharing cooperation plans and supporting exploration activities of the participating nations.

Specific measures to be addressed in the Terms of Reference for the GES Coordination Mechanism currently being drafted include interoperability standards, sharing of science data and analyses, identifying services, infrastructure, and payload opportunities suitable for sharing and/or cooperation, broad participation in planning and coordination processes, and requirements for relevant international legal agreements. The initial framework document was drafted, reviewed, revised, and finally accepted by Australia, Canada, China, ESA, France, Germany, India, Italy, Japan, South Korea, Russia, Ukraine, the U.K., and the U.S.

The agreement identified a list of "challenging technologies" to be developed by the space-faring nations, either individually or jointly. They include efficient power generation and energy storage; space and surface transportation; communications and navigation; health care for human explorers, including telemedicine; autonomous operation and smart decision-making for robot explorers; planetary resource extraction and utilization; on-orbit spacecraft servicing; human-robot cooperation; and safe habitats with efficient life support and environmental control. It identified the Moon as the nearest first goal, and emphasized the value of multinational cooperation in both robotic and, eventually, human exploration of Mars.

(2) International Institute of Space Law (IISL) Activities

IISL 50th International Colloquium

The IISL held its 50th International Colloquium on the Law of Outer Space during the 58th International Astronautical Congress, Hyderabad, India. The Colloquium was divided into 5 sessions on the following topics:

- The Impact of Outer Space Law on Regional Policies;
- Legal Issues of Private Spaceflight and Space Tourism;
- New Legal Developments in the Protection of the Space Environment;
- Legal Aspects of Satellite Navigation;
- 40th Anniversary of the Outer Space Treaty, and other legal matters.

Eleven papers were submitted for the 2007 Isabella H.Ph.Diederiks - Verschoor Award and Prize for Best Paper by a Young Author. The Evaluation Committee awarded this prize to Fabio Tronchetti for his paper entitled "The Non-Appropriation Principle Under Attack Using Article II of the Outer Space Treaty in its Defence". Mr. Tronchetti is in the LL.M. programme at the Institute of Air and Space Law, Leiden University, the Netherlands.

Manfred Lachs Space Law Moot Court Competition

Since 1992, the IISL has organized the annual Manfred Lachs Space Law Moot Court Competition. The 16th Space Moot Court competition was held in Hyderabad, India, during the IISL Colloquium. Three regions were represented: North America (9 teams); Europe (6 teams), and Asia-Pacific, with a record 39 teams. The NALSAR University of Law at Hyderabad and the Indian Space Research Organisation (ISRO) at Bangalore, India were the sponsors of the Space Moot Court Final Rounds.

The winning team of the final rounds came from George Washington University, Washington, DC, and the runner up was the University of Queensland, Australia; second runner up was the University of Leiden, the Netherlands. As has become tradition, the finalists were judged by three justices from the International Court of Justice: H.E. Judge Abdul Koroma, H.E. Judge Hisashi Owada, and H.E. Judge Peter Tomka.

The University of Queensland, Australia, was the winner of the Eilene Galloway Award for Best Brief. The Sterns and Tennen award for Best Oralist went to Ms Rola Lin, University of Queensland, Australia.

IISL's Statutory Changes

As of 18 June 2007, the IISL is a legal association (a 'Vereniging') under Dutch law, statutorily seated in Leiden but with its business address at 94 bis, avenue de Suffren, 75015 Paris, France. The IISL was originally established in 1960, and with the change to its Statutes of Incorporation, it is now an independent international Non-Governmental Organisation (NGO) under the laws of the Netherlands.

IISL Elections

At Hyderabad, the IISL convened a General Assembly of its members, and held elections for new officers. Dr. Nandisiri Jasentuliyana, former Director of the United Nations Office for Outer Space Affairs, who has been President of the IISL since 1993, will be stepping down in January 2008. The Nominating Committee endorsed Tanja

Masson-Zwaan for President as of January 2008. Dr. Masson-Zwaan has been a member of the IISL Board since 1991, and has served as the Secretary of the IISL since 1991. Corinne Contant-Jorgensen will serve as the new IISL Secretary.

Eilene M. Galloway Symposium on Critical Issues in Space Law

The first "Eilene M. Galloway Symposium on Critical Issues in Space Law", sponsored by the National Center for Remote Sensing, Air and Space Law of the University of Mississippi, was held at the Cosmos Club in Washington DC, USA, on 11 December 2006. The symposium, held in honor of Dr. Galloway and her long-standing contribution to space law, included presentation of the Summary Report of the "IASL–IISL International and Interdisciplinary Workshop on Policy and Law relating to Outer Space Resources: the example of the Moon, Mars and other Celestial Bodies" that was held from 28 to 30 June in Montreal, Canada; and other topics such as maintaining space for peaceful purposes, interstitial space and the definition of celestial bodies, and space traffic control.

The second "Eilene M. Galloway Symposium on Critical Issues in Space Law" was held on 6 December 2007, at the Cosmos Club, in Washington, DC., sponsored by the National Center for Remote Sensing, Air and Space Law, University of Mississippi.

Conference on Space Law and Space Applications for Disaster Management in the Asia Pacific Region

The IISL, together with the Institute of Air and Space Law of McGill University (McGill IASL), the National Center for Remote Sensing, Air and Space Law at the University of Mississippi School of Law (NCRSASL Mississippi), the Japanese Aerospace and Exploration Agency (JAXA), and Chiangmai University and Rangsit University of Thailand, organized a conference entitled "Space Law and Space Applications for Disaster Management in the Asia Pacific Region," from 20 to 22 November 2007 in Chiangmai, Thailand. The conference was officially supported by the President of Rangsit University.

IISL, ECSL, other NGOs and UNCOPUOS Activities

IISL, in cooperation with the European Centre for Space Law (ECSL) organized a two-session symposium entitled "Capacity-building in space law", which was held during the session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), on 26 and 27 March 2007.

The following presentations were made during session 1, chaired by Peter Jankowitsch (Austria): (i) "General introduction to and overview of space law teaching and education" by Armel Kerrest, on behalf of Gabriel Lafferranderie; (ii) "The state of the art of space law teaching and the need for a multidisciplinary approach" by Armel Kerrest; (iii) "Networking and federative initiatives (ECSL, IISL, Moot Court and other)" by Sergio Marchisio; (iv) "The needs of teaching institutions in the Latin American and

Caribbean region: specific features and initiatives” by José Monserrat Filho; (v) "The needs of teaching institutions in Eastern Europe: specific features and initiatives” by Nataliya Malysheva; (vi) “The need for space law teaching: the view of industry” by Francesco Giobbe.

Session 2 of the symposium, chaired by Vladimir Kopal (Czech Republic), included the following presentations: (i) “General introduction and overview of the workshops organized by United Nations Office for Outer Space Affairs” by Joanne Gabrynowicz; (ii) “Networking and federative initiatives (e.g. ECSL Practitioners Forum, IISL regional conferences, ILA etc.)” by Stephan Hobe; (iii) “United Nations Regional Centres for Space Technology Education, the example of India (CSSTEAP) and capacity-building efforts in space law in India” by B. Vasudevan; (iv) “Initiatives in the North African region” by Riffi Tamsamani Saïd; and (v) “Initiatives in the Latin American region” by Ciro Arévalo Yepes. A concluding panel discussion was chaired by Raimundo González Aninat (Chile). The papers and presentations delivered during the symposium are available at <http://www.unoosa.org/oosa/COPUOS/Legal/2007/symposium.html>. The symposium was coordinated by Tanja Masson-Zwaan of IISL. The IISL and ECSL were invited to hold a further symposium on space law during the forty-seventh session of the Legal Subcommittee of UNCOPUOS in 2008.

The IISL also presented the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) with the report on its most recent contributions relating to capacity building, training and education in space law. UNCOPUOS noted the importance of education, training and capacity-building in space law, in particular in support of the establishment and development of national space legislation. The Legal Subcommittee of UNCOPUOS further noted these efforts to be of great importance to international, regional and national efforts in the further development of space activities and to the spreading of knowledge on the existing legal framework within which space activities are carried out. A directory of educational opportunities, including fellowships available for developing countries to study space law has been compiled by the United Nations Office for Outer Space Affairs (UNOOSA) and is available at <http://www.unoosa.org>.

ESA and UNCOPUOS

The European Space Agency (ESA) presented a report to UNCOPUOS on its activities related to space law in 2006, which included lectures on legal implications of space activities, and a publication of legal studies on various aspects of space law, such as the protection of intellectual property rights in space activities, and the legal aspects of space debris.

ILA and UNCOPUOS

The Space Law Committee of the International Law Association (ILA) presented a report to UNCOPUOS on the ILA’s most recent activities, including comments and suggestions on registration practice issues. The ILA recently set up a Study Group on

Responsibility of International Organizations, that have been working closely with the International Law Commission. The Legal Subcommittee of UNCOPUOS invited the Space Law Committee to continue informing it of relevant matters dealt with by the International Law Commission.

(3) European Centre for Space Law (ECSL) Activities

The European Centre for Space Law (ECSL) was established in 1989, at the initiative and under the auspices of the European Space Agency, with the support of a number of pioneers in this field. The Centre (a name designating the whole structure) gathers mainly professionals, lawyers, academia, students and it encourages interdisciplinary exchanges. The Centre also holds an annual forum and coordinates a summer course in Space Law and Policy.

ECSL Practitioners' Forum

The 2007 ECSL Practitioners' Forum, entitled "Recent developments within the European space industry: legal aspects", was held on 27 April at ESA Headquarters. Attended by some 40 participants from various institutional, commercial and academic professions, the forum addressed major developments in the European space industry, in particular the restructuring and consolidation on a corporate level, where a series of convergences, joint ventures, takeovers and statutory consolidations took place. These trends raise several legal issues with respect to applicability of sections of the United Nations Space Treaties, such as the issue of nationality and State liability for actions of legal and corporate persons. Many of these issues also entail different facets of the laws within the European Union (EU), ESA and EU - USA agreements. The Forum addressed issues of corporate consolidation, State and corporate liability in the context of the United Nations Space Treaties as well as issues related to the Global Monitoring for Environment and Security (GMES) satellite system, as a major cornerstone for the future European economy and society insofar as they involve space activities and programmes.

A representative of the European Commission described GMES as a major cornerstone for the future European economy and society insofar as they involve space activities and programmes. Strong and globally competitive companies in the development and manufacture of space systems, related areas and value-added services are critical to key areas of the economy. It was also noted that GMES would contribute to the Global Earth Observation System of Systems (GEOSS), a U.S. initiative involving satellites and other monitoring systems, in the prevention and mitigation of natural disasters.

A representative of ESA presented the new Financial Policy (FINPOL) system, in use since 1 January 2006. The reformed FINPOL is helping ESA to adapt itself in times when most countries face restrictions in their national budgets and their contributions need to be justified and used as efficiently as possible. The various flexibility systems put in place in 1998, produced important improvements in the yearly allocations in ESA

budgets, but they also had their drawbacks. FINPOL is a simpler, more transparent system, providing greater flexibility for programme managers and ESA member states.

European Centre for Space Law (ECSL /ESA) “National Points of Contact”

Several years ago, the ECSL instituted “National Points of Contact” as a means for its members / space practitioners to stay up-to-date on space events, and to provide networking opportunities and personal contacts in different countries. This year, members of the Austrian National Point of Contact attended the 46th session of the UN-COPUOS Legal Subcommittee, held in Vienna from 26 March to 5 April 2007; 5 law students from the University of Graz and 8 law students from the University of Vienna were also part of the Austrian delegation.

European Centre for Space Law (ECSL /ESA) Summer Course

The 2007 ECSL Summer Course took place at the European Space research and Technology Centre (ESTEC), Noordwijk, the Netherlands, in September 2007. The main objective of the Summer Course is to stimulate students’ interest in this particular field of international law and to provide them with a basic, solid knowledge upon which to build their professional career or carry out further academic research. Each year, more students from many different countries are attending this 2-week course.

B. Europe

(a) European Space Agency (ESA)

88 scientists and national representatives from ESA member states met in Athens, Greece from 15 to 16 May to establish recommendations on a European science-driven scenario for space exploration. The workshop, organised by the European Science Foundation (ESF) and sponsored by ESA, was initiated by the draft report of an ad hoc group set up by the ESF’s European Space Sciences Committee (ESSC). The report establishes a framework for the definition of Europe’s Exploration Programme (EEP) based on an overarching science goal: “Emergence and Evolution of Life with its Planetary Environment,” and five sub-themes: Mars (robotic and human exploration), the Moon (robotic and human exploration), and Near-Earth Object (NEO) sample returns (robotic exploration). A series of science goals and mission concepts were proposed for the short term (up to 2020), medium term (2020-2030), and long term (after 2030).

Participants agreed that the EEP should focus on targets that can ultimately be reached by humans. The planet Mars is recognised as the focus of this programme, with Mars Sample Return as its driving project; furthermore Europe should position itself as a major actor in defining and driving Mars Sample Return missions. There is also unique science to be done on, of, and from the Moon and of/on NEOs or asteroids. Hence if these bodies are to be considered a component of the EEP, further science should be pursued. The first steps of this programme should be done robotically, but since EEP’s ultimate goal is to send humans to Mars in the longer term, research on humans in a space

environment must be strengthened. Finally, international cooperation among agencies engaged in planetary exploration should be a major feature of this programme, substantiated by concrete joint ventures.

In December 2006, the European Space Agency (ESA) created a special layer of content that will appear in Google Earth, enabling access to more than 130 new satellite images including natural phenomena and manmade landmarks such as the Palm Islands in Dubai. The new images can be accessed by clicking first on the checkbox of Google Earth's "Featured Content" sidebar, and then on the ESA icon.

As users explore detailed images of landmarks and changes to the environment, information including facts, figures, scientific explanations and theories will appear underneath the images. The images in the collection are acquired by ESA's Envisat, ERS and Proba satellites. Envisat, launched in 2002, acquires data using three imaging sensors: advanced synthetic aperture radar (ASAR), medium resolution imaging spectrometer (MERIS) and advanced along-track scanning radiometer (AATSR).

ESA and the European Union

The European Commission (EC) has adopted the European Space Policy, which reflects the key strategic importance that space systems and space applications have for Europe, in order to live up to its global leadership aspirations. On 22 May this joint policy document of EC and ESA, was presented to the Space Council, a joint meeting of EU and ESA Councils. The Resolution on the European Space Policy adopted by Ministers shows, for the first time, their strong political support at European Union level to provide the necessary comprehensive political support framework for the development of a viable and strong space sector.

The new European Space Policy recognizes the inherently dual-use nature of space technology and urges for the creation of a legal structure that makes it easier to fund multi-year space projects. The policy resolves the long-ongoing turf battles between the European Commission (EC) and ESA by directing the EC to set European space priorities and ESA to serve as the technical manager of EU space programmes. Although the 9-page document puts off any plan for implementing its new principles, it is generally recognized as an effective instrument to reduce duplication in space spending and to offer taxpayers assurance that their money is being well spent. The new policy does not cover the organization or operation of the Galileo system, which is the responsibility of the European transport ministers, not the industry and research ministers that met on 22 May.

Galileo

After Europe's Galileo satellite navigation system's prospective service entry date was postponed to 2012 - 2013 due to management concerns, the European transport ministers agreed to scrap the public-private partnership (PPP) funding scheme and finance Galileo wholly with government funds, and the European Commission laid out the details of a new policy for Galileo's management structure, operation, and

procurement. In November, the EU secured Galileo's future by allocating additional 2.4 billion euros (\$3.56 billion) to the Galileo project from its unused budget funds. Critics of the new funding plan stress that Galileo should prove its economic viability, or else that the project should be re-considered.

(b) Belgium

Belgium's Ministry of Defense signed a contract with Spain's Hisdesat to provide X-band communications services using the Xtar-Eur and Spain's Hisdesat satellites. The ministry ordered fixed capacity for an initial period and reserves the right to order additional capacity at an agreed price. The contract will be tacitly renewed annually for an indefinite term, according to Hisdesat.

Located at 29 degrees East, Xtar-Eur carries a dozen X-band transponders covering from Eastern Brazil and the Atlantic Ocean, across Europe, Africa and the Middle East to Southeast Asia. Hisdesat has eight X-band transponders and is located at 30 degrees West, providing coverage from the Eastern Pacific Ocean to Iraq.

(c) Cyprus

PlanetSky Ltd., based in Limassol, Cyprus announced an important anchor-customer lease agreement with ProtoStar Ltd., a Bermuda corporation, to secure C band capacity on ProtoStar's first satellite, to be launched in May 2008. The agreement provides PlanetSky with five 36MHz equivalent transponders for its rapidly-expanding global satellite systems that support GPRS and GSM broadband services, wireless, VoIP, broadcasting and radio transmissions

ProtoStar Ltd., and PlanetSky Ltd., emphasized that the agreement allows PlanetSky to extend the reach of its media and entertainment services for its customer base further into Africa, Asia and the Middle East. For ProtoStar, the agreement extends its customer base into Europe and the Middle East from its Asian base in Singapore.

PlanetSky offers a unique opportunity to work with an innovative, entrepreneurial organization that shares ProtoStar's objective of bringing new satellite-based value-added services into newly-expanding geographic markets. ProtoStar's first satellite is currently being manufactured at Space Systems/Loral in Palo Alto, CA, for a May 2008 launch on an Arianespace launch vehicle. ProtoStar is developing a satellite constellation of high-powered geostationary satellites that will provide a satellite network enabling robust DTH services in Asia.

(d) France

Alcatel Alenia Space will manufacture the W7 satellite for Eutelsat Communications, the two companies announced in December 2006. The spacecraft, scheduled for launch in the second quarter of 2009, will be located at Eutelsat's 36

degrees East location and double the current available capacity in a key neighborhood for the company's fleet of geostationary satellites.

Alcatel announced late in 2006 the successful demonstration of Europe's first broadcast of live TV channels on mobile handsets in S-band. Using the new satellite services for handhelds (DVB-SH) standard currently being drafted by the DVB Project, Alcatel was assisted by UK broadcasters Sky, ITV and BBC in Alcatel's London offices. Representatives from European mobile operators, TV broadcasters, industry analyst firms and regulatory bodies attending this demonstration were able to see high-quality images displayed on Sagem MymobileTV handsets.

DVB-SH, a standard related to DVB-H, is a new technology targeting the S-band. With DVB-SH, mobile TV signals can be broadcast from satellites as well as from terrestrial transmitters directly to handhelds. DVB-SH handhelds can be designed in such a way that they become compatible with DVB-H so that both standards can be received in one end-user terminal. DVB-SH is said to be a perfect complement to other standards, such as DVB-H, which uses UHF frequencies but is capable of using the L-band. Thus DVB-SH may have a significant impact on the global mobile TV industry.

Alcatel - Lucent

Although the merger between Alcatel (France) and Lucent (USA) in March 2006 considered to be a good match, it was reportedly experiencing some difficulties. Revenues were not as high as anticipated, in part due to Lucent's lack of investment in mobile networks. As a result of dwindling revenues more than 12,500 employees worldwide were let go. Out-sourcing, and competition from Asian countries may also have contributed to the problems faced by the merged companies.

Arianespace

Arianespace's initial heavy-lift Ariane 5 flight in 2007 consisted of a dual mission: the launch of India's Iinsat-4B and the United Kingdom's Skynet-5A secure military communications platform.

The Ariane 5 ECA launcher was delivered to Arianespace at their Spaceport in French Guiana in October. The spacecraft had to undergo payload integration and final checkout before its launch on 9 November. The launcher carried the United Kingdom's Skynet 5B military communications satellite and Brazil's Star One C1 telecommunications platform. This was Arianespace's fifth Ariane 5 mission this year, following flights in March, May, August and October that delivered eight telecommunications satellites into geostationary orbit. Arianespace plans to launch one more Ariane 5 mission before the end of 2007.

Arianespace also announced in September 2007, that it had won a new deal with Astrium to launch four satellites for a key European space programme, the ELISA (Electronic Intelligence by Satellite) demonstrator. ELISA satellites will use radar

transmitters to map the entire globe, with precise feature definition. They are a first step towards the future ROEM(Renseignement d'Origine ElectroMagnetique) electromagnetic reconnaissance program.

Astrium is lead manager for the programme, working with co-contractor Thales for the French Ministry of Defense procurement agency, DGA. Astrium is prime contractor for the demonstration program, which comprises four satellites, each weighing about 135 kg. The satellites are built on a Myriade platform and designed by the French space agency CNES (Centre National d'Études Spatiales).

Eutelsat

In August Eutelsat signed a capacity deal with MultiChoice Africa for four Ku-band transponders on the Sesat 1 satellite. MultiChoice, one of the leading pay-TV operators in Africa will use the additional capacity to expand its pay-TV and Internet services in sub-Saharan Africa. MultiChoice has nearly 450,000 subscribers throughout 48 countries in sub-Saharan Africa.

The new deal will enable MultiChoice to extend the range of digital channels it markets to subscribers in Central and Eastern Africa as well as its offer of residential and corporate Internet access. MultiChoice now leases a total of 13 transponders on Eutelsat's W4 and Sesat 1 satellites, which are co-located at 36° East.

Eutelsat Communications was selected by Turner Broadcasting System Inc. (TBS) to supply capacity and services to deliver three entertainment channels to cable networks in Austria, Germany, Luxembourg and Switzerland, Eutelsat announced earlier in the year. Eutelsat will provide a broadcasting package to include multiplexing, encryption and uplinking as well as transmission to cable markets in continental Europe.

Broadcasting with English and German soundtracks, the three TBS channels - Boomerang, Cartoon Network and Turner Classic Movies - will benefit from access to more than 170 regional cable network partners offering subscribers the KabelKiosk channel product commercialized by Eutelsat's German subsidiary.

Eutelsat's broadband affiliate Skylogic has teamed with ViaSat to provide in-flight communications to business jets flying over Europe. The D-Star aero service is used by Arinc, which provides European and Mediterranean Basin communications to aircraft through Ku-band capacity on Eutelsat's Atlantic Bird 2. The service supplier provides business aviation passengers with e-mail and Internet access, voice over IP (VoIP), fax over IP (FoIP), and corporate intranets.

Thales Alenia Space has signed a contract to provide Spanish telecommunications satellite service provider Hispasat with an Interactive Multimedia Communication Amerhis-2 Repeater. The on-board processor will extend the current capacity and allow direct terminal-to-terminal mesh connectivity between user terminals to support voice and data services such as Voice Over IP or videoconferencing. Thales Alenia Space

España will design, integrate and test the processor and associated ground control. The processor is scheduled to begin commercial services in late 2009 on board the Amazonas-2 satellite built by EADS Astrium.

(e) Germany

The German Aerospace Center (DLR) awarded a contract to EADS Astrium to develop concepts for a new upper stage of Europe's Vega rocket, EADS Astrium announced in July. Vega, a small launch vehicle being developed by the Italian Space Agency under contract to the European Space Agency, is scheduled for its first launch in 2009. The current upper stage of the rocket, designed to carry payloads weighing from 300 kilograms to 2,000 kilograms, will have a Russian/Ukrainian propulsion system.

Germany has not yet participated in the Vega program, but the project could lead to its developing and building the upper stages of every future European launcher. The DLR will take advantage of its extensive expertise built up on Ariane, as it progresses with the Vega study, and could help establish Germany's reputation as the specialist for building the upper stages of launchers throughout Europe. The 18-month contract is valued at 500,000 euros (US \$692,000).

(f) Ireland

A significant development in Irish law is the expected incorporation of the Comprehensive Nuclear-Test-Ban Treaty adopted by the General Assembly of the United Nations on 10 September 1996 into national law. The Bill on the Comprehensive Nuclear-Test-Ban Treaty is currently at the second stage of reading and has yet to be passed by the Oireachtas and signed into law. More information is available at <http://www.oireachtas.ie/viewdoc.asp?fn=/documents/bills28/bills/2006/4606/document1.htm>.

(g) Italy

Network Teleport Italia signed a capacity deal with the Russian satellite operator Gascom. This is Gascom's first deal with an Italian company. Network Teleport Italia will lease capacity on the Yamal-202 satellite at 49° East that will be used to provide services, such as data and Internet transmission, satellite TV, radio and IP content distribution. Network Teleport Italia stated that Gascom has the competence and the infrastructure to act as a key player in the global satellite communications environment, and this first contract with such a strategic partner could mark the beginning of a solid and long-term collaboration.

Telespazio, the Italian satellite operator, opened its SpaceOPS academy in October. The academy aims to develop students' technical and professional skills in the areas of satellite management, integration of satellite capabilities, Earth observation services, satellite navigation, integrated connectivity and value-added services. The Space OPS Academy aims to become a center of excellence that will promote networking

between companies, universities, research bodies and government agencies. The academy will begin with an international workshop entitled “Novel Spaceways for Scientific and Exploration Missions,” held at the Fucino Space Center and at the Scuola Superiore Reiss Romoli in L’Aquila.

Telespazio announced in October that it has acquired 85 percent of Fileas, a satellite broadcasting company, from Agence France Presse. This acquisition extends Telespazio’s range of satellite data broadcasting services and intensifies its efforts towards developing other service activities. It provides a unique opportunity to support the development of its services as well as to expand its presence in France. Agence France Presse holds the remaining 15 percent of the company.

Tuscany’s governor, Claudio Martini has requested a RAI International satellite channel to promote Italian tourism worldwide, a request that has the support of the Italian Ministry of Culture. The proposal was presented at the international convention on tourism in Siena. The proposal calls for setting up a workshop with government, regions and RAI to set up a specific, high-quality satellite channel for tourism in Italy.

(h) Luxembourg

SES

SES Astra’s latest contract for a new satellite, including the design and construction of its Astra-3B spacecraft was awarded to Astrium. Astra 3B will be a Ku- and Ka-band satellite designed to distribute both direct-to-home (DTH) broadcast services and two-way broadband services across Europe. Astra 3B will have 52 transponders, 32 of them creating new capacity and the other 20 to replace existing in-orbit capacity. Overall it will strengthen 23.5 degrees East as the third orbital hotspot for European DTH services. Astra 3B is expected to be launched in early 2009.

A joint venture created by SES Global and Eutelsat, targeting the mobile TV market, was approved by the European Commission (EC) in July. The two competitors announced in October they were teaming up to jointly invest in what they called “the first European satellite infrastructure for broadcasting video, radio and data to mobile devices and vehicle receivers.” The EC ruled that the joint venture was good news for European customers as they would continue to have a sufficient choice of alternative infrastructures based on a variety of technical transmission standards for broadcasting content to mobile devices, such as mobile telephones. Upon regulatory approval, the joint venture will start to commercialize the payload and approach potential customers.

The first contracts were to be signed in 2007, and the satellite should be in orbit no later than early 2009, when the revenues are expected to begin to flow in. Although mobile TV is seen as a strong area for future growth, the role of satellites in the market remains unclear. A number of different standards already exist, including digital multimedia broadcasting (DMB), digital video broadcasting–handheld (DVB-H) and Digital Audio Broadcasting–Internet Protocol (DAB-IP).

(i) The Netherlands

The Dutch Government issued a new national space law, the Space Activities Act, which includes Rules Concerning Space Activities and the Establishment of a Registry of Space Objects. In summary, the Space Activities Act contains 3 important points: an authorization and licensing regime, applicable to both physical and legal persons of Dutch nationality; a national register of space objects, and a mechanism whereby the Dutch Government will accept responsibility and liability for damages caused by Dutch space objects registered in the Netherlands.

The law serves to regulate space activities that fall under Dutch jurisdiction and the establishment and management of a registry for space objects. The most important provisions of the law concern the establishment of a mandatory licensing system for the performance of space activities (e.g. launches or navigational and operational activities) and the inclusion of a redress provision in the event of State liability. The law does not set out to lay down rules for activities that can be undertaken with the aid of space technology (e.g. telecommunications, earth observation or geo informatics). Products and services of this kind are principally governed by the statutory regulations in the field of telecommunications and broadcasting.

The Netherlands ratified the United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies in 1983 and considers it is necessary to draw up statutory regulations with regard to national activities of non-governmental entities. Private activities of this kind have been conducted from within the Netherlands on a limited scale since 1998, notably operational management of commercial communications satellites (New Skies). In practice, this law will relate only to a limited number of activities and a single private-sector entity. This is a new area of legislation for the Netherlands.

SES New Skies, based in the Netherlands, signed a five-year deal in July with one of Africa's largest VSAT companies for capacity on its NSS-7 satellite. Afsat contracted additional capacity for its iWay broadband via satellite services, which it will use to target the sub-Saharan customers, notably in the western and southern parts of Africa. NSS-7 is a hybrid Ku- and C-Band spacecraft located at 338° East over the Atlantic Ocean, and provides coverage of Europe, Africa, the Middle East, and the Americas.

SES New Skies suffered a major loss in January, when its satellite, NSS-8, was destroyed during a catastrophic failure of a Zenit rocket used by Sea Launch, to place it in orbit. The satellite carried 92 C- and Ku-Band transponders, was built by Boeing. As a result of this failure, and of many delays in fulfilling the NSS-Boeing contract, SES terminated its contract with Boeing, and will be seeking legal remedies.

SES New Skies selected the Orbital Sciences Corp., a USA company, to design, build and deliver the NSS-9 commercial communications satellite, to be located at 183 degrees East longitude. The satellite will be capable of deployment to other locations in the SES fleet. The NSS-9 satellite order is the 18th Orbital geosynchronous commercial

communications satellite ordered by customers in the North American, European and Asia/Pacific markets.

(j) Norway

Telenor Satellite Services in 2007 expanded a multi-year contract with Intelsat to include transmission services on three different spacecraft in C- and Ku-band. This contract is intended for its Sealink maritime high-speed data communications, using the Intelsat 903 and Intelsat 704 satellites for C-band capacity connectivity in the Atlantic and Indian oceans, respectively, and Ku-band capacity on the Intelsat 907 satellite for distribution above the North Sea and Atlantic Ocean.

Sealink utilizes Intelsat's flexible geostationary satellite constellation in conjunction with Telenor Satellite Services' gateways located around the world to provide always-on maritime VSAT services to the shipping and oil-and-gas industries. With Intelsat's C- and Ku-band transmissions, Sealink can offer business and entertainment communications including crew and passenger telephony; radio contact; Internet access; video conferencing; large-volume data communications; and TV reception.

Telenor Satellite Services and Verso Technologies were selected in March 2007 by NASA to provide digital voice and data satellite communications equipment and service to all of NASA's Trans-Atlantic landing sites. The sites are used as emergency landing locations for the Space Shuttle during launch, and the companies provide mission-critical voice communications between all ground stations during the launch process.

Telenor will supply Global Area Network satellite communications equipment for the Kennedy Space Center in Florida and all the remote sites, as well as installation assistance, system configuration and operator training sessions. Verso will provide hardware, software and support services.

Late in 2006, Telenor Satellite Broadcasting issued a request for proposal (RFP) for a new satellite to replace Thor 3. The new satellite, scheduled for launch in 2009, will be positioned at 1° degree West, to cover the Nordic and Central European markets with direct-to-home capacity. Thor 3, launched in 1998, is scheduled for retirement in 2010.

Telenor Satellite Services added Inmarsat's Broadband Global Area Network (BGAN) service as well as other satellite services to its offerings under its U.S. General Services Administration (GSA) Federal Technology Service contract. Under the contract, awarded in 2000, Telenor provides satellite services to all U.S. government agencies and authorized government contractors. The latest modification to the contract adds BGAN service and equipment as well as a portfolio of equipment supporting Iridium, Globalstar and Thuraya satellite services to Telenor's portfolio.

(k) Poland

Poland became the fourth ESA Cooperating State on 4 May, broadening its ability to participate in most ESA programmes. Up to then Poland's projects with ESA had been limited to ESA fellowships for Polish students to study at ESA centers and Polish scientists participating as Principal Investigators in ESA science and Earth observation missions. Prior ESA Cooperating States are the Czech Republic, Hungary, and Romania.

(l) Portugal

Portuguese telecom regulator Anacom reportedly filed 28 objections to what had been the expected regulatory approval of Sonae's hostile \$13 billion takeover bid for Portugal Telecom (PT). This will cause further delays in the bid's formal launch.

(m) Slovenia

On 9 March Slovenia signed an agreement with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), which will pave the way for the country's accession as EUMETSAT's twenty-first Member State. The Slovenian Hydrometeorological Institute is using EUMETSAT data to improve its weather forecasting and monitoring of environmental data.

(n) Spain

Spain's Hisdesat entered into a contract with Belgium's Ministry of Defense to provide X-band communications services using the Xtar-Eur and Spain's Hisdesat satellites. The ministry ordered fixed capacity for an initial period and reserves the right to order additional capacity at an agreed price. The contract will be tacitly renewed annually for an indefinite term, according to Hisdesat. Located at 29 degrees East, Xtar-Eur carries a dozen X-band transponders covering from Eastern Brazil and the Atlantic Ocean, across Europe, Africa and the Middle East to Southeast Asia. Hisdesat has eight X-band transponders and is located at 30 degrees West, providing coverage from the Eastern Pacific Ocean to Iraq.

Hispasat has contracted with Astrium Satellites to build Amazonas-2, a telecommunications satellite that will be placed in orbit in 2009, in a Brazil-registered slot now occupied by Amazonas-1. Amazonas-1 will have to be retired before its expected 15 year life in orbit, due to a fuel leak.

Hispasat's Amazonas satellite, with 32 Ku-Band and 19 C-Band transponders, posted an increase in revenues of nearly 21% in 2006, and is now 88% full. It provides digital-TV broadcasting in Latin America.

(o) The Russian Federation

An expanded tripartite cooperative agreement reached late in March among ESA, the European Commission, and the Russian space agency Roskosmos called for Russia to provide a gamma ray and neutron spectrometer for ESA's 2013 Bepi-Colombo probe to Mercury; invited Russian scientists to offer proposals for ESA's new Cosmic Vision science programme; established a data-exchange mechanism for Earth observations; addressed compatibility issues between Russia's Glonass and Europe's Galileo satellite navigation systems; expanded cooperative space communications applications; and included Russian participation in the European Commission's new Seventh Framework research and development programme for 2007 – 2013.

On 3 October the U.S. and Russia signed an agreement to include Russian science instruments on two NASA missions. Russia's Lunar Exploration Neutron Detector will fly on the Lunar Reconnaissance Orbiter to search the lunar surface and subsurface for water ice in the form of hydrogen, and the Russian-built Dynamic Albedo of Neutrons instrument will study hydrogen interactions with neutrons on Mars' surface as part of NASA's Mars Science Laboratory payload.

Russia and India signed a ten year cooperation agreement from December 2007 through 2017, for the development of a shared space vehicle for Moon exploration, which includes a lunar orbital module and a lunar lander with a mobile scientific laboratory. The agreement envisages specifically the launch of a satellite vehicle composed of a lunar orbital module and a lander with the help of an Indian missile launching vehicle between 2011 and 2012. The Russian space agency Roskosmos announced its first unmanned flight would include a lunar orbiter that will fire 12 penetrators across diverse regions of the Moon to create a seismic network, which will be used to study the Moon's origin. After firing the penetrators, the mother ship will deliver a polar station, equipped with a mass spectrometer and neutron spectrometer, to the surface. The objective of the station is to detect water ice deposits in the polar zones of the Moon. The device, developed by Russian scientists, will first be tested through NASA's Lunar Reconnaissance Orbiter project, to be launched in 2008.

(p) Ukraine

The National Space Agency of Ukraine announced on 18 July that the Ukraine government had approved a national space exploration programme for 2008-2015 with annual budgets of \$61 million, nearly five times the annual space budgets in previous years. The programme includes development of satellite constellations for Earth observations and telecommunications.

The Government of Ukraine, the National Space Agency of Ukraine and the Ukrainian International Center for Space Law co-sponsored the United Nations/Ukraine Workshop on Space Law, on the theme of "Status, application and progressive development of international and national space law." The Workshop was held in Kiev from 6 to 9 November 2006. The United Nations Office for Outer Space Affairs

(UNOOSA) co-organized the workshop, which was attended by experts from 21 countries.

The Ukraine/United Nations Workshop on Space Law, which is one of a series organized by UNOOSA, provided an overview of the United Nations treaties and principles on outer space, addressed the development of national space laws and policies and considered ways and means of enhancing the availability and development of university-level studies and programmes in space law, particularly in Central and Eastern Europe, and in Central Asia and the Caucasus. The Workshop made a positive contribution to the dissemination and development of international and national space law and to the promotion of the universality of the five United Nations treaties on outer space.

(r) United Kingdom

The United Kingdom's House of Commons Science and Technology Committee issued a new Space Policy report on 15 July to guide UK space activities through 2010. The new policy retains the current user-driven focus of the British space programme and does not call for creation of a formal UK space agency or recommend any major increase in space funding. It does, however, call for a change in the current space-programme management, which involves nine different ministries and is coordinated by the British National Space Council (BNSC).

Suggested changes include development by the BNSC of a 30-year space roadmap, a higher profile for the BNSC, and stronger BNSC oversight of space programmes. Specific recommendations are to increase BNSC staff and to give the BNSC its own budget, along with lead responsibility for managing space programmes, with the user ministries restricted to defining requirements. The report calls for closer interaction between Britain's civil and military space programmes, and for BNSC to take over responsibility for the Galileo satellite navigation project from the Transport Department and for the Global Monitoring for Environment and Security (GMES) project from the Environment, Food, and Rural Affairs Department, along with increased British funding for GMES. The Committee also recommended a stronger British role in ESA and a push to establish an ESA facility in the UK.

BSkyB, a satellite pay-TV operator in the United Kingdom, has announced that it will take a stake of nearly 18 percent in commercial broadcaster ITV. The total cost of the acquisition is 940 million British pounds (US \$1.78 billion). BSkyB said the acquisition took place without the prior knowledge of the ITV board of directors, but the operator communicated to ITV's board its intention to be a supportive shareholder. BSkyB said it had no intention of acquiring shares that would result in BSkyB's stake exceeding 19.9 percent, or of making an offer for the whole of ITV's remaining share capital. The acquisition comes less than two weeks after its rival, cable operator Ntl, announced it was in talks with ITV regarding a possible link-up.

Inmarsat

Inmarsat launched its first commercially available handheld satellite phone on July 16. The IsatPhone is a dual-mode satellite and GSM phone, targeting business and personal users who travel or work in areas where local telephone networks are unreliable or nonexistent. The handsets are expected to retail at about \$500, with voice call charges expected to cost less than \$1 per minute. Inmarsat is targeting a 10 percent share of the satellite phone market by 2010.

Inmarsat has commercially launched SwiftBroadband, its high-speed data service for aeronautical use. SwiftBroadband is capable of supporting broadband IP data at speeds up to 432kbps. The service, which became operational on October 22, is available through distribution partners MVS, OnAir, Stratos and Vizada, and their extensive reseller networks. According to Inmarsat, the majority of new long-haul aircraft currently being built by Boeing and Airbus, such as the Boeing 777 and Airbus A380, are fitted with antennas capable of accessing SwiftBroadband.

Inmarsat awarded Lockheed Martin a contract to develop enabling technology for Inmarsat's mobile satellite network. Under the \$36.5 million contract, Lockheed Martin will deliver and install three network control center/gateways that will provide connectivity to public terrestrial networks.

Inmarsat also plans to implement a global network in 2008 that will expand its market reach into the commercial handheld mobile satellite service market. The network will rely on existing Inmarsat I-4 satellites and dual-mode global system for mobile communications/satellite handheld terminals.

Surrey Satellite Technology Ltd. (SSTL) was recognized as the winner among the Times Higher Educational Supplement Awards 2006 in the category of "Outstanding Contribution to Innovation & Technology," rewarding its successful spin-out from academic research at the University of Surrey. Sponsored by Toshiba, the prize was awarded to SSTL in a unanimous decision by the judging panel.

SSTL was awarded a development contract from the European Space Agency (ESA) to continue work on a geostationary small satellite platform in January. Under the contract, valued at 2.3 million British pounds (\$4.5 million), Surrey will extend its work on the Geostationary Mini-satellite Platform. SSTL began work on this programme under the British National Space Center's Micro-Satellite Application in Collaboration (MOSAIC) programme. Under MOSAIC, Surrey developed ESA's Giove-A satellite, the first test satellite for the Galileo program, which was placed into orbit in December 2005.

In the fourth quarter 2008, SSTL plans to launch two new Disaster Monitoring Constellation (DMC) satellites. The satellites, Deimos-1, built for Deimos SL in Spain, and SSTL's UK-DMC2, will be launched onboard a Dnepr rocket from the Kosmotras site in southern Ural. Both satellites will carry a version of the DMC wide area imaging system, which provides 600 km (372.8 miles) wide views of the Earth in three spectral

bands at a ground resolution of 22 meters (72 feet). The new spacecraft also have more than ten times the capacity for information provision. These enhancements reflect SSTL's evolutionary approach to development that provides state-of-the-art performance with minimal risk. The improved resolution and capacity enable the system to better meet European Global Monitoring for Environment and Security (GMES) programme needs, particularly in the areas of forestry and fire.

C. Africa and the Middle East

(a) Israel

Israel has embarked on a major expansion of its satellite capabilities, to be used primarily for defense purposes. Both the satellites and launch vehicles are being developed and produced by the State-owned Israel Aerospace Industries, Ltd. (IAI). Israel plans on launching at least 3 additional spacecraft by 2011.

Minority stockholders in Imagesat International (ISI, Israel) filed suit in New York on 2 July against the major investors and the firm's management for allegedly blocking bids by Venezuela to purchase high-resolution commercial satellite imagery in order to satisfy their own interests in potential Venezuelan commercial opportunities. Targets of the lawsuit included ISI management, the State-owned Israel Aerospace Industries, Ltd (IAI), and Elbit Systems Ltd. The suit claimed \$210 million in direct damages and up to \$6 billion in corollary losses, including a potential \$1.6-billion agreement signed in April between IAI and Northrop Grumman for eight radar satellites.

(b) Lebanon

The government of Lebanon is making plans to sell off two cellular carriers, hoping to rake in as much as US \$7 billion for the licenses.

(c) Niger

Niger's benefit from satellite communications has been on the increase. The country's Télécoms Sans Frontières (TSF) has been active in responding to disasters in various regions of the world, in cooperation with several United Nations agencies and with non-governmental organizations. A new satellite system is the basis of an improved information network designed to enable Niger to better communicate prior to, and in times of disasters.

(d) Nigeria

In 2006, Nigeria's National Space Research and Development Agency signed a contract with Surrey Satellite Technology Ltd. for a small Earth observation satellite. Nigeriasat-2 will be based on a new generation of small satellite technology and will become part of the Disaster Monitoring Constellation (DMC). Nigeria already operates Nigeriasat-1 as part of the DMC, a constellation of small satellites that provide disaster monitoring around the globe as well as imaging for government and commercial use.

Nigeria's long term plans include the use of space for the benefit of Nigeria and Africa, since space-based systems provide a cost-effective means of addressing many of the issues facing African nations, such as mapping, water resources management, agricultural land use monitoring, population estimation, health hazard monitoring and disaster mitigation and management.

(e) South Africa

In September 2007, the Independent Communications Authority of South Africa (ICASA) awarded a new set of individual licenses for commercial satellite and cable subscription broadcasting services. ICASA had received up to 18 applications by the end of August from a variety of parties looking to gain more access to the broadcast market in South Africa. At the end of process, ICASA decided to award broadcast licenses to MultiChoice Africa, Telkom Media (a Telkom South Africa company), e-Sat, and On Digital Media and Walking on Water.

Thuraya, the Middle-East-based MSS operator, has announced deals with four satellite application developers, which it hopes will lead to innovative new products and services. Thuraya signed Memorandums of Understanding with SpaceCom, European Antennas, Sattrans and Teknobil. SpaceCom and European Antenna will create specialized high-power marine antennas for ThurayaDSL and ThurayaFDU services. Sattrans will produce the vehicle docking adapter accessory for the second-generation handheld phones, whereas Teknobil will craft a new solution for fleet management and tracking based on the Thuraya Module.

These new partnerships for applications and accessories development are part of Thuraya's consistent strategy to expand its services and products portfolio, and enhance its positioning in all key market segments of satellite telecom, including maritime, broadband and fleet management.

D. Asia and the Pacific

Measat Satellite Systems, the Asian satellite operator, signed a deal with StarHub Cable Vision (StarHub) for the delivery of the Golf Channel to Singapore. StarHub's Golf Channel is a 24-hour channel featuring tournaments played around the world.

With 70 % of the content made up of live coverage of leading golf events, the channel features events such as the U.S. Professional Golfers' Association (PGA) Tour, European PGA Tour, Ladies Professional Golf Association Tour, Champions Tour and Nationwide Tour.

Satguard Asia announced the launch of its latest GPS-based vehicle security and tracking devices designed to bring the technology within the reach of the majority of vehicle owners. Based on the latest GPS, global information system (GIS), global system for mobile communications (GSM) and general packet radio service (GPRS) technologies, the devices can locate and track any moving asset in real time with an

accuracy of less than a meter. The products are specially targeted for Asian markets including India.

(a) Australia

On 3 October the Australian Defence Ministry announced that Australia will invest \$707 million to cover the construction and launch of a sixth satellite in the U.S. Wideband Global Satcom (WGS) communications system, in exchange for access to the full constellation. The Australian investment will also cover the satellite's associated ground infrastructure. The first WGS satellite, built by Boeing Satellite Systems (USA), was launched from the Cape Canaveral Air Force Station by a United Launch Alliance Atlas-5 rocket on 10 October. Each of the WGS satellites provides as much bandwidth as the entire constellation of the predecessor U.S. Defense Satellite Communications System (DSCS). The first WGS satellite is scheduled to begin operations in early 2008, with full operational capability expected in 2013 following the launch of the sixth satellite.

Applied Satellite Technology Australia Pty Ltd. (AST Australia), a reseller of Iridium Satellite services, was awarded a contract to supply the Australian Department of Environment and Conservation West Australian Fire Management Services with a satellite communications system that will provide automatic tracking of 150 fire fighting vehicles using Iridium's short-burst data service (SBD), as well as voice and data communications using fixed and handheld satellite phones. The system will also provide for automated filing of status and after-action reports to headquarters through the satellite SBD link. AST Australia will supply a mix of Iridium 9601 SBD transceivers, Iridium 9505A satellite handsets and Beam Communications RST620 satellite voice/data kits.

The government of the Australian state of New South Wales (NSW) in January issued a call for proposals to build what it says will be the first municipal Wi-Fi mesh to offer free broadband access to anyone in its service area.

Tropos Networks signed in Las Vegas, Nevada its 500th customer that is considered a milestone in the municipal wireless-mesh-growth battle in which Tropos is battling Cisco for the Number One market position. Several other municipalities in various parts of the world are now providing, or seeking to provide wireless mesh to their constituents. Citywide broadband wireless networks and applications are fast emerging as an effective way for local governments to better manage their community while helping to ensure cost savings and spurring economic development.

(b) China

On 28 March China and Russia agreed that a Chinese microsatellite would be carried aboard Russia's Phobos Explorer mission to the Mars moon in 2009. The agreement calls for the Chinese microsatellite to be detached from the Phobos Explorer spacecraft after it begins to orbit Mars, before it proceeds to land on Phobos and collect a sample for return to Earth. The Chinese probe will then study the space environment of

Mars. China and Russia had previously agreed that the Phobos Explorer spacecraft would carry a Chinese sensor.

China Space Mobile Satellite Telecommunications Co. Ltd. (China Spacecom) expects to open an Iridium gateway by the end of 2007. China Spacecom has been an Iridium service provider since December 2005; it will provide technical assistance for commercial activation and ongoing maintenance of the gateway, which will be located in Beijing. There is a rising demand for Iridium's short-burst data links for water resources management, hydrological monitoring, weather data collection, fishing vessel tracking, heavy machinery automation, environmental protection and other industries as well as voice and e-mail communications with ships and aircraft on domestic and international routes, according to China Spacecom.

In June 2007, China University of Political Science and Law (CUPL) established an Institute of Air and Space Law. This Institute has already established a cooperative relationship with the National Center for Remote Sensing at the University of Mississippi School of Law. Among the cooperative projects between the two universities is also the translation of Chinese space regulations into English.

An international conference on air and space law was held in Beijing on 25-26 June 2007. Experts from International Organization of Civil Aviation, Asia-Pacific Association of Civil Aviation, China Ministry of Foreign Affairs, China Bureau of Civil Aviation, European Delegation to China, Embassy of USA, China University of Political Science and Law, Northwest University of Political Science and Law, Haerbin University of Technology, City University of Hong Kong, University of Mississippi of USA and Cologne University of Germany participated in the conference. Issues of aviation policy in Asia and China, open sky market, teaching air and space law, space law and policy, commercialization of outer space activities were among the issues discussed.

(c) India

India hosted the 58th International Astronautical Congress, and the 50th Colloquium of the IISL on Space Law, in Hyderabad from 24 to 28 September. The Congress focused on the theme of "Touching Humanity: Space for improving Quality of Life." More than 1500 participants attended the events; their proceedings will be published in the near future.

India and Brazil signed an agreement on 4 June whereby the Indian Space Research Organization (ISRO) will provide equipment for a Brazilian Earth station that will enable it to receive and process information from India's remote sensing satellites. The agreement is a cooperative one that identifies the only exchange of funds as payment by Brazil for the data and images received. It also covers exchanges of space scientists by the two nations.

The Indian Space Research Organization (ISRO) and the Russian Federal Space Agency (Roskosmos) signed an agreement on 25 January allowing India full access to

Russia's Glonass satellite navigation system for both civil and military use. India will launch a Glonass-M satellite and will work with Russia on the development of the next-generation Glonass-K spacecraft.

India's cabinet has approved a contract worth up to \$67.5 million, signed between the Indian Space Research Organization (ISRO) and Arianespace to launch the Insat-4G satellite and others.

Tata Sky, the Indian direct-to-home (DTH) operator, has reached 1 million subscribers within its first year of launching its services. As India represents one of the world's largest DTH markets, it anticipates having 8 million subscribers by 2012.

India's adoption of wireless communications is moving faster than anticipated, with predictions spiking to more than 265 million users by 2010 from more than 100 million today.

Two Indian Air Force pilots broke a world record using Iridium technology. The pilots, Wing Commanders Rahul Monga and Anil Kumar, flew 70,497 kilometers (43,804 miles) in 79 days using flight and voice communications via the Iridium network. They beat the previous world record by 19 days. One of the pilots stated that every aircraft should have Iridium technology on board, for several reasons: the communication helped shave days off the existing record through frequent route alterations and in-flight communications. It was also a very good flight safety aid and would have proven invaluable in any survival situation if the need had arisen.

AeroMechanical Services Ltd. provided the tracking and communications equipment, allowing India-based air force control officers to constantly monitor Monga and Kumar's status.

(d) Japan

In May the Japan's parliament passed legislation committing the Japanese Government to fund the initial satellite of an augmented GPS system, the "Quazi Zenith Satellite System" (QZSS). The "Fundamental Law on the Promotion of Geospatial Information Activities will bring together 4 Ministries to fund and develop at least the initial satellite of a 4-satellite program. The satellite, to be launched in 2010, will provide GPS signals and broadcasting from a highly elliptical orbit. Initially, the QZSS was to be funded by both public and private capital, but with the new law in place, the government will be taking on most of the risk related to the first satellite.

A new "Basic Law of Space Activities" was submitted to the Japanese House of Representatives on 20 June. The objective of the new legislation is to review the R&D oriented space development policy, and to establish a balanced space policy with three pillars: comprehensive security; promotion of industry; and research and development. It is intended to override the parliament's resolution of 1969 on "exclusively peaceful purposes", by which Japan's space activities have been limited to "non-military"

activities. The changes in the “peaceful-purposes” interpretation would affect future Earth observation mission planning, especially for defense purposes. Japanese governmental Earth observation satellite data has been commercially available through private data distributors (except for the Information Gathering Satellite).

(e) Malaysia

Shin Satellite signed a key deal to bring its state-of-the-art satellite broadband services to Malaysia. The company has contracted with Time dotCom (Time), one of Malaysia's leading telcos, to deploy IPStar broadband satellite services in Malaysia later this year. Malaysia has a population of around 25 million people.

The deal between Shin and Time will see an IPStar gateway located in Time's existing facilities in Kuala Lumpur. Currently, Time provides broadband solutions to both domestic and international markets. IPStar will enable Time to expand its broadband services to serve the rural and underserved markets in Malaysia targeting the government's Universal Service Provision (USPs), as well as other market segments such as corporate and retail. In addition to providing services to Time, the IPStar service through Time will also be marketed to other service providers in Malaysia as well.

TimedotCom, which is one of the most progressive telephone companies in Malaysia, recently announced plans to offer 10 megabits per second high-speed broadband to residential homes, as the first operator to offer such high speeds in the residential market in Malaysia. The service called Netlynx is being offered in collaboration with Palette Multimedia.

(f) New Zealand

The New Zealand Ministry of Health signed a contract with Iridium Satellite to provide services in times of disasters. The Ministry will rely on Iridium Satellite services to augment land-based telecommunications capabilities and ensure continuity of operations in the event of natural or manmade disasters. New Zealand's 21 District Health Boards have received 9505A Iridium handsets.

(g) Pakistan

The Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), Pakistan's national space agency, has contracted with Telesat (Canada) to assist in the procurement and 2010 launch of the Paksat-1R satellite to replace the existing Paksat-1. Telesat will initiate, evaluate and recommend manufacturer proposals for the satellite while providing technical and commercial advisors during negotiations. The operator will also help oversee the construction of the new satellite, and will monitor the launch and in-orbit testing services.

(h) The Philippines

Smart Communications, a top wireless operator in the Philippines has teamed up with Inmarsat to expand the reach of its satellite phone offering, Smart Link. With over 27 million GSM subscribers (total population of the country is estimated to more than 90 million), Smart plays an important role in the wireless market of the country.

The collaboration with Inmarsat involves a \$5 million investment by Smart to set up a gateway facility and ground infrastructure in Subic, Zambales. It will result in an expanded coverage area for the Smart Link prepaid wireless satellite phone service that will initially include India, the Indian Ocean, the Middle East, Africa, and the Pacific Ocean. The Smart services will be carried on the Inmarsat-4 F1 satellite, which can support both voice call services and data connectivity.

(i) Vietnam

The Vietnam Telecom International Co. (VTI) has set up the Vinasat Satellite Information Centre to manage and operate ground stations for the Vinasat satellite. The first mission of this new center will be to oversee the installation of a pair of satellite operating stations, one in the northern part of the country and an identical station in the southern half of Vietnam. VTI also will train staff to operate Vinasat.

VinaSat-1 is being manufactured by Lockheed Martin Commercial Space Systems and will carry 20 C- and Ku-band transponders for radio, television and telephone transmission services to Vietnam and the Asia-Pacific region.

The launch of Vietnam's first telecommunications satellite will be assisted by Telesat (Canada). The launch is scheduled on Arianespace before the end of March 2008.

Representatives of Telenor Satellite Services and Inmarsat were in Hanoi to give a demonstration of how businesses and government can use satellite communications, in particular on how integrating the newest mobile satellite service from Inmarsat's Broadband Global Area Network (BGAN) into their existing operations may improve the mobility and flexibility of their workforce. The workshop was part of a region-wide Telenor-Inmarsat BGAN "technology road show" for service partners and communications companies throughout the Asia Pacific region.

According to the Ministry of Post and Telematics of Vietnam, in 2005 the country had more than 200,000 broadband users, and by March 2006 had 13.2 million mobile subscribers, showing a rapid growth in telecommunications services. A research firm estimates that Vietnam and other emerging Asian countries (including Bangladesh, Pakistan, Sri Lanka, and others) will grow at 12 percent in 2007, contributing a combined 16.1 percent of the \$15.6 billion IT market estimated among those countries in 2007.

E. The Americas

(a) Argentina

The Inter-American Development Bank (IADB) has financed for the first time a space-related project, i.e. the development of L-Band remote sensing satellites for Argentina. Further information about the project, that was approved in 2006, can be found at <http://www.iadb.org/>.

Impsat, originally an Argentinean company and one of the first VSAT networks in Latin America, and now a wholly owned subsidiary of Global Crossing, has contracted the equivalent of about 2.5 transponders on SES New Skies' NSS-10 satellite, SES New Skies announced in July. Located at 322.5 degrees East, the satellite's C-band beams will help support Impsat's single channel per carrier and VSAT Internet Protocol network in Latin America.

(b) Aruba

Aruba Networks Inc. and iDirect Inc. have completed integration testing of a wireless local area network (WLAN)-to-satellite connection, Aruba announced on October 31. The two companies have certified the interoperability of Aruba's secure mobility solution with iDirect's satellite platform, allowing satellite customers to provide a wide area network interface to Aruba's adaptive wireless LANs. The solution is expected to be used with video surveillance, perimeter security monitoring, disaster recovery, distance learning, logistics management and storage depots. The integration of the wireless component will simplify access to the satellite network, and increase the variety of devices that can be used; these include wireless bar code and RFID scanners, Wi-Fi enabled handsets, PDAs, and Wi-Fi enabled cameras and sensors.

(c) Brazil

Brazil entered into a cooperative agreement with the Indian Space Research Organization (ISRO), for the provision of remote-sensing data and images, to be received and processed at one of Brazil's earth stations. This agreement also opens the door to ISRO's presence in Latin America.

Brazil and China have cooperated for several years in the area of remote sensing/Earth observation. A second Brazil-Chinese Earth observation satellite, CBERS, was launched from China in September 2007.

The Brazilian National Institute for Space Research (INPE) renewed a contract with DMC (Disaster Monitoring Constellation) International Imaging Ltd. for a third year, to acquire high-resolution satellite images of the Amazon rainforest. The programme, which monitors deforestation, has reduced the rate of logging in the rainforest from 27,000 square kilometers per year to 10,000 square kilometers in 2007. The Director General of INPE considers the DMC data as an important affordable

contribution to the assessment of deforestation of the Amazon rainforest. The constellation of 5 satellites is able to rapidly acquire and deliver high quality imagery providing up-to-date information to focus Brazil's monitoring efforts. The DMC small satellites, built by Surrey Satellite Technology Ltd (SSTL), use wide area cameras to capture the high-resolution images. Two new DMC satellites are scheduled to be launched in 2008 and a third in 2009. The new satellites will add considerably to INPE's ability to monitor and combat changes in the rainforest and their consequences for both the local people and the global climate.

Anatel, the Brazilian telecommunications regulatory agency, confirmed operational authority for the full suite of Iridium products and services throughout the country. Omnilink, a maker of vehicle tracking systems based in Sao Paulo, Brazil, will serve as an Iridium value-added reseller, providing data and voice communications services in Brazil, starting with the transportation market. The Brazilian National Land Transport Agency (Agencia Nacional de Transportes Terrestres) estimates potential for the transportation tracking sector includes 1.5 million load vehicles circulating in the country. Omnilink already has more than 20,000 vehicle-tracking units installed in Brazil, including cars, trucks, buses and other means of professional transportation. Omnilink, in alliance with Iridium Satellite LLC, has launched products and offers services throughout Brazil.

Anatel has authorized Spanish carrier Telefonica's acquisition of a 10 percent stake in Italian rival Telecom Italia, imposing light conditions, despite the fact that the \$7 billion deal gives Telefonica indirect equity in 53 percent of Brazil's cellular industry.

A new book on Space Law and Policy was published in Brazil in July, in Portuguese language. Its author, Jose Monserrat Filho is also the Editor of the Brazilian Scientific Journal.

(d) Canada

The Canadian Space Agency announced that it was ready to launch Radarsat-2 in December 2007. The satellite, scheduled to be launched from the Baikonur Cosmodrome in Kazakhstan will provide improved surveillance and monitoring capabilities, and critical data for the active management of natural resources and monitoring of the environment. In the event of a disaster Radarsat-2 will be an indispensable tool to provide rescue and humanitarian aid to those most in need in those areas.

MacDonald Dettwiler and Associates Ltd. (MDA) received two advanced technology contracts from EADS Astrium to provide a pair of data reception and transmission subsystems, MDA announced. One of the advanced communication satellite solutions is for the German Ministry of Defense, while the second is for an advanced broadcasting solution for Eutelsat. The combine value of the awards is about 13.2 million Canadian dollars (US \$11.2 million).

MacDonald, Dettwiler and Associates Ltd. (MDA) has signed a five-year, multi-million dollar contract with Petroleos Mexicanos (Pemex) to continue monitoring natural oil seeps and oil spills in the Gulf of Mexico. The contract allows Pemex to use Radarsat satellite data to establish a maritime monitoring programme to increase its environmental performance in oil spill prevention and response. The company is also interested in gaining a deeper understanding of the behavior of natural oil seeps and oil spills in the Gulf of Mexico.

Norsat International Inc. signed an order for to supply a turnkey satellite newsgathering system to Global TV. Global TV, a division of CanWest Media Works, is a Canadian broadcast network that reaches 96 percent of English-speaking Canada. The turnkey solution includes the supply of a portable satellite terminal, training and maintenance.

Telesat Canada has been acquired by Canada's Public Sector Pension Investment Board (PSP Investments) and US-based Loral Space and Communications. Both Industry Canada and the US Federal Communications Commission have given their regulatory approval to the acquisition. Loral and PSP Investments acquired 100 percent of the stock of Telesat Canada for 3.25 billion Canadian dollars (\$3.4 billion) and assumed 160 million Canadian dollars (\$167.5 million) in Telesat debt. The assets of Telesat Canada and Loral Skynet will be combined under a company dubbed Telesat that will be the fourth largest communications satellite operator in the world.

With this acquisition, Loral has transformed its regional fixed satellite services business into a 64 percent interest in the fourth largest FSS operator in the world, according to Loral Space and Communications. Loral's international satellite services, combined with Telesat's large North American presence, will offer customers a broad array of global satellite based video and data services.

Telesat also has one of the satellite industry's largest backlogs, representing nearly eight times 2006 pro-forma revenue, which will provide resources for meaningful deleveraging and growth initiatives. Telesat's blue-chip customer base includes video and data service providers from around the world, including both of Canada's direct-to-home service providers. While Telesat will remain headquartered in Ottawa, Loral announced that the company will restructure its corporate functions, reducing the number of employees and consolidating critical functions at satellite manufacturing subsidiary Space Systems/Loral.

Telesat Canada awarded a contract for a new satellite to Loral Space & Communications, a subsidiary of Space Systems/Loral (SS/L). SS/L will manufacture the Nimiq 5 satellite, which will be the first among Telesat's satellite fleet to be manufactured by SS/L. The \$300 million Canadian dollar (\$259.2 million) contract came less than three weeks after Loral and BCE Inc., parent company of Telesat, announced they would combine Telesat and Loral Skynet into a single satellite services provider. Telesat's Nimiq 1 and 2 were built by Lockheed Martin, while Nimiq 4 is under construction at EADS Astrium. Nimiq 5 will be based on SS/L's 1300 platform and will carry 32 Ku-

band transponders. The entire payload already is under contract to Bell ExpressVu, Canada's leading direct- to-home service provider. The satellite is scheduled to be completed in 2009.

(e) Colombia

Pursuant to a decree issued in July 2006, Colombia established the “Comisión Colombiana del Espacio” (CCE), the Colombian Commission on Space, which is comprised of representatives from the following sectors: telecommunications, satellite navigation, Earth observation, astronautics, astronomy and aerospace medicine, legal and policy, and the Colombian Infrastructure of Space Data. Many national institutions utilize data from remote-sensing /earth observation satellites, as well as make use of communications satellite capacity. One aim of the new commission is to promote space activities and space sciences nationally. For further information on the Colombian Space Commission, see <http://www.cce.gov.co>.

In April, a satellite built by the University Sergio Arboleda, in Bogota, was launched aboard a Dnepr rocket from Baikonur. The satellite, “Libertad 1”, was one of 14 launched into space on the same flight. The satellite relays information on temperature and other data to any Earth station that can receive its signals. However, the signals are decoded in Colombia, and will serve as the basis for further research at the Sergio Arboleda University and other universities in Colombia.

Gilat Satellite Networks Ltd. will supply a SkyEdge broadband satellite network to Axesat, a satellite service provider in Latin America. Axesat will deploy SkyEdge Pro and SkyEdge IP VSATs to provide Colombian enterprises with private networking services, including interactive data, broadband Internet access, and Voice over Internet Protocol (VOIP) services. The contract increases the number of Gilat VSATs used by Axesat to more than 2,500 nationwide.

(f) Mexico

The Agencia Espacial Mexicana (AEXA), Mexican Space Agency is expected to be approved by the Mexican Chamber of Senators in December 2007. AEXA intends to continue the research of the former Comisión Nacional del Espacio Exterior, CONEE (National Commission for Outer Space), which existed between 1962 and 1977. If the Chamber of Senators agrees, the President of Mexico will take the final decision.

Satmex, which emerged from bankruptcy proceedings in 2006, was aiming to auction off its assets, yet neither of the bids met the initial bidding price of US \$500 million. The Satmex fleet consists of 3 spacecraft in orbit, 2 of which are quite old, and likely to be placed in inclined orbit, thus prolonging their useful life in orbit. After being in storage for quite a while, Satmex 6 was launched in May 2006. The current owners of Satmex were hoping to order a new satellite, Satmex 7, with the auction's proceeds. Satmex also provides distance learning and telemedicine programmes and services within Mexico, and some other services in the region.

(g) United States

Government

The U.S. Department of Defense plans to stop procuring GPS satellites that provide Pentagon with the capability to intentionally degrade the accuracy of civil signals. The United States halted the intentional degradation of GPS satellite signals in May 2000 after announcing it had the capability to degrade the signal only in certain areas when needed, which the Pentagon dubbed Selective Availability. The ability will no longer be present in GPS 3 satellites, the Pentagon said. According to the Pentagon, this decision reflects the United States strong commitment to users of GPS that this free global utility can be counted on to support peaceful civil activities around the world.

Separately, Boeing and the U.S. Air Force have deployed a ground control system to enhance the operation of the GPS constellation. The distributed server-based system, known as the Architecture Evolution Plan, is designed to improve operations, increase efficiency and accommodate future GPS capabilities as they become available.

The U.S. Air Force operates the Global Positioning System (GPS). GPS provides 3-D position data in longitude, latitude and elevation as well as precise time and velocity. The satellites orbit the Earth every 12 hours, emitting continuous navigation signals, which are accurate enough that time can be figured to within one millionth of a second, velocity within a fraction of a mile-per-second and location to within 100 feet.

Late last year, a Boeing Delta II launch vehicle successfully delivered to orbit a replenishment Block 2R satellite for the U.S. Air Force. The Delta II has launched all of the GPS 2R satellites. The launch also marked the second GPS mission aboard a Boeing Delta II in less than two months. GPS 2R-16(M) is the third of the modernized GPS satellites that feature greater accuracy, increased resistance to interference and enhanced performance for military and civilian users.

The U.S. Air Force awarded the Boeing Co. a \$674,116,428 cost-plus-award fee contract providing for Delta 4 launch capability for the Evolved Expendable Launch Vehicle (EELV) rocket programme. The plan includes launch and range operations for Vandenberg Air Force Base, California, and Cape Canaveral Air Force Station, Florida; mission integration, mission unique development and integration; system engineering and program management; subcontractor support; factory support engineering; and special studies. Thus far, more than \$405 million has been obligated; work is expected to be completed in late 2007.

Federal Communications Commission (FCC)

The U.S. Federal Communications Commission (FCC) was accepting comments until 13 August on its rule that would prohibit the merger of Sirius Satellite Radio and XM Satellite Radio. The FCC issued a call for comment in June about whether its 1997

satellite digital audio radio service prohibition against the companies combining should be waived, modified or repealed. The merger of the only two satellite radio companies was objected to by other broadcasters, while seen as a positive move by market analysts (Wall Street). The merger seems to have been completed, and Sirius folded into XM Satellite Radio.

The FCC released its semi-annual report on broadband penetration in the United States with figures for 2006. According to the report, there were 82.5 million “high speed lines” in the United States, with 58.2 million residential users, up 61 percent from a year earlier. The FCC counts 200 Kb/s as broadband, and if one house in an entire zip code gets DSL or cable broadband, the FCC deems that entire area is broadband-enabled. As a result, the FCC’s figures imply that broadband is available to at least one house in 99 percent of the zip codes in the United States. The industry however estimates that broadband was available to only 79 percent of the households to whom incumbent LECs could provide local telephone service as of 31 December 2006. High-speed cable modem service, which the FCC does not, was available to 96 percent of the households to which cable operators could provide TV service. Subject to criticism for its outmoded concepts of surveying broadband, the FCC circulated a proposal among its commissioners to change the reporting methods.

The FCC recently expanded the right of telephony subscribers to port their current phone numbers when switching to a new carrier, adding Voice over Internet Protocol (VoIP) providers to the list of those that must comply. The FCC made it clear that the obligation to provide local number portability (LNP) extends to interconnected VoIP carriers and the telecommunications carriers that obtain numbers for them. This action was, in part, a response to numerous complaints by subscribers about their inability to port numbers to or from interconnected VoIP providers. The FCC also initiated a Notice of Proposed Rulemaking seeking comment on additional VoIP numbering issues. In addition, the FCC clarified in its order that telephone companies cannot obstruct or delay number porting by demanding excess information from the customer's new provider. In its Notice, the FCC also tentatively concluded that it should require the industry to complete simple ports in 48 hours.

The FCC's Order also ensures that customers of small wireline carriers can port their telephone numbers to wireless carriers. The decision responds to a stay of the FCC’s *Intermodal Number Portability Order* by the D.C. Circuit, which required the FCC to analyze the impact of its requirements on small entities under the Regulatory Flexibility Act.

One commissioner in the FCC commented that, based on the success of local number portability, the FCC should seek out additional ways to break down barriers that impede consumers from taking advantage of competition, such as wireless and broadband early termination fees and the locking of phone features. Such initiatives would improve the situation for consumers and competition. However, doubts were raised by some other representative of the FCC whether this would help resolve a fundamental issue, i.e. intercarrier compensation, which has been the subject of debate for the last four years.

NASA

On 21 March NASA and ESA signed an umbrella agreement aimed at reducing heavy regulation involved in interchanging telemetry, tracking, spacecraft trajectory, and other mission support operations. The Network and Operations Cross-Support agreement eliminates the need for Letters of Agreement before providing support for missions that are not already covered by specific agreements. The new pact was implemented with NASA's 4-August launch of the Phoenix mission to Mars, and the Agency's Dawn mission to asteroids in September, both of which employ ESA's 15-m antennas at the Guiana Space Center and Perth, Australia.

NASA signed Space Act agreements with PlanetSpace Inc. and Transformational Space Corp. to support the companies' development of commercial systems that could transport humans and cargo to low-Earth orbit. Under the agreements, NASA will not provide any funding for the work under the Agency's Commercial Crew and Cargo Program, but will share information on requirements for space station crew and cargo transportation launch vehicles, spacecraft and NASA human rating criteria.

National Telecommunications and Information Administration (NTIA)

The National Telecommunications and Information Administration (NTIA), part of the Department of Commerce, and the Federal Communications Commission are establishing a committee to assess and submit a report to Congress on the communications capabilities and needs of emergency medical and public health care facilities, and the options to accommodate growth of communications services and to improve integration of communications systems used by these facilities. The Committee consists of 11 representatives, appointed for a term of six months.

The U.S. General Services Administration (GSA), under its Federal Technology Service contract with Telenor Satellite Services has added Inmarsat's Broadband Global Area Network (BGAN) service as well as other satellite services to its offerings. Under the contract, awarded in 2000, Telenor provides satellite services to all U.S. government agencies and authorized government contractors. The latest modification to the award adds BGAN service and equipment as well as a portfolio of equipment supporting Iridium, Globalstar and Thuraya satellite services to Telenor's portfolio.

Non-Governmental Organizations

The American Red Cross selected Global Relief Technologies LLC (GRT) to equip disaster relief professionals with equipment to augment disaster response communications. GRT will provide a Red Cross Quick Assessment Team with its Rapid Data Management System (RDMS)-powered equipment and services. The contract initially covers deployment during the current hurricane season, which ends on 30 November.

The capabilities of RDMS will assist the American Red Cross in achieving its vitally important mission. RDMS is a field user-friendly product designed to perform effectively in extreme and disconnected environments on a global basis. This product allows field workers to provide reliable and accurate situational awareness to their headquarters and provides headquarters with unprecedented flexibility to manage data collection and relief efforts in the field. GRT hopes to make a big difference to the American Red Cross as it continues to make a big difference to the nation and the world.

A recent study, released by Forecast International states that the global communications satellite market is expected to generate deliveries of nearly 300 satellites in the next 10 years, but the U.S. share of those orders could fall. While demand for satellite services is growing, an increase in satellite size, power and service life actually has decreased the demand for satellites, according to the study "Commercial Communications Satellites, 2007-2016."

About 218 satellites for geostationary and medium Earth orbit valued at a total of \$26 billion will be delivered. Low Earth orbiting market will see production of 69 spacecraft worth about \$927 million, mainly generated by fleet replacement plans for Orbcomm and Globalstar.

The U.S. share of the manufacturing market has eroded by about 30 percent throughout the last three years, according to Forecast International. In 2004, 75 percent of all the commercial communications satellites ordered around the globe were awarded to three U.S. companies, while just three orders went to non-U.S. manufacturers. In 2005, the U.S. share slipped to 63 percent, and in 2006 the number fell to 40 percent.

Northern Sky Research, a research firm, asserted in its report, "WiMax - Opportunity or Threat for Satellite Communications," that the widespread use of C-band will clearly be a challenge between extended and standard C-band users and emerging WiMax services using the 3.5 gigahertz spectrum. While many in the satellite industry fear the potential loss of some C-band spectrum to terrestrial providers, by working satellite and WiMax technologies together, a variety of distinct opportunities, highly dependent on the frequency band in use and regional competitive considerations can be produced, according to the report. The big issue is not bandwidth, but interference, due to the widespread use of C-band. This challenge was one of the agenda items at the World Radio Conference (WRC-07, held in Geneva, Switzerland from 22 October to 16 November 2007).

Research and Markets announced the release of its "State of the Space Industry 2005" report in November 2006. Designed to provide industry, government, and financiers with an independent assessment of the trends and issues affecting the industry, "State of the Space Industry 2005" offers quantitative and qualitative analysis and commentary on developments in the space industry by providing a top-level overview of the industry overall, sector-by-sector reviews and consensus revenue estimates and forecasts

The report states that whether one's focus is on military, civil government, or commercial activities, there are numerous opportunities in the space/satellite industry, but warns that the U.S. International Traffic in Arms Regulations (ITAR) represents “the industry's most serious issue,” adding “what initially was a nuisance to businesses has evolved into a serious problem for U.S. industry.”

The report also cites several important issues and items of note, stating that more than \$18 billion is spent annually on the development of space systems. U.S. defense spending on space has grown from approximately \$15 billion in 2000 to more than \$22 billion today, and is forecast to reach \$28 billion by 2010. Also, India and China have joined the U.S., Europe, Russia, and Japan as having fully independent capabilities. In addition, satellite-to-consumer television has become a \$40 billion market worldwide, while market growth for satellite radio and GPS positioning and tracking is being measured in the billions. The report also states that the development of a substantial space tourism market would have a positive yet disruptive influence on the industry, though is unlikely to happen before 2010.

Private Sector

Avaya is a private telephone company, a VoIP vendor that specializes in business communications and call center technology. Avaya delivers Intelligent Communications solutions that help companies of all sizes transform their businesses to achieve marketplace advantage. Its biggest competitor is Cisco. Avaya was publicly traded until it was acquired by Silver Lake Partners and the Texas Pacific Group for an \$8.2 billion buyout.

Avaya and Avaya Financial Services (AFS) announced in October, that they are offering a 0-percent finance plan they say will enable customers of Avaya Business Partners to lease equipment and pay for services for two years with no interest and no upfront charges. However, only European customers need apply. The 0-percent finance offered by AFS is available in Belgium, France, Germany, Italy, Spain, Switzerland the Netherlands and in the U.K. According to Avaya, this new approach to financing is designed to help customers get the technology that their business needs and not what the budget dictates. At the end of the two-year term, the customer can continue to use the equipment, buy it for a nominal amount, return it or upgrade it.

The offer is targeting customers who decide to lease a new Avaya Small Medium Business (SMB) solution that includes the Avaya IP Office 500 with VoiceMail Pro messaging for business use. Avaya IP Office 500 is a modular system suitable for companies scaling from fewer than 30 staffers to as many as 272 users. The built-in Standard Edition software is designed for very small businesses and offers multi-site networking. If a company upgrades to the Professional edition, they can take advantage of enhanced unified communications and customer-service intelligence.

What is particularly attractive about this offer is that it is not a residual value-based product, but is a true 0-percent finance promotion, whereby the customer can

purchase the equipment at the end of the lease term for a nominal amount, if they so wish. This kind of financing plan should and could be emulated in developing countries, which could greatly benefit from 0% financing for the first 2 years, and buyback at the end of the lease period.

DirecTV Inc. announced it was now offering local HD programming to customers in the Green Bay, Wisc., Greensboro, N.C., Grand Rapids, Mich. and Providence, R.I., markets. The additions mean that DirecTV offers local HD broadcast channels in 49 cities, representing more than 65 percent of U.S. TV households.

DirecTV plans to launch an additional eight HD local markets throughout the remainder of the year, part of its nationwide expansion of HD programming to culminate in 2007, with DirecTV's ability to deliver more than 1,500 local HD channels and more than 150 national HD channels.

Globalstar

Four Globalstar, Inc. satellites were launched on 21 October from the Baikonur Cosmodrome in Kazakhstan, using the Soyuz-Fregat version of the Soyuz launch vehicle (see Chapter (2) Mobile Communications). The four satellites, along with four satellites launched in May, will augment the 40-satellite constellation, providing satellite voice and data service through the launch of the second-generation constellation, which begins in 2009.

Globalstar has invested approximately \$120 million to launch these satellites and considers them as representatives of the beginning of the next-generation constellation, since they will last long into and seamlessly operate with, Globalstar's second-generation constellation. The company will continue to use the reliable Soyuz launch vehicle when it resumes launches of its second-generation spacecraft in 2009.

Globalstar-2 satellite payload will be developed and produced by Anaren, Inc, who is also integrating the beam-forming assemblies. The contract, awarded by prime contractor Alcatel Alenia Space, is valued at more than US \$8 million and covers design services and manufacture of up to 48 beam-forming networks. Work is to begin immediately, with production deliveries starting in May 2008. The European consortium of Alcatel Alenia Space received an \$880.9 million contract in December 2006 to build Globalstar's second-generation constellation.

ICO Global Communications (ICO)

ICO Global Communications Ltd. (ICO) announced in February that it had been granted milestone extensions for the construction and launch of its ICO G1 satellite. The U.S. Federal Communications Commission (FCC) granted the company's request to extend the dates outlined in ICO's authorization for the construction and launch of the satellite, which include: Complete reference performance test (30 April); complete thermal vacuum test (15 June); satellite launch (30 November); and certification of the

mobile satellite services system as in operation (31 December). ICO has expended over \$310 million so far on its satellite and launch programs alone for ICO G, and millions more on a terrestrial, device and radio layer activities. ICO continues its work to bring next-generation satellite services to the U.S. as soon as possible. ICO reportedly filed the request for extensions due to technical issues beyond its control after the satellite's manufacturer, Space Systems/Loral Inc., found technical problems with three of the satellite's subsystems.

The UK's regulator, Ofcom, and the European Commission have been more reluctant to grant ICO extensions and licenses. In May Ofcom required ICO to show more progress on its constellation in order to retain its license; thus ICO signed a launch agreement with International Launch Services (ILS). ICO's headquarters are in Virginia, it is registered in the British Cayman Islands, and under the jurisdiction of Ofcom, the UK's regulator.

Intelsat, Ltd.

Intelsat, the former intergovernmental organization, was privatized in 2001 pursuant to the U.S. "Orbit Act", and acquired by Zeus Holdings. Intelsat acquired its former rival PANAMSAT in 2006, and is now being acquired by another consortium of investors, Serafina Holdings Limited. Once the deal is consummated, Intelsat's subsidiary, Intelsat Bermuda, will transfer all of its assets and liabilities to a new subsidiary, to be named Intelsat Jackson Holdings, Ltd., and the debt issued in connection with the acquisition of Intelsat will be assigned to Intelsat Bermuda. The aggregate value of the transaction, including the assumption by Serafina of approximately \$11.4 billion of debt, is \$16.4 billion.

In the meantime, ITSO, the remaining intergovernmental part of Intelsat, continues to maintain that Intelsat should be contractually bound under a Public Service Agreement (PSA) with the ITSO to ensure continued global connectivity, particularly to countries dependent on Intelsat's satellite services. Abiding by the PSA was one of the conditions for accepting the privatization of Intelsat.

Iridium

In September Iridium Satellite signed contracts with four North American air ambulance and medical transportation fleets to provide mobile satellite communications services. Air Methods Corp., which provides air medical transport services for hospitals and communities in 42 states, and the California Shock/Trauma Air Rescue fleet are installing Sky Connect tracker systems for automatic flight following and cockpit voice and data communications.

Orange, an Ontario-based aero-medical transport services provider, is installing Latitude Technologies' Skynode S200 terminals on its fleet of Sikorsky S76 helicopters and King Air 200 fixed-wing aircraft. Reach Air Medical Services has chosen SkyTrac

Systems to provide Iridium-based automatic flight following and satellite communication solutions.

Iridium Satellite announced in October that it had formed a partnership with Tesacom to help grow the South American market. Tesacom, a South American channel partner for Iridium service provider Stratos Global Corp., provides integrated communication solutions to South American markets such as Argentina, Brazil, Chile, Paraguay, Peru and Uruguay. Tesacom offers satellite voice and data transmission, text messaging, localization and monitoring, mail and file transfer, network integration, software services, professional, consulting and field support services. The alliance with Stratos and Tesacom, both leaders in the telecommunications sector, will provide an important boost in offering Iridium services to the growing South American market. Iridium voice and circuit switched data traffic originating in South America has grown by 25 percent throughout the last year.

Mobile Satellite Ventures

Mobile Satellite Ventures LP (MSV) entered into a three-year strategic distribution deal with Sprint's Emergency Response Team (ERT) to offer continuous wireless connectivity for public safety agencies and end users. Since Hurricane Katrina in September 2005, the USA has become more sensitive to the need for reliable communications between public safety agencies and the general population.

Northrop Grumman Corp.

Northrop Grumman Corp. and Space Exploration Technologies Corp. (SpaceX) filed complaints with the U.S. Federal Trade Commission over pending approval of the United Launch Alliance (ULA). The joint venture, which received preliminary approval in 2006, would combine the government launch vehicle operations of Boeing Co. and Lockheed Martin Corp. SpaceX, which would be a competitor for U.S. government business, calls the ULA a monopoly in violation of U.S. antitrust laws.

Northrop Grumman does not compete in the launch vehicle market, but based its protest on competition in the satellite manufacturing arena: Northrop Grumman claims that, during the formation of the ULA, Northrop Grumman would have to share confidential information with Boeing and Lockheed Martin that may work to the latter companies' advantage in future competition.

Orbital Sciences Corp.

Orbital Sciences Corp. won a \$29.5 million contract to support a nanosatellite program for the U.S. Air Force Research Laboratory's (AFRL) Space Vehicles Directorate. Orbital will support the Autonomous Nanosatellite Guardian for Evaluating Local Space satellite program (ANGELS), which supports the directorate's initiative to develop nanosatellite technologies capable of independently providing localized space situational awareness. The ANGELS programme will develop key technologies and

capabilities for a broad spectrum of defense and civilian space missions, according to Orbital Sciences.

Satellite Radio

XM Satellite Radio Holdings, Inc. ("XM") and Sirius Satellite Radio, Inc. ("Sirius"), pursuant to Section 310(d) of the Communications Act of 1934, submitted a consolidated application for authority to transfer control of FCC radio licenses held by XM, Sirius and their subsidiaries, to a new combined company. XM and Sirius state that the combined company will be formed pursuant to a merger agreement they have entered into, and that the combined company will be owned equally by the former shareholders of XM and Sirius, and will be controlled by a new Board of Directors selected by both XM and Sirius.

Stockholders of Sirius Satellite Radio Inc. and XM Satellite Radio Holdings Inc. approved the proposed merger of the two satellite radio companies, Sirius and XM, with more than 96 percent of Sirius shares and 99.8 percent of XM shares voting for the deal. However, the deal must still be approved by the U.S. Federal Communications Commission (FCC) and the U.S. Department of Justice. Changes in the entertainment market since the licenses were granted should outweigh the FCC rule that forbid the companies from merging.

Scaled Composites

Scaled Composites, the builder of the X-Prize winner, SpaceShip One, was acquired in early July by Northrop Grumman, but was awaiting regulatory approval for the deal to close. Some commenters wonder if Scaled Composites will be able to remain as innovative as before, now that it is part of such a large corporation.

SeaMobile Enterprises

SeaMobile Enterprises had been awarded two contracts to provide global VSAT services to the National Oceanographic and Atmospheric Administration (NOAA), the company announced in October. SeaMobile will provide voice and data access to up to 21 ships in the NOAA fleet. The network enables broadband connectivity between the ships and NOAA headquarters so that environmental scientists can interact in real-time with ships at sea. NOAA will be able to conduct voice calls, large data transfers and video conferencing simultaneously while operating in the northern Alaska, Pacific and Atlantic Ocean regions.

The company also won a contract to integrate, install, operate and provide maintenance for a 3.7-meter VSAT terminal system for a new NOAA ship, Okeano Explorer. The ship is the first U.S. government ship dedicated to exploring unknown parts of the ocean. The VSAT terminal will be able to transmit HDTV and high-speed data from any ocean region in the world.

SES Americom

SES Americom, part of the Luxembourg-based SES company, signed a marketing agreement in March 2007 with NewCom International, to add SES Americom's Redisat to NewCom's communications offerings available across the Southeast United States. NewCom, a Miami-based teleport operator, will offer Redisat's always-on, satellite-delivered emergency broadband connection to communications service providers and businesses serving markets including hospitals, banks, hotels, and utilities companies. The service is delivered via the AMC-6 satellite.

SES Americom's AMC-18 satellite completed in-orbit tests and began operations in early 2007. Built by Lockheed Martin and placed into orbit in December by an Arianespace Ariane 5 rocket, AMC-18 will provide broadcast coverage throughout North America, the Caribbean and Mexico from its orbital slot at 105 degrees East.

Space Adventures

Space Adventures is the pioneering company providing space travel opportunities to affluent tourists. The first tourist, Dennis Tito, allegedly paid US \$20 million to be the first private party to go to the International Space Station (ISS). Since then, Space Adventures has launched 5 other customers and has contracts with at least another two. The price tag for the flight to the ISS has increased, due in part to inflation. The new cost is US \$30 million, but does not include a space walk; this can be acquired for another \$15 million. The founder of Space Adventures foresees continued market growth, and is negotiating to have more seats available for his customers on board a Soyuz rocket, and eventually to fly to the Moon, for about \$100 million.

(h) Uruguay

The Centro de Investigación y Difusión Aeronáutico - Espacial (CIDA-E), which is one of the few research centers in Latin America dedicated to research in air and space law, celebrated its thirty-second year of existence. The centre organizes symposia, round tables and other events, attended by specialists in the field of air and space law, primarily from the Latin American countries. As the only member from Uruguay, CIDA-E's Director General, Dr. Eduardo Gaggero, was elected a full member of the International Academy of Astronautics (IAA).

During the Third Regional Meeting of the Society of Science and Technology (CTS III) in June, the Uruguayan Society for the Progress of Science and Technology (Sociedad Uruguaya para el Progreso de la Ciencia y la Tecnología (SUPCYT)) hosted a Round Table titled "Teaching and Research in Space Law in Latin America." The principal speakers, among them Dr. Eduardo Gaggero, CIDA-E's Director General; Prof. Jose Monserrat Filho of Brazil and Prof. Maureen Williams of Argentina, emphasized the need for a multi-disciplinary approach to space activities and space law.

The Round Table concluded that there was a need for Latin American countries to teach space law at all levels, particularly at universities, so that in future, Latin America would have trained people to cooperate in international programmes, as well as at the regional level. Another outcome of the Round Table was a draft Montevideo Declaration on Cooperation in Space, which includes a series of recommendations and proposals on the teaching and dissemination of space law in the Latin American region.

The CIDA-E also hosted a Round Table on the “Development of transportation in and for Uruguay”, which addressed issues on terrestrial transportation, aviation, as well as space tourism and liability in space transportation.

(i) Venezuela

Venezuela’s satellite, “Simon Bolivar” is scheduled for launch in 2008. The Venezuelan government negotiated with the Chinese to build and launch a telecommunications satellite. The satellite will be operated by Venezuelan experts who have been training in China. The satellite will be launched from China, which won the investment worth \$240 million by offering technology transfer. The agreement will allow Venezuela to operate the satellite, as well as design and make operational two other satellites in the future. The Simon Bolivar satellite boasts completely digital technology and weighs about 5 tons. It is expected to benefit Venezuela, as well as other countries in the region, including Cuba, Haiti, Jamaica, the Dominican Republic, and parts of Central and South America, but not the southernmost parts of Chile and Argentina.

In October Venezuela established its national space centre, the Bolivarian Space Activity Agency, which will assist in the satellite’s operations with its main goal to put into orbit the satellite by August 2008. The agency will regulate and coordinate Venezuelan space activities to secure and serve the country’s interests in the economic, political, social, and cultural development.

CONTRIBUTORS

This publications was based on a report prepared by Jerry Grey, President Emeritus of the International Astronautical Federation (IAF) for Anne-Marie Mainguy (Vice-President, Technical Activities, IAF) and Madhavan Nair (Vice-President, Scientific Activities, International Academy of Astronautics). It was approved by James Zimmerman, President of IAF. The International Institute of Space Law (IISL) contribution on international cooperation and space law 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.

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