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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE AT ITS THIRTY-FIFTH SESSION

Report by the Secretariat

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INTRODUCTION

1. During the thirty-fifth session of the Scientific and Technical Subcommittee, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions and the International Astronautical Federation (IAF) organized, in liaison with Member States, a symposium on scientific and technical aspects and applications of space-based meteorology, to complement discussions within the Subcommittee on that theme. The symposium was organized in accordance with the recommendation of the Subcommittee at its thirty-fourth session (A/AC.105/672, para. 170), which was subsequently endorsed by the Committee on the Peaceful Uses of Outer Space at its fortieth session[1] and by the General Assembly in its resolution 52/56 of 10 December 1997.

2. The symposium was the fourteenth to be organized by COSPAR and IAF during the annual meetings of the Scientific and Technical Subcommittee, with the topic for each year selected by the Subcommittee at its previous session. The symposium was held on 9 and 10 February 1998, following the completion of debate in the afternoon meetings of the Subcommittee.

3. In addition to the special presentations organized by COSPAR and IAF at the request of the Subcommittee, delegations of Member States provided a number of scientific and technical presentations by specialists in space science and applications relating to various items on the Subcommittee agenda. Several national and international organizations also made special presentations on their scientific and technical activities.

4. In order to make the information on recent developments in space science, technology and applications presented during the symposium and the session of the Subcommittee more widely available, the Secretariat has prepared a summary of that information, which is presented below.

5. The annex contains a detailed description of the scientific and technical presentations made to the Scientific and Technical Subcommittee at its thirty-fifth session. The annex is in English only. A list of the presentations and speakers is appended to the annex.

I. SYMPOSIUM ON SCIENTIFIC AND TECHNICAL ASPECTS AND APPLICATIONS OF SPACE-BASED METEOROLOGY

A. Technical aspects of space-based meteorology

6. The World Weather Watch (WWW) programme is the major infrastructure in providing countries with the necessary data and information to prepare and issue timely weather warnings and forecasts to their population. Weather transcends political and geographic boundaries. Extreme temperatures, cyclones and large air masses are constantly on the move and can travel thousand of km in one day. At the same time, weather systems can be evolving, either becoming more intense or abating in severity. Therefore, the data needs to be collected in a timely way from a large area of the globe. WWW serves that purpose and is implemented through what the World Meteorological Organization has designated as basic systems. The fundamental concept is that each of the 185 members (for the most part States) contributes, according to its means, to meet certain responsibilities in the agreed global scheme.

7. WWW has three readily identifiable components: the global observing system (GOS); the global telecommunication system and the global data-processing system. Those components, which became known as the basic systems, were designed primarily to meet the objectives of WWW, and of weather forecasting in particular. However, they also serve the needs of States in support of different activities, such as the World Climate Research Programme and the transmission of seismological data for earthquake prediction, as well as the provision of information to the Conference on Disarmament and in accordance with the International Atomic Energy Agency conventions relating to nuclear accidents.

8. GOS comprises surface-based and space-based subsystems; the surface-based subsystem includes nearly 10,000 stations on land, of which about 4,000 are included in the regional basic synoptic networks and about 1,000 make up the balloon-launched radiosonde network. In addition, there are more than 7,000 voluntary observing ships, 15 specially equipped, automated upper-air observing ships, more than 600 active drifting data buoys and 100 moored data buoys covering the coastal and open ocean areas. This subsystem also includes automated observing commercial aircraft that now provide nearly 45,000 observations per day. There are also hundreds of other observing tools such as Doppler radars and wind profiles that are a part of regional and bilateral data exchanges that use the facilities of WWW.

9. The space-based subsystem continues to evolve and grow. The current operational constellation includes at least three polar-orbiting and six geostationary satellites. They produce real-time meteorological data on a regular basis many times a day through direct broadcast to thousands of locations in over 130 States. The geostationary component, consisting of satellites provided by China, India, Japan, Russian Federation, United States of America and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), provides a continuous view of weather systems from 70 degrees north to 70 degrees south with considerable overlap in most cases. Polar-orbiting satellites are currently provided by the Russian Federation and the United States, but several other parties, including China and EUMETSAT, are expected to add to that constellation in the next few years.

10. Satellite-based data collection and dissemination systems are essential in those geographical areas where conventional telecommunications cannot provide cost-effective services. Also, data collection and position- fixing systems (such as ARGOS) are most important in remote locations such as ocean and mountain areas. Both public and private satellite-based services such as those of the International Mobile Satellite Organization and the data collection missions on meteorological satellites are used particularly in acquiring data from ships and data buoys.

11. EUMETSAT is an intergovernmental organization of 17 States of western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and United Kingdom). Its primary objective is to establish, maintain and exploit European systems of operational meteorological satellites. Since December 1995, EUMETSAT is operating from a new purpose-built control centre at Darmstadt, Germany. The centre is part of a new ground system that includes a primary ground station at Fucino (Italy) and data uplink stations at Bracknell (United Kingdom), Toulouse (France) and Rome.

12. EUMETSAT geostationary satellite programmes include the continuation of the current Meteosat system until at least the year 2000, with a second generation under development for the years until 2012. EUMETSAT has already launched three satellites of the operational Meteosat series and a fourth of the same design is being constructed under a new contract. Those satellites enable operations to be ensured until the end of the current decade.

13. The United States National Oceanic and Atmospheric Administration (NOAA) operational environmental satellite system comprises the Geostationary Operational Environmental Satellites (GOES) and the Polar-Orbiting Operational Environmental Satellites (POES). One of the two operational GOES satellites (there is usually one back-up satellite available) monitors North and South America and most of the Atlantic Ocean, while the other monitors North America and the Pacific Ocean basin. The two satellites operate together to provide images of the western hemisphere both by day and by night. Complementing the geostationary satellites are two POES. Operating as a pair, they ensure that observations of any region of the Earth are no more than six hours old.

14. China, as a country with a vast territory, complicated weather and a large population, is in urgent need of improved accuracy of weather forecasts, particularly for early warning of dangerous weather conditions such as tropical cyclones, storms, cold waves and hail. China began the development of its satellite meteorological systems during the early 1970s, began to participate in the Coordination Group for Meteorological Satellites in 1986 and became a member in 1989. The first Chinese polar meteorological satellite, FY-1A, was successfully launched in September 1988. FY-1B was launched in September 1990 and FY-1C is scheduled for launch in late 1998.

15. During the 1980s, emphasis was placed on the development of a geostationary meteorological satellite, the FY-2. The FY-2(02) satellite was successfully launched by a Chinese LM-3 rocket on 10 June 1997. On 17 June 1997, it was positioned over the equator at 105 degrees east longitude. The main functions of the satellite are: to obtain pictures by day and by night and to chart water-vapour distribution in visible, infrared and water-vapour channels of the scanning radiometer; to disseminate high-resolution, digital stretched cloud pictures, low-resolution cloud pictures and weather charts for facsimile broadcasting to the meteorological data terminals at home and abroad; to collect meteorological, hydrological and oceanographic data from data- collecting platforms; and to monitor solar activity and the space environment by the on-board space environment monitor.

16. The Tropical Rainfall Measuring Mission (TRMM) is the first satellite in the Mission to Planet Earth programme of the United States National Aeronautics and Space Administration (NASA). It is a joint mission between Japan and the United States, with strong scientific participation from other countries, including Australia, Brazil, France, Israel, Italy, Singapore, Thailand and United Kingdom. The TRMM spacecraft was launched successfully by the Japanese H2 rocket from the spaceport at Tanegashima, Japan, on 27 November 1997. The largest science instrument on the TRMM spacecraft is the precipitation radar, the first rain-profiling radar to be flown in space. The spacecraft is orbiting at an altitude of 350 km with an inclination angle of 35 degrees. The initial instrument check was completed and all five instruments are in excellent condition, so that the data acquisition phase has already begun.

17. TRMM will provide the scientific community with data and information about tropical rain systems and the global latent-heating time series, improving understanding of the global energy budget and climate variability in different time scales. However, atmospheric dynamics are very complex and TRMM will provide data for only three to four years. There will be many longer-term phenomena that cannot be registered by TRMM. Therefore, plans are already being made for a mission to follow up TRMM, which could be launched around 2002 into slightly higher orbit.

B. Scientific aspects and operational applications of space-based meteorology

18. The global impact of El Niño is varied and far-reaching. It typically includes drought in southern Africa, Ethiopia, Indonesia, eastern Australia, the southern Philippines, north-east Brazil, and Central America. Flooding is likely to occur in southern Ecuador, northern Peru, southern Brazil, northern Argentina and Uruguay, among other locations. And in India, the rain-bearing, life-giving monsoon tends to become irregular, making food production less reliable. Scientists have linked the El Niño that began in 1997, for example, to extraordinarily dry conditions that withered crops and caused widespread forest fires in Indonesia, Malaysia and parts of Brazil, not because people were less cautious than usual, but because of extreme drought. In Indonesia, the fires covered more than 1 million hectares of rainforest, producing a thick, smoky haze that blanketed much of south-east Asia for several months. Air pollution from the fires was blamed for causing tens of thousands of respiratory infections in Indonesia and for the widespread cancellation of air traffic in the region.

19. In countries such as Zimbabwe, where the economy is critically tied to maize production, the effects of drought can be devastating, while farmers in western South America can benefit by planting more rice instead of a normal crop of cotton during El Niño, as they are likely to experience heavier than normal rainfall. The economic consequences of El Niño can therefore be staggering. Over 8 billion US dollars in damages can be directly attributed to the 1982 El Niño. Economic effects caused by the 1997/98 El Niño have not been assessed yet, but they are expected to be very high.

20. The weather forecasts of the 1997/98 El Niño were available well in advance and there were about 60 countries that could have benefited from them. However, most of the Governments did not react properly. As the situation slowly improves, more people are paying attention to El Niño and to the forecasts. Some groups are starting to take preventive measures to cope with its effects. Vaccination programmes in Ecuador, for example, have sought to

inoculate people against water-borne diseases that might be unleashed as a result of flooding. In many regions, sewers and drainage infrastructures are being cleared of debris to permit water to flow more freely through the system. Berms are being constructed along vulnerable coastal areas. Emergency flood plans are being developed and people advised on how to manage the scarce water resources in case of drought.

21. It is evident that weather forecasting has improved significantly in recent years. However, even when all the space projects and agencies for a global weather-observing system are fully implemented, there will still be several gaps in necessary input data up to 2005. There still will not be a complete three-dimensional monitoring of liquid water and ice in the atmosphere to the degree that is needed for good parametrization of clouds. Another major gap will still persist in the monitoring of soil moisture. In many places, atmospheric moisture depends on the storage of water in the soil. Plants are able to use the water and bring it back to the atmosphere, where it can in turn feed the precipitation. Unfortunately, there is no easy way to measure that parameter from space. There are some experimental methods of obtaining soil moisture values indirectly from satellite microwave data, but they are far from operational.

22. Developing countries, with their diverse agro-climatic situation, high and unstable mountains, perennial waterways coupled with peak seasonal discharge, as well as arid and semi-arid ecological conditions, are vulnerable to drought and desertification. Ironically, most of the large-scale natural disasters predominantly occur in the tropical regions, which encompass most of the developing countries that have no capability to withstand the heavy losses inflicted by such disasters. Hence, realization of an efficient disaster management system, which could address the social issues related to disaster mitigation, would help in reducing the impact of disasters on the vulnerable socio-economic profile of developing countries.

23. Space technology for flood monitoring and management has been successfully made operational in India. Near real-time monitoring and damage assessment of major floods are being carried out using Geographic Information Systems (GIS) for the Brahmaputra river basin to provide information on flooded areas and damage to croplands, roads and railways. Having successfully demonstrated the potential of Earth observation and communication satellites in addressing various aspects of disaster warning, mitigation and management, Indian efforts in the coming years will be designed to emphasize synergetic use of the systems and to arrive at the Integrated Disaster Monitoring Management System.

24. While the Indian Remote Sensing satellite series provides the required data on terrain features and topographic aspects as well as on the spatial extent and distribution once a disaster occurs, the series of Indian National Satellites (INSAT) is planned to be used for ensuring the appropriate connectivity and flow of information, including dissemination of disaster warning signals. Moreover, the INSAT series consists of multi-purpose missions, carrying meteorological payloads, the data from which are being effectively used for a number of applications related to disaster management. Efforts have already been initiated and the realization of the system on a pilot scale is planned for 2000.

25. On the regional and national level, the most useful data are provided by the NOAA polar orbiting satellites. The standard resolution data enable monitoring on a weekly, monthly and yearly time-scale of the cover of natural vegetation. The ARTEMIS project of the Food and Agriculture Organization of the United Nations is aimed at production of monthly maps of the vegetation index for all of Africa. For the Sahel region, such data are already available for a nine-year period. The European Union projects Tropical Ecosystem Environment Observations by Satellite (TREES) and FIRE provide data on deforestation and the presence of forest fires in tropical regions. There are also national programmes in countries such as Jordan, Kenya and Morocco. In Jordan, the existing GIS data made it possible to distinguish between four types of desertification (slight, medium, severe and very severe).

26. A pilot project to investigate the vegetation in the Maamora forest region in Morocco (150,000 hectares) using data provided by the Système pour l’observation de la Terre (Earth observation satellite system) should result in a

map (scale 1/50,000) of the forest changes and their statistical inventory. In principle, such inventories of vegetation, soil composition and moisture are perfect tools for further detailed monitoring of desertification. The final goal is the development of the complex information system on desertification, referred to as the Système d'information sur la désertification, making possible the integration, compilation and analysis of data diagnosing the local ecosystem. The first step towards such a system is the Space Assisted Network against Desertification, proposed by the International Space University at Strasbourg (France).

27. The spatial and temporal distribution of moisture in the atmosphere is of major meteorological significance. Meteorological satellite observations can provide much-needed information on global and regional moisture distribution at higher temporal resolutions. Such calculations, although promising in many respects, have yet to be fully developed. In particular, current infrared estimates are not sufficiently accurate for numerical weather predictions. In the Republic of Korea, an attempt has been made to retrieve the moisture fields of the 1994 and 1995 *changmas* (rainy fronts). Am examination of *changma* moisture fields, corresponding to the variation and structure of the east Asian monsoon and subtropic high, is urgently needed for predicting *changma* characteristics (intensity, duration, onset and offset times etc.) because *changmas* are the source of water over the peninsula of the Republic of Korea and the Democratic People's Republic of Korea.

28. Data obtained from NOAA environmental satellites are operationally used to assess weather information and to monitor land cover and forest fires in Brazil. In the last few years, a number of studies concerned with land-cover variables have been conducted at the Instituto Nacional de Pesquisas Espaciais (Brazilian Institute for Space Research) using advanced very high resolution radiometer data and other information from NOAA satellites. The aim of the studies is to monitor vegetation cover and forest fires to understand their effects on processes of global change. Forest fires have been monitored in Brazil since 1988 using meteorological satellite data. A total of 39,778 forest fires were detected in 1995 and 31,944 in 1996 using NOAA-12 data. Mato Grosso and Pará were the States that presented the highest incidence of fire pixels during the study period. They accounted for approximately 50 per cent of the total number of fires over the entire country.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Space debris environment and mitigation

29. The United States of America has had the longest experience in space debris mitigation. Its current policy was established by Presidential Decision Directive NSC-48/NSTC-8, on national space policy, of 14 September 1996. In August 1995, the Office of Safety and Mission Assurance of the National Aeronautics and Space Administration (NASA) issued NASA Safety Standard 170.14, concerning guidelines and assessment procedures for limiting orbital debris. The policies of the Department of Defense are defined in its space policy document of February 1987 and in the United States Space Command Satellite Disposal Procedures of November 1997, and policies of the commercial sector are covered in the Commercial Space Launch Activities act issued in 1994.

30. The space debris mitigation priorities of the United States are to make spacecraft safe by eliminating all stored energy (propellants, pressurants and batteries) at the end-of-life; to relocate spacecraft to a disposal orbit (decreasing the perigee of the low Earth orbit (LEO) to limit orbital lifetime to less than 25 years and raising the perigee not less than 300 km above geostationary orbit (GSO) for GSO objects); and, when feasible, to do the relocation before “safing” the spacecraft.

31. All newly launched United States upper stages and spacecraft have been modified to eliminate operational debris, to retain captive separation devices, to keep captive deployment and restraint devices and to disable pyrotechnic devices. With regard to United States manned spaceflights, the Space Shuttle is being modified to achieve greater debris and meteoroid tolerance; the International Space Station (ISS) has been shielded to withstand impacts of debris smaller than 1 centimetre in diameter; and collision avoidance manoeuvres are performed to avoid tracked objects both at launch and in orbit.

32. The Japanese Society for Aeronautical and Space Sciences committee on design standards for space debris prevention published its final report on standards and design criteria for the Japanese National Space Development Agency (NASDA) in March 1996. On the basis of that report, NASDA established the NASDA-STD-18 space debris mitigation standard of 28 March 1996. The NASDA standard includes the following mitigation measures: passivation of the spacecraft and the upper stages at the end of the mission; reorbiting the spacecraft and upper stages at the end of the mission; disposal of objects in geostationary transfer orbit in order not to pose a risk to the geostationary orbit; minimizing the debris released during normal operations; and post-mission disposal of spacecraft from LEO.

33. Strict mitigation measures are applied to all launches of the Centre national d’études spatiales (CNES) (French National Centre for Space Studies). The basic requirement is to leave no more than one piece of passivated debris in orbit per payload. That means the upper stage of the launcher in the case of a single launch and the upper stage with link structure in the case of a dual launch. The separation of the payload from the last stage of the Ariane 4 launcher should not generate any other debris (pyrotechnic separation should be clean and remains of pyrobolts should be trapped). Pyrotechnic valves to empty the tanks and decrease the internal pressures are added to passivate the upper stage. During the development of a new Ariane 5 launcher, passivation requirements were taken into account in the early design phase.

34. In connection with the introduction of major commercial satellite constellations in LEO, the impact of such a large number of satellites on the space and space debris environment has been studied at different institutions, such as the Defense Evaluation Research Agency of the United Kingdom and the Institute for Flight Mechanics and Spaceflight Technology of the Technical University of Braunschweig (Germany). Interest has been mainly focused on the internal collision risk in case of a fragmentation within the constellation, on the one hand, and its contribution to the global debris evolution, on the other.

35. The *Space Debris Mitigation Handbook* of the European Space Agency (ESA) is to be published shortly. Its purpose is to provide technical information on the space debris situation and guidance on how to avoid space debris in future spacecraft design and mission planning. The *Handbook* is intended to be used for that purpose within ESA and in the European industry, as well as in planning space research. The *Handbook* has no regulatory character. However, if regulations were to be introduced in Europe by other instruments, reference could be made to suitable paragraphs of the *Handbook*.

36. In the space programme of the Russian Federation, the measures envisaged for preventing explosions include the passivation of spent rocket stages and space objects remaining in orbit, that is, the release from tanks and gas bottles of propellants and pressurants that could cause their explosion even after a considerable period of time. It is proposed to fit the DM upper module of the Proton and the second stages of Zenit launchers with appropriate equipment. Modifications of the on-board power-supply circuits of the Ekran satellite should improve its structural integrity and prevent accidental creation of debris due to electrical faults.

37. Specific programmes and techniques are being developed in the Russian Federation to avoid upper rocket stages from entering into orbit around Earth. The spacecraft itself is inserted into its working orbit by means of an additional smaller booster module or apogee stage. Such techniques will be used operationally on the newly developed Zenit and Angara launchers. Work is under way to reduce the periods of time during which spacecraft and upper rocket stages remain in orbit in passive ballistic mode. In particular, the modernized Soyuz-2 launcher will be fitted with a passive braking system consisting of a deployable light construction on its upper stage, increasing its diameter to 10 metres. The orbital lifetime of the stage could thus be reduced by a factor of 5 to 6.

38. The International Academy of Astronautics supports the position that there are several space debris mitigation actions that should be initiated immediately to ensure the future viability of space operations. They fall into two categories: those requiring minimal impact on the design and operations and those requiring significant changes in hardware or operations. Neither category of measures requires the development of new technology.

39. In 1993, an Inter-Agency Space Debris Coordination Committee (IADC) was formally established in order to exchange information on space debris research activities between member space agencies; to review progress of ongoing cooperative activities; to facilitate opportunities for cooperation in research on space debris; and to identify options for debris mitigation. The founding members were Japan, ESA, NASA and the Russian Space Agency (RSA). China joined in 1995, the British National Space Centre (United Kingdom), CNES (France) and the Indian Space Research Organization in 1996, and the German Aerospace Research Establishment (DLR) in 1997. The Italian Space Agency (ASI) has recently applied for membership.

40. The chairmen of IADC working groups are elected to serve a term of two consecutive sessions. Each member State or organization must be represented in the Steering Group and in working group 4 on mitigation. Representation in other working groups is desirable but not mandatory. Formal meetings of the full IADC are scheduled about once a year. All agreements of IADC are made by consensus, and the voluntary mitigation measures have proven effective in both low and geostationary orbits. In the future, however, wide compliance with the full range of mitigation measures will be needed in order to avoid an uncontrolled growth of the debris population.

B. Russian segment of the International Space Station

41. The Russian Federation has accumulated significant scientific and technological experience in the field of manned spaceflight, most recently, through the 12 years of continuous operation of the Mir orbital station. From 1992 to 1997, there were 14 primary crew expeditions (numbers 11 to 24) and six visiting expeditions to Mir, involving representatives of France four times, Germany twice and several other ESA countries. The total duration of foreign cosmonauts staying on Mir during that period was over 600 days and the recent trend is to extend the duration of visiting expeditions from the traditional 7 to 8 days to 20 to 21 days, and to incorporate foreign cosmonaut researchers into the crews of primary expeditions.

42. An important factor in developing and strengthening international cooperation in space is phase one of the ISS programme, which involves the docking of the United States Space Shuttle at the Mir station and long-duration stays of United States astronauts on the station. The priority in the programme is given to basic research (including space medicine, biology and materials science) and testing the advanced technology and processing equipment. The most important aim is to gain experience in organizing long-term activities of the international crew on the station, as the precursor to ISS.

43. The RSA Science and Technology Advisory Committee conducts preliminary appraisal and selection of proposals filed for the research and applications programme in the Russian segment of ISS. Foreign scientists also present their proposals. The Committee has already selected over 170 proposals for scientific investigations and experiments and recommended them for implementation on ISS. The ISS project is seen as a model of cooperation by the world community in implementing large-scale projects and consolidating the scientific, technological and economic potential of different countries to solve problems for the benefit of mankind.

C. Planetary research and astronomy

44. The Cassini spacecraft, in development since October 1989, is a cooperative endeavour of ASI, ESA and NASA. The mission will send a sophisticated robotic spacecraft equipped with 12 scientific experiments to orbit Saturn for a four-year period and to study the Saturnian system in detail. The ESA-built Huygens probe that will parachute into the thick atmosphere of Titan is carrying another six packages of scientific instruments.

45. The launch of the Cassini/Huygens spacecraft was performed successfully on 15 October, when the Titan IVB/Centaur rocket lofted the spacecraft onto the interplanetary trajectory that will deliver it into orbit around Saturn (as its first artificial satellite) almost seven years later, on 1 July 2004. The primary mission of Cassini should conclude in July 2008. In manoeuvres called gravity-assist swing-bys, Cassini will twice fly past Venus (on 26 April 1998 and 24 June 1999), then once past Earth (on 18 August 1999 at a distance of 1,150 km) and Jupiter (on 30 December 2000) on its way to Saturn. The speed of the spacecraft relative to the Sun increases as it approaches and swings past each planet, giving Cassini the cumulative boost it needs to reach its ultimate destination. On 6 November 2004, Cassini will release the disc-shaped Huygens probe towards Titan.

D. Remote sensing

46. The data from the Landsat spacecraft constitute the longest record of the Earth surface as seen from space. The new satellite, Landsat 7, is to be launched in late 1998 not only to maintain its current performance level, but also to add new possibilities. It will carry the Enhanced Thematic Mapper Plus (ETM+) providing panchromatic images with 15-metre spatial resolution, a thermal infrared channel with 60-metre resolution and the possibility of on-board radiometric calibration. At the same time, the ETM+ will continue to provide data continuity with the Thematic Mapper that flew on Landsat 4 and 5.

47. There was a fundamental shift in the United States policy toward Earth remote sensing in 1984. After intense discussion, focused on the roles of government and the private sector, the Land Remote Sensing Commercialization Act was adopted. The Earth Observing Satellite Company was awarded a contract to operate the Landsat system for 10 years and to develop and build two new satellites, including the ground system. In May 1994, a Presidential Decision Directive was signed to further stabilize the Landsat programme. That directive clarified the roles of NASA and the United States Departments of Commerce, Interior and Defense. In particular, it charged NASA with the previously shared responsibilities and with developing a strategy to maintain the continuity of Landsat-type data beyond Landsat 7.

48. The Government of the Russian Federation, in a spirit of openness, decided in 1992 that imagery from the Russian defence satellites could be used for civilian purposes. Space imagery has the same characteristics as aero-cartographic imagery, but is substantially cheaper and covers wider areas, including remote regions. The Russian defence satellite imagery is available as monographic (areas of 40 by 160 km with 2-metre details) and stereographic (areas of 200 by 300 km with 10-metre details) imagery. The geographic location of the imagery is also provided with high accuracy. On a commercial basis, the archive data can be provided or new imagery of the given area ordered. For the time being, the catalogue of existing data is not open to public search. The data are provided either as an original film, a copy of the negative, print, digital data on magnetic media or a computer-ready compact disc.

49. Rangelands occupy nearly 80 per cent of the territory of Morocco and cover about 30 per cent of the nutritional requirements of the national livestock. They are located in fragile ecosystems and have been subject to strong degradation for many years, owing to environmental stress (arid climate, poor soils, strong erosion, overgrazing and demographic expansion). The ecosystems need rigorous management and frequent monitoring. The Geostat-Morocco project was conducted to develop a methodology based on remote sensing and GIS techniques, and will provide regular estimates of rangeland acreage both quickly and cost-effectively. The Geostat-Morocco feasibility project was conducted jointly by the Centre royal de télédétection spatiale (Royal Centre for Remote Sensing) of Morocco, Scot Conceil of France and several other Moroccan and French partners.

50. First results of the Geostat-Morocco project are very encouraging in terms of vegetation mapping and statistical inventory. After the success of the feasibility study, it is possible to look forward to the operational implementation of the project. The methodology developed within the framework of the Geostat-Morocco project could be applied in other counties of the Mediterranean basin and other regions of Africa, America, Asia and Australia. The Geostat-Morocco project deals with rangeland inventory and monitoring and is also directly related to monitoring desertification and its consequences for natural resources and the environment, which are of prime importance for many regional and international organizations.

51. At the University of Concepción in Chile, a Programa Multidisciplinario de Percepción Remota (PMPR), (multi-disciplinary programme for remote sensing) has been developed since 1993. It comprises research and development of the acquisition of digital information, *in situ* spectrography and aerial and satellite remote sensing. A catalogue of NOAA satellite images in seven spectral bands over the territory between 15 and 59 degrees south and 95 to 55 degrees west was established. Since October 1994, about two pictures per day have been added to the database. Under an agreement with NASA, there would be direct ground reception of data from the OrbView-2 satellite SeaWIFS (Sea-Viewing Wide Field Sensor) on aerosols and ocean colour and biology, thus making it possible to monitor concentrations of sea phytoplankton. Within the framework of PMPR, research is also being pursued in the field of GIS applications for forestry, fisheries and urban monitoring.

E. Satellite Health Access for Remote Environment Demonstrator

52. The Satellite Health Access for Remote Environment Demonstrator (SHARED) project is a pilot platform based on the ESA Direct Inter-establishment Communications Experiment system to support remote health-care infrastructure, proposed by the Scientific Institute San Raffaele and coordinated by ASI, ESA, Telbios (San Raffaele Biomedical Science Park and Alenia Aerospazio) and the Italian Army. The SHARED mission is to set up and operate on a trial basis a laboratory for re-engineering health-care delivery through the use of information and telecommunications technologies, including the space segment. Participating institutions at Bologna, Bucharest, Milan, Rome, Sarajevo and Tirana are connected through the Integrated Service Digital Network (ISDN) and also through the SHARED network by the geostationary satellite of the European Telecommunications Satellite Organization.

53. From 16 September 1996 to 31 December 1997, there were 560 hours of telemedicine sessions and 260 hours of teleconsultation sessions; 180 cases were treated to support the Clinical Centre of Sarajevo University; and 10 doctors were involved in telemedicine sessions at Milan, 8 at Rome, 15 at Sarajevo and 8 at Tirana. Medical disciplines covered were ophthalmology, orthopaedics, pathology and dermatology. In February 1998, within the framework of SHARED, phase 2, establishments at Bologna, Bucharest and Rome and three hospitals in urban areas were added. The future permanent European Telemedicine Network (EUROMEDNET) might consist of 20 sites connected by satellite and many more locations accessible through the ISDN gateway. To make the network operational, sponsorship is being sought from ASI, ESA and the European Commission, as well as from different humanitarian organizations and local sponsors.

F. Space and education

54. Space education activities have been one of the missions of the French space agency CNES since its founding in 1962. The main objective of those activities is to foster space studies by young enthusiasts and to give rise to scientific vocations. Since 1976, efforts have been undertaken to promote the understanding and use of satellite imagery in educational activities (use of Landsat images), and since 1987, the French Ministry of Education has supported educational experiments to promote satellite remote sensing in courses given in three educational disciplines. In 1991, an official agreement was concluded between CNES and the Ministry of Education with a view to developing training courses for teachers, supporting and enlarging educational experimentation in high schools and supporting the production of teaching material (booklets, video, multimedia).

55. The current activities of CNES still involve the support of youth clubs (launchings of small model rockets up to an altitude of 3 km and of stratospheric balloons with 20-kilogram payloads up to 14 km and experiments with microgravity in the Airbus A300 0G plane). Over 2,000 youngsters participate in such activities each year. For primary and secondary schools, CNES is producing small monothematic books and videos with simple approaches on different space activities (tectonic plates viewed by satellites, activities of primary schools related to human spaceflight, space-technology applications etc.).

56. CNES also regularly organizes short training courses to create awareness of space activities at the institutes for initial training of teachers and at summer university programmes for more detailed education in the field of space physics, applications of Earth observation etc. The high standard of the summer university is guaranteed by a scientific committee, by the close cooperation of scientists and teachers during the workshops, and by the use of new educational technologies. Visits to space and aeronautics companies form an important part of the programme. The courses are also open to French-speaking foreigners.

57. With the establishment of the Royal Centre for Remote Sensing in 1989, Morocco took an important step forward in applications of space-related technology. The Centre is responsible, among its different space-related tasks, for distributing satellite images and centralizing the national records of satellite data and data from projects

using space-borne remote sensing and GIS. A number of projects using those techniques are currently in progress or being set up in Morocco in response to needs in the areas of natural resource inventory and management, environmental protection and land development.

58. Training and education form an important part of the activities of the Royal Centre for Remote Sensing. They are performed in cooperation with international, regional and national institutions. Cooperation with the United Nations-advocated regional centres for space science and technology education will be essential. Cooperating national centres in the Mediterranean region include the National Authority for Remote Sensing and Space Sciences in Egypt, the Royal Jordanian Geographic Centre, the Centre for Remote Sensing and Space Science in the Libyan Arab Jamahiriya and the National Centre for Remote Sensing in Tunisia.

Notes

[1]*Official Records of the General Assembly, Fifty-second Session, Supplement No. 20* (A/52/20), para. 105.

*Annex**

SUMMARY OF THE SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE AT ITS THIRTY-FIFTH SESSION

CONTENTS

*This annex has not been formally edited.

I. SYMPOSIUM ON SCIENTIFIC AND TECHNICAL ASPECTS AND APPLICATIONS OF SPACE-BASED METEOROLOGY

A. The World Weather Watch programme

1. The World Weather Watch (WWW) programme is the major infrastructure in providing countries with the necessary data and information to prepare and issue timely weather warnings and forecasts to their populace. Weather transcends political and geographic boundaries. Extreme temperatures, cyclones and large air masses are constantly on the move and can travel thousand of km in one day. At the same time these weather systems can be evolving, either becoming more intense or abating in severity. Therefore, the data needs to be collected in a timely way from a large area of the globe. The WWW serves this purpose and is implemented through what the World Meteorological Organization (WMO) has designated as basic systems. The fundamental concept is that each of the 185 members (for the most part countries) contributes, according to its means, to meet certain responsibilities in the agreed global scheme.

2. The most obvious benefits are the protection of life and property through, for example, detection, tracking and prediction of severe storms and other extreme and adverse weather conditions. Many other activities, such as agriculture, construction, transportation, and tourism, are also influenced by the weather and benefit from the data and information, including forecast guidance, provided by the WWW extending over the next few days, weeks and seasons.

3. The advent of electronic computers, high-speed telecommunications and the launch of Earth orbiting satellites provided unprecedented opportunities for international meteorology and allowed for the complete appraisal and redesign of a world system of gathering, processing and redistributing meteorological information. This major turning point in operational meteorology is usually marked by the date of 20 December 1961, when the United Nations General Assembly passed a resolution calling for a new concerted approach to weather forecasting by making full use of these new technologies. This resolution included a specific reference to the opportunities made available by space technologies.

4. In response, the WMO established the WWW Programme at its 4th Meteorological Congress in April 1963. It included a voluntary assistance programme, now called the voluntary cooperation programme, focusing on coordination and provision of assistance so that all members of WMO could participate and share in the benefits of the programme. At the same time, WMO adopted, jointly with the International Council of Scientific Unions (ICSU), the Global Atmospheric Research Programme (GARP) in order to understand the transient behaviour of large-scale atmospheric fluctuation and subsequently increase the accuracy of forecasts from one day to several weeks.

5. The WWW has three readily identifiable components: the global observing system (GOS); the global telecommunication system and the global data-processing system. These components, which became known as the “basic systems”, were designed primarily to meet the objectives of the WWW, and of weather forecasting in particular. However, they are also serving the needs of States in support of different activities, such as the World Climate Research Programme, the transmission of seismological data for earthquake prediction and even support and information to the Conference on Disarmament and in accordance with the International Atomic Energy Agency (IAEA) conventions relating to nuclear accidents.

6. The GOS is comprised of surface-based and space-based subsystems; the surface-based subsystem includes nearly 10,000 stations on land, of which about 4,000 are included in the regional basic synoptic networks and about 1,000 comprising the balloon-launched radiosonde network. In addition, there are more than 7,000 voluntary observing ships, 15 specially equipped automated upper air observing ships, more than 600 active drifting data buoys, and 100 moored data buoys covering the coastal and open ocean areas. This subsystem also includes automated observing commercial aircraft that now provide nearly 45,000 observations per day. There are also

hundreds of other observing tools such as Doppler radars and wind profiles that are a part of regional and bilateral data exchanges that use the facilities of the WWW.

7. The space-based subsystem continues to evolve and grow. The present operational constellation includes at least three polar-orbiting and six geostationary satellites. They produce real-time meteorological data on a regular basis many times a day through direct broadcast to thousands of locations in over 130 States. The geostationary component, consisting of satellites provided by China, India, Japan, Russian Federation, United States of America and EUMETSAT, provides a continuous view of weather systems from 70 degrees north to 70 degrees south with considerable overlap in most cases.

8. This capability allows for the detection, at the earliest stages, the development, growth, and movement of most major cyclones and storms on a global basis. This is certainly one of the most significant contributions to the world's efforts to provide early warning in support of natural disaster reduction. In addition, the geostationary satellites provide tracking of identifiable features, such as clouds, water vapour, and ozone in consecutive satellite images that provide determination of wind velocity at several layers in the atmosphere. These fields along with temperature profiles from several geostationary satellites are important input to numerical weather prediction, particularly in support of tropical cyclone warnings and forecasts.

9. Polar orbiting satellites are principally used to obtain three main quantitative measurements: daily global cloud cover; surface temperature; and most important, measurements of the vertical temperature and water vapour in the atmosphere. At present, polar-orbiting satellites are provided by the Russian Federation and the United States, but several other parties, including EUMETSAT and China, are expected to add to this constellation in the next few years. The polar satellites are used on a limited basis for acquiring profiles of atmospheric temperature and moisture primarily in areas not adequately covered by surface-based subsystems mostly in the southern hemisphere and high latitudes such as the Arctic and Antarctic.

10. The GOS continues to develop as a composite system with no single observing component or measuring technique able to provide the total required data set. The integration of conventional and remotely sensed data remains an area of technological development for the coming decades supporting all scales of motion from local to global.

11. The most promising areas for observation improvement are related to the use of navigational satellites, such as the Global Positioning System (GPS), in conjunction with low Earth orbiting satellites. Through the atmospheric occultation technique, it will be possible to derive high-quality profiles of temperature and moisture for a large segment of Earth's troposphere. This type of technique not only holds promise for areas that were difficult to observe in the past, but also at potentially low cost. With the demise of the omega navigational system, the GPS has now become the major mechanism for deriving wind velocity from balloon launched radiosondes. It is also expected that complete vertical profiles of wind velocity will be possible within the next decade from laser instrumentation on newly developed small satellite systems.

12. The global telecommunications system (GTS) comprises the arteries, heart and veins of the WWW. All GTS components must operate well if observations and forecast products are to be collected, processed and disseminated to national meteorological services. The GTS conveys daily more than the equivalent of 70 million characters of data and over 2,000 weather charts, operating with a degree of speed, automation and efficiency not even conceived at its beginning. Since that time, it has evolved into three cascading levels: the main telecommunication network (MTN); the regional meteorological telecommunication networks (RMTNs); and the national meteorological telecommunication networks (NMTNs).

13. The MTN is the core of the GTS, composed of 23 circuits. Operating at up to 64 kbps, it links together the three world meteorological centres (WMCs) to the regional specialized meteorological centres (RSMCs) and 16 regional telecommunication hubs (RTHs). Through the RMTNs, the RTHs provide major access for the national

meteorological centres of the WWW's 185 members. This is accomplished through 300 point-to-point circuits, satellite-based data dissemination and broadcast systems and, in a few cases, VHF and HF radio. The telecommunication techniques and procedures now in use in the GTS are based on advanced international standards for data communications and computing, including X.25 and TCP/IP protocols. There is an increasingly complex use of space technology in the GTS, particularly in point-to-multipoint communications.

14. Satellite-based data collection and dissemination systems are essential in those geographical areas where conventional telecommunications cannot provide cost-effective services. Also, data collection and position fixing systems (such as service ARGOS) are most important in remote locations such as ocean and mountain areas. Both public and private satellite-based services such as INMARSAT and the data collection missions on meteorological satellites are used particularly in acquiring the data from ships and data buoys.

15. The global data-processing system (GDPS) consists of a three level system of centres operated by WMO members. They include the world meteorological centres located in Melbourne, Moscow and Washington, where numerical models are used on an operational basis to provide global and hemispheric forecast guidance on time scales out to days and weeks along with climate monitoring. The second tier of the GDPS includes the 34 RSMCs that provide numerical weather guidance on a regional geographic basis or regarding a specific set of applications. For example, there are five centres devoted to providing guidance on tropical cyclone track warnings and forecasts, nine centres that are prepared to provide atmospheric transport model forecasts for environmental emergency response in the event of a nuclear accident, or a related natural disaster such as volcanic eruption. In addition, there is a specialized centre, the European Centre for Medium-range Weather Forecasts (ECMWF), that provides forecast guidance on a worldwide basis out to 10 days from sophisticated numerical models.

16. The ultimate responsibility for the provision of weather and climate services, particularly warnings of severe and extreme weather as well as climate events and episodes of degraded environmental quality, rests with national meteorological services. As a result, each participant had to establish a real-time capability to process guidance material related to weather analyses and forecasts specifically to meet national needs.

17. Finally, the entire WWW has been already significantly upgraded by the use of many of the space-based communication features; for example, it has proved the ability to use low electrical power at remote locations. This is further enhanced by the ability for highly reliable point-to-multipoint and point-to-point communications. While this has already been implemented in the WWW for the Americas, there is still a need for improvement in data speed and its application to other WMO regions, particularly in the Pacific and parts of Asia.

B. Satellites of the European Organization for the Exploitation of Meteorological Satellites

18. The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) is an intergovernmental organization of 17 western European States (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom of Great Britain and Northern Ireland). Its primary objective is to establish, maintain and exploit European systems of operational meteorological satellites. The activities of EUMETSAT substantially contribute to a global meteorological satellite observing system coordinated with other spacefaring nations. In addition to essential input to numerical weather prediction systems, the capacity of weather satellites to gather long-term measurements from space in support of climate change studies is of growing importance. Since December 1995, EUMETSAT is operating from a new purpose-built control centre in Darmstadt (Germany). This centre is part of a new ground system that includes a primary ground station in Fucino (Italy) and data up-link stations in Bracknell (United Kingdom), Toulouse (France) and Rome (Italy).

19. EUMETSAT geostationary satellite programmes include the continuation of the current Meteosat system until at least the year 2000 with a second generation under development for the years until 2012. EUMETSAT has now launched three satellites of the operational Meteosat series and a fourth of the same design is being constructed under

a new contract. These satellites enable operations to be assured until the end of the present decade. The Meteosat system provides continuous and reliable meteorological observations from space to a large user community. In addition to providing images of Earth and its atmosphere every 30 minutes in three spectral channels (visible, infrared and water vapour), a range of processed meteorological parameters is also produced. Meteosat also supports the retransmission of data from data collection platforms in remote locations, at sea and on board aircraft, as well as dissemination of meteorological information in graphical and text formats.

20. With the progression of science, and developments in the accuracy of numerical weather prediction, the need for more frequent and comprehensive data from space has evolved. This has led to the current work on the Meteosat Second Generation system. The new satellite will be spin-stabilized like the current generation, but also have many design improvements, including a new radiometer which will produce images every 15 minutes, in 12 spectral channels. The more frequent and comprehensive data will also aid forecasters in the swift recognition and prediction of dangerous weather phenomena such as thunderstorms, fog and explosive development of small but intense depressions, which can lead to devastating windstorms. In cooperation with EUMETSAT, ESA is responsible for the development of the first satellite planned for launch in the year 2000. Construction of follow-on models, their launches, development of a new ground system and operations are being implemented by EUMETSAT so that regular observations are provided from space from 2002.

21. While geostationary satellites provide a continuous view of the Earth disc from an apparently stationary position in space, the instruments on polar orbiting satellites, flying at a much lower altitude, provide more precise detail about global atmospheric temperature and moisture profiles. The lack of observational coverage in certain parts of the globe, particularly the Pacific Ocean and continents of the southern hemisphere, has led to an increasingly important role for polar orbiting satellite data in numerical weather prediction and climate monitoring.

22. EUMETSAT is currently preparing the European component of a joint European/United States polar satellite system. It plans to assume responsibility for the “morning” (referring to a local time of overfly over a given surface region) satellite, while the United States will continue with the “afternoon” coverage. Plans call for EUMETSAT instruments to be carried on the METOP satellite, developed in cooperation with ESA, for launch in 2001. METOP-1 should be the first of a series of operational satellites providing service well into the second decade of the twenty-first century.

C. Satellites of the National Oceanic and Atmospheric Administration

23. The United States National Oceanic and Atmospheric Administration (NOAA) operational environmental satellite system comprises the Geostationary Operational Environmental Satellites (GOES) and the Polar-Orbiting Operational Environmental Satellites (POES). One of the two operational (there is usually one back-up satellite available) GOES satellites monitors North and South America and most of the Atlantic Ocean, while the other North America and the Pacific Ocean basin. The two satellites operate together to provide images of the Western hemisphere both day and night. Complementing the geostationary satellites are two POES. Continuously circling the Earth in Sun-synchronous orbit at about 850 km altitude, these satellites support large-scale, long-range forecasts. Operating as a pair, they ensure that observations of any region of the Earth are no more than six hours old.

24. The improved resolution and dynamic range of the GOES spacecraft allowed for the development of advanced image products and virtual real-time forecasting techniques. With the new generation of GOES, imagery was taken over the continental United States and coastal waters, Hawaii and Alaska once every 15 minutes under normal operational modes and at approximately 7.5 minute intervals when severe weather threatened. In special cases, analysts obtained imagery over hurricanes at one-minute intervals and over tornado thunderstorms once every 30 seconds. Satellite sensors also detect ice fields and map the movements of sea and lake ice. The rapid scan imaging made a number of exciting new quantitative observations possible.

25. Technicians installed a demonstration, evaluation, and training program that allows for the receipt and analysis of digital GOES imagery at more than 50 National Weather Service field offices. The capabilities of using digital GOES imagery significantly improved the use of satellite imagery for virtual real-time forecasting at those offices. The family of experimental products to forecast and predict flash floods include precipitation estimates that covered the entire GOES image derived from the GOES 8 Automatic Flash Flood Precipitation Algorithms, precipitation efficiency analyses for detecting precipitable water plumes, and soil wetness indices for flooded areas and ground conditions prior to flash flood.

26. NOAA began developing a gridded cloud product from the GOES 8/9 imager as a replacement for the sounder product. Other cloud-related research with GOES imager data included images to detect fog by use of temperature differences, aircraft icing risk images, and an aerosol optical thickness image. In October 1996, NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) began regularly producing an experimental version of the GOES infrared histogram programme for the National Weather Service's Climate Prediction Center.

27. NOAA polar-orbiting satellites track atmospheric variables and patterns that affect the weather and climate over the land surface and provide atmospheric and oceanographic data. They also provide visible and infrared radiometer data used for imaging, radiation measurements, temperature profiles, and sea surface temperatures, as well as measurements important to long-term global climate change, ozone depletion, oceanographic variables, and land surface change. Their signals are processed (usually in real-time) into environmental information by national civilian and military organizations, private sector companies, researchers, schools and foreign users. The Presidential Directive of 5 May 1994 ordered the consolidation of the United States civilian and military polar-orbiting environmental satellite programmes. This consolidation calls for the Departments of Commerce and Defense to merge their respective programmes and for NASA, through its Earth Observing System, to provide new remote sensing and spacecraft technologies.

D. Chinese meteorological satellites

28. China, as a country with vast territory, complicated weather and large population, is in urgent need for improved accuracy of weather forecasts, particularly for early warning of dangerous weather conditions like tropical cyclones, storms, cold waves and hail. China began the development of its satellite meteorological systems in the early 1970s, began to participate at the Coordination Group for Meteorological Satellites (CGMS) in 1986 and became a member in 1989. The first Chinese polar meteorological satellite, FY-1A, was successfully launched in September 1988. FY-1B was launched in September 1990 and FY-1C is scheduled for launch later this year.

29. The FY-1 is a three-axis stabilized satellite with a hexahedron main body and two solar panel wings mounted on each side along the flight direction. Its tasks are to obtain visible and infrared radiation data from the atmosphere from the onboard scanning radiometer (ground resolution of the analog image is 4 km, of the digital image 1.1 km); remotely sense the ocean by two visible light channels of the radiometer; and monitor the composition of cosmic rays by the space environment monitor. Its standard Sun-synchronous orbit has an inclination of 99 degrees, altitude of 870 km and orbital period of 102.86 minutes.

30. In the 1980s, emphasis was put on the development of a geostationary meteorological satellite, the FY-2. The FY-2(02) satellite was successfully launched by a Chinese LM-3 rocket on 10 June 1997. On 17 June, it was positioned over the equator at 105 degrees East longitude. The first images were obtained on 13 July and the satellite was declared operational on 1 December 1997. The main functions of the satellite are to: obtain day-night pictures and chart water vapour distribution in visible, infrared and water vapour channels of the scanning radiometer; disseminate high-resolution digital stretched cloud pictures, low resolution cloud pictures and weather charts for facsimile broadcasting to the meteorological data terminals at home and abroad; collect meteorological, hydrological and oceanographic data from data collecting platforms; and monitor the solar activity and the space environment by the on-board Space Environment Monitor.

31. The FY-2 satellite is dual-spin stabilized, its main cylindrical body is spinning 100 times per minute and its C-band, S-band and UHF-band antennas are mounted on the de-spun part. The apogee motor is located at the bottom of the satellite and after its separation, the total length of the satellite is reduced to 3 metres. The designed lifetime is three to four years and the solar cells provide 3,000 W of power at the end of life.

E. Applications of satellite meteorology in the Republic of Korea

32. The spatial and temporal distribution of moisture in the atmosphere is of major meteorological significance. Meteorological satellite observations can provide much needed information on global and regional moisture distribution at higher temporal resolutions. These calculations, although promising in many aspects, have yet to be fully developed. In particular, current infrared estimates do not have sufficient accuracy for numerical weather predictions. In the Republic of Korea, an attempt has been made to retrieve the moisture fields of the 1994 and 1995 *changmas* (rainy fronts).

33. Examination of *changma* moisture fields, corresponding to the variation and structure of the East Asian monsoon and subtropic high, is urgently needed for predicting *changma* characteristics (intensity, duration, onset and offset times, etc.) because this is the source of water over the peninsula of the Republic of Korea and the Democratic People’s Republic of Korea. The vast majority of annual precipitation for this region falls between late June and August. The area of heaviest rainfall usually migrates northward during this period, from the southern coastal areas and then up to the border between China and the Democratic People’s Republic of Korea, according to the monsoon front.

34. The total precipitable water fields, derived from the measurements of the TIROS Operational Vertical Sounder (TOVS) instrument on NOAA satellites for 1994 and 1995 *changmas*, revealed an apparent contrast between two significant moisture features corresponding to the evolution of the moving monsoon front. According to preliminary results, the total precipitable water fields seem to be largely controlled by the horizontal transport of water from the north-western Pacific Ocean, which plays a dominant role in maintaining and migrating its characteristics toward the peninsula.

F. Climate variability and the El Niño effect

35. In 1985, climatologists started serious investigations into whether it was feasible to make predictions beyond short-term weather forecasting. They were looking for seasonal predictions on a global scale, and naturally they selected the only clearly visible circulation anomaly on our globe which has obvious consequences to many nations. El Niño is an oceanic and atmospheric phenomenon in the Pacific Ocean, during which unusually warm ocean conditions appear along the western coast of Ecuador and Peru, causing climatic disturbances of varying severity. The term El Niño (Spanish for “the child” and referring to the infant Jesus Christ) originally was used to describe the warm southward current that appears in the region usually during the Christmas season, but it is now reserved for occurrences that are exceptionally intense and persistent. These occur every three to seven years and can affect climates around the world for more than a year. Because a fluctuation in air pressure and wind patterns in the southern Pacific accompanies El Niño, the phenomenon is also known as the El Niño Southern Oscillation, or ENSO.

36. The climate disturbances caused by El Niño occur when sea surface temperatures in the south-eastern tropical Pacific are unusually high. Normally, the warm waters are confined to the western tropical Pacific, with temperatures more than 10 Celsius degrees higher than the eastern waters of coastal Peru and Ecuador. The air pressure is quite low over the warmer waters. Moist air rises in the region, causing the clouds and heavy rainfall characteristic of south-eastern Asia, New Guinea, and northern Australia. In the eastern Pacific, the water is cold and air pressure is high, creating the typically arid conditions along coastal South America. The trade winds blow from east to west, pushing Sun-warmed surface waters westward and exposing cold water to the surface in the east.

37. During El Niño, however, the easterly trade winds collapse or even reverse. As the slight weakening of the winds causes a modest change in sea surface temperatures, the change in wind and pressure increases. The warm water of the western Pacific flows back eastward, and sea surface temperatures increase significantly off the western coast of South America. As this happens, the wet weather conditions normally present in the western Pacific move to the east, and the arid conditions common in the east appear in the west. This brings heavy rains to South America and can cause droughts in south-eastern Asia, India, and southern Africa.

38. Researchers have also learned that El Niño is the warm phase of a cycle that includes a cold phase, called La Niña, which appears when surface water in the eastern Pacific is abnormally cold. There has been less scientific interest in La Niña in the past two decades because there have been fewer cold events than warm ones. Although there are also weather anomalies associated with La Niña, researchers have yet to focus significant attention on this part of the cycle.

39. The global impacts of El Niño are varied and far-reaching. They typically include drought in southern Africa, Ethiopia, north-east Brazil, Indonesia, eastern Australia, southern Philippines and Central America. Flooding is likely to occur in northern Peru, southern Ecuador, southern Brazil, northern Argentina and Uruguay, among other locations. And in India, the rain-bearing life-giving monsoon tends to become irregular, making food production less reliable. Scientists have linked the El Niño that began in 1997, for example, to extraordinarily dry conditions that withered crops and caused widespread forest fires in Indonesia, Malaysia and parts of Brazil, not because people were less cautious than usual, but because of extreme drought. In Indonesia, the fires covered more than one million hectares of rain forest, producing a thick, smoky haze that blanketed much of south-east Asia for several months. Air pollution from the fires was blamed for causing tens of thousands of respiratory infections in Indonesia and for the widespread cancellation of air traffic in the region.

40. In countries such as Zimbabwe, where the economy is critically tied to maize production, the effects of drought can be devastating, while farmers in western South America can benefit by planting more rice instead of a normal crop of cotton during an El Niño, as they are likely to experience heavier than normal rainfall. The economic consequences therefore of El Niño can be staggering. Over $8 billion in damages can be directly attributed to the 1982 El Niño. Economic effects caused by the 1997/98 El Niño have not been assessed yet, but they are expected to be very high.

41. The weather forecasts of the 1997/98 El Niño have been available well in advance and there were about 60 countries which could have benefited from them. However, most of the local governments did not react properly. Now, the situation is slowly improving and more people are paying attention to El Niño and to its forecasts. Some groups are starting to take preventive measures to cope with its effects. Vaccination programmes in Ecuador, for example, have sought to inoculate people against waterborne diseases that might be unleashed as a result of flooding. In many regions, sewers and drainage infrastructures are being cleared of debris to permit water to flow more freely through the system. Berms are being constructed along vulnerable coastal areas. Emergency flood plans are being developed and people advised on how to manage the scarce water resources in case of drought.

42. The El Niño event of 1982/83 was considered the most severe of the 20th century. Other recent occurrences began in 1972, 1976, 1987, 1991 and 1994. But some scientists believe that the El Niño of 1997/98 may one day be known as “the climate event of the century”. Generally, there are more frequent and stronger El Niños now, compared with a few decades ago and the first half of the century. There are suggestions that human-enhanced greenhouse effects—the buildup of gases such as carbon dioxide, methane, and ozone that trap the Sun’s heat within the Earth’s atmosphere—is fundamentally altering El Niño by artificially warming Earth’s atmosphere. To answer this question, it would be necessary to have data going back a few hundred years. But instrumental records started in 1850 at the earliest. This is why the World Climate Research Programme has started paleoclimatic studies as well as attempts to reconstruct from isotope analysis of old trees what has happened since 1723 on a global scale. The project of establishing a global picture of circulation anomalies since that time could be finished by 2005 or 2010.

43. The 1982/83 event also fuelled a major international research effort to improve scientific knowledge of El Niño in order to forecast the onset of the phenomenon several months to a year in advance. The effort, which began in 1985 and ended in 1994, was called the Tropical Ocean and Global Atmosphere (TOGA) programme. This was the first attempt to produce realistic forecasts of sea surface temperature anomalies for periods of up to 12 months. The TOGA programme utilized new advances in technology to study El Niño, including specialized weather satellites, ocean-borne buoys equipped with sophisticated sensors and powerful computer weather models.

44. As a result of the basic infrastructure established by the TOGA programme, the 1997/98 El Niño event will be the most closely watched in history. Researchers, for example, rely on a network of moored and drifting buoys deployed across the Pacific Ocean to monitor water temperatures at various depths, wind velocity and direction, ocean currents, humidity and air temperature. This network, known as the Tropical Atmosphere Ocean (TAO) array, is jointly administered by France, Japan, the Republic of Korea, the United States and other Pacific Rim countries. Information from the array is relayed by satellite to research centres on a real-time basis.

45. The on-the-spot monitoring system (down to one-kilometre scale), as well as the space segment for collecting measurements and delivering them near-real-time to oceanographic and meteorological centres are essential for the development of complex computer models and generation of reliable forecasts. For example, the European Centre for Medium Range Weather Forecasts (ECMWF) is now using an 18-year series of weather observations to validate their predictions. Thus, if recent observations correspond with some of these series, specialists know that they are on a right track and can make their predictions available to the public. This was the case last December, when they correctly predicted the winter situation for the next two months. The ECMWF forecasts are now available on the Internet.

46. The most advanced method of predicting weather parameters now in use is the so-called ensemble prediction. It starts with the development of a complete three-dimensional model of the ocean-atmosphere system. New data are included and then the model is run several times with slightly different (a few days difference) starting dates. The degree in which individual predictions differ from each other shows the strength of the whole prediction. It is usually much better in the Pacific than in Europe, because chaotic weather systems over Europe make the predictions very difficult. On the other hand, these systems dump large anomalies over Europe and spare the continent of effects such as El Niño.

47. It is evident that weather forecasting is improving significantly in recent years. However, even when all the space projects and agencies for a global weather observing system are fully implemented, there will still be several gaps in necessary input data by 2005. There still will not be a complete three-dimensional monitoring of liquid water and ice in the atmosphere to a degree that is needed for good parametrization of clouds. The second major gap will still persist in the monitoring of soil moisture. In many places, atmospheric moisture depends on the storage of water in the soil. Plants are able to use this water and bring it back to the atmosphere, where it can in turn feed the precipitation. Unfortunately, there is no easy way to measure this parameter from space. There are some experimental methods to obtain soil moisture values indirectly from satellite microwave data, but they are far from operational.

48. A third gap in meteorologically important data that will also likely persist into the next century is the imprecise knowledge of the shape of the globe—the so-called geoid. Satellite altimetry can measure the sea level to an accuracy of several millimetres. However, in order to derive from these data the information on sea currents and other changes in the time scale of about 10 days, the geoid should be known at least with the same precision. This is why atmospheric scientists and oceanographers are supporting efforts of other scientists for so-called gravity missions.

G. Tropical Rainfall Measuring Mission

49. The Tropical Rainfall Measuring Mission (TRMM) is the first satellite in NASA’s Mission to Planet Earth programme. It is a joint mission between Japan and the United States, with strong scientific participation from other countries, including Australia, Brazil, France, Israel, Italy, Singapore, Thailand and the United Kingdom. The

TRMM spacecraft was launched successfully by the Japanese H2 rocket from Tanegashima spaceport on 27 November 1997. The largest science instrument on the TRMM spacecraft is the precipitation radar, the first rain profiling radar to be flown in space. Its sampling resolution is about 4 km spatially and 250 metres vertically. In addition, the satellite carries a five-channel passive microwave imager, a visible/infrared sensor, a lightning imaging sensor, and a clouds and Earth radiant energy monitoring system. The spacecraft is orbiting at an altitude of 350 km with an inclination angle of 35 degrees. The initial instrument checkout was completed and all five instruments are in excellent condition so that the data acquisition phase has already begun.

50. The three scientific objectives of the TRMM mission are to obtain and study multi-year science data sets of tropical and subtropical rainfall measurements; to understand how interactions between the ocean, air, and land masses produce changes in global rainfall and climate; and to improve modelling of tropical rainfall processes and their influence on global circulation in order to predict rainfall and its variability at various space and time scales. The second objective is closely connected with investigations of normal atmospheric circulation (so-called Walker Circulation) and anomalies like El Niño. There are already instruments in space to track climatic anomalies, including sea-surface temperature, ocean waveheight and wind stresses. TRMM is the latest member of these monitoring devices and it is the only one that can track vertical profiles on precipitation anomaly associated with El Niño.

51. TRMM will provide the scientific community with data and information about tropical rain systems and the global latent heating time series, improving understanding of the global energy budget and climate variability in different time scales. However, atmospheric dynamics are very complex and TRMM will only provide data for three to four years. There will be a lot of longer-term phenomena which cannot be registered by TRMM. Therefore, there are already plans for a follow-on mission to TRMM, which could be launched around 2002 into slightly higher orbit.

52. The primary objectives of the follow-on mission are: to study the role of horizontal-vertical distribution of latent heating fields on global climate variations at different time scales; to extend tropical rainfall time series for four more years; to have data synergy with Earth Observation Satellite instruments; and to provide more accurate inputs for the planned Global Climate Mission. The two key instruments of this mission would be a dual-frequency Doppler radar and a five-frequency channel radiometer.

53. The radiometer capability will be comparable to the TRMM microwave radiometer but the new radar will be significantly more powerful. For example, it could measure vertical motions associated with precipitation (TRMM does not have this capability because of budgetary reasons). This capability will significantly improve the accuracy in retrieving the latent heating profiles, which recently have been shown to be very sensitive to vertical air motion. The new radar will also have a second, 35 GHz radar frequency so that it can measure very light rain as well as ice particles.

H. Disaster management using Indian remote sensing satellites

54. Developing countries, with their diverse agro-climatic situation, high and unstable mountains, perennial waterways coupled with peak seasonal discharge, arid and semi-arid ecological conditions, are vulnerable to drought and desertification. Ironically, most of the large-scale natural disasters predominantly occur in the tropical regions, which encompass most of the developing countries that have no capability to withstand the heavy losses inflicted by such disasters. Hence, realization of an efficient disaster management system, which could address the social issues related to disaster mitigation, would help in reducing the impact of disasters on the vulnerable socio-economic profile of developing countries.

55. An effective system consists of three main components: disaster warning, management and relief. Clearly, the most important application of satellites is in detecting, providing and delivering early warning of impending disasters such as floods, droughts, cyclones and even forest fires. Continuous monitoring by both geostationary and low orbiting satellites like GOES, INSAT, METEOSAT and NOAA is capable of providing early warning on cyclones and floods. Remote sensing satellites have proven their capability to predict the onset of droughts by monitoring

vegetation on a continuous basis. Forest fires, environmental hazards, volcanic eruptions and even propagation of desert locust phenomena can be detected well in time by remote sensing satellites like Landsat, SPOT and Indian Remote Sensing Satellite (IRS). Data relay and communication satellites have the ability not only to deliver early warnings on various disasters, but also in disseminating requisite information on awareness and educating the local people in preparing themselves to face such hazards. Locale-specific unattended Disaster Warning Systems (DWS), installed by India along the vulnerable eastern coast of the country, using communication and meteorological capability of INSAT multi-purpose geostationary satellites, have proven their immense value in providing timely warning on cyclone and flood disasters over the last ten years.

56. Space technology for flood monitoring and management has been successfully made operational in India. Near real-time monitoring and damage assessment of major flood events are being carried out using the Geographic Information System (GIS) for the Brahmaputra river basin to provide information on flooded areas and damage to croplands, roads and railtracks. The GPS system is used to aid development of a Digital Elevation Model (DEM) of a flood-prone area in Andhra Pradesh State, to enable assessment of spatial inundation at different water levels in the river. When the satellite derived land cover/use and ground based socio-economic data is draped over DEM, flood vulnerability can be assessed to provide location-specific flood warnings. Microwave data from ERS-1 is also used in conjunction with optical data to overcome the limitation of cloud cover.

57. A remote sensing based National Agricultural Drought Assessment and Monitoring System (NADAMS) for country-wide monitoring in India has been developed and is being used for operational monitoring. NADAMS integrates the rainfall and aridity anomaly with a vegetation index data set to provide realistic assessment of droughts. Initially, biweekly drought bulletins for 246 drought-prone districts of the country were issued to concerned user agencies at all levels for necessary action. Based on the user feedback, the second phase of NADAMS, which includes detailed monthly drought assessment in terms of spatial variability and impact on crop/fodder production, was launched in 1992.

58. Satellite remote sensing based Integrated Mission for Sustainable Development (IMSD) is a unique Indian experience to evolve action plans towards combating droughts in the backdrop of socio-economic conditions of watersheds. The implementation of action plans has resulted in: reducing the run-off loss to one half; raising the water level from 0.9 to 5 metres due to impact of check dams and percolation tanks; and enhancing the agricultural productivity by a magnitude of two to five. Similarly, in a typical drought-prone region of Uma Gani watershed of Chandrapur District, these action plans were implemented with the active involvement of district officials, farmers and NGOs. There has been a remarkable change in the overall status of the watershed. Such efforts demonstrate that the mission of drought proofing/mitigation is accomplishable with the help of remotely sensed data, properly integrated with other collateral information.

59. Earthquake risk assessment involves identification of seismic zones through collection of geological/structural, geophysical (primarily seismological) and geomorphological data and mapping of known seismic phenomena in the region (mainly epicentres with magnitudes). Satellite imagery could be used in delineating neotectonic structures and to clarify seismo-tectonic conditions in earthquake risk zones. Space techniques have also overcome the limitation of ground geodetic surveys and have become an essential tool to assess the movement/displacements along faults and plate boundaries to even millimetre-level accuracy. This involves the Very Long Baseline Interferometry (VLBI), the three-dimensional differential interferometry (D-INSAR) and the GPS system.

60. A number of studies have been carried out in India using satellite data and aerial photographs to develop appropriate methodologies for terrain classification and preparing maps showing land hazard in the Garhwal Himalayan region, the Nilgiri hills in South India and in the Sikkim forest area. In the Tehri dam reservoir periphery, these images have helped in identifying 71 potential landslide areas. The exercise carried out in Niligiris has helped in delineating landslide hazard zones and identifying areas least prone to this hazard, where house building activities can be taken up. The availability of one-metre resolution data from the future satellites can easily help in delineating contour levels at two-metre intervals making space remote sensing a highly cost-effective tool in this regard.

61. An innovative use of INSAT spacecraft has been in the implementation of the unique, unattended locale-specific DWS, consisting of over 150 disaster warning receivers installed in selected cyclone prone areas of the country, designed to provide warning to coastal villages about an impending cyclone. Since the commissioning of DWS and its first operational use for disaster warning in 1987, it has become a vital disaster mitigation mechanism. The most memorable use of DWS was during the cyclone that hit the Andhra Pradesh coast on 9 May 1990, enabling the Government to evacuate over 1,700,000 people and thus saving thousands of lives and livestock in this area. Additional DWS units are being established to cover the entire coastal areas of the country. Cyclones in the southern hemispheric Indian Ocean are also regularly monitored by INSAT and advisories are issued to various countries of this region.

62. Having successfully demonstrated the potential of Earth observation and communication satellites in addressing various aspects of disaster warning, mitigation and management, the Indian efforts in the coming years puts emphasis on synergetic use of the systems and arriving at the Integrated Disaster Monitoring Management System. While the IRS satellite series provide the required data on terrain features and topographic aspects as well as on the spatial extent and distribution once the disaster occurs, the INSAT series of satellites are planned to be used for ensuring appropriate connectivity and flow of information, including dissemination of disaster warning signals. Besides, the INSAT series are multipurpose missions, carrying meteorological payloads, the data from which are being effectively used for a number of applications related to disaster management. The realization of such an integrated system also calls for appropriate interface with concerned central state departments, agencies, as well as involvement of a large section of society starting from the decision makers to grass-root level officials. Efforts have already been initiated and the realization of the system on a pilot scale is targeted by 2000.

I. Desert monitoring in Morocco and other countries of the Mediterranean region

63. On the regional and national level, the most useful are the data from the NOAA polar orbiting satellites. The standard resolution data enable monitoring on a weekly, monthly and yearly time scale of the natural vegetation cover. Frequently used parameters comprise albedo (AL), normalized difference vegetation index (NDVI), and surface temperature (ST) and they can be used to characterize the hydraulic stress in soil and zones prone to desertification. The FAO project ARTEMIS is aimed at production of monthly maps of the vegetation index for all of Africa. For the Sahel region, such data are already available for a nine-year period. The European Union projects TREES and FIRE provide data on deforestation and presence of forest fires in tropical regions.

64. In the Mediterranean region, there are many additional regional projects. The first category is directed towards the development of new databases: project CEO-DIN connects existing databases in different organizations (FAO, Joint Research Centre of the European Commission) through the Internet. The programme MEDALUS is developing an information database for climatological and socio-economic studies in southern Europe.

65. The second group of regional projects is related to the monitoring of environmental degradation by remote sensing technology. Project DEMON is devoted to mapping the soil degradation and vegetation changes in the Mediterranean area, while EFEDA is studying the interaction of biology and climatic factors at different stages of the local development. The third group of projects (ASMODE, in cooperation with the Netherlands and Spain, and CAMELEO) are developing methodologies of evaluation of desertification data obtained by the remote sensing technique.

66. There are also national programmes in countries like Jordan, Kenya and Morocco. In Jordan, the existing GIS data enabled distinctions to be made between four types of desertification (slight, medium, severe and very severe). In Kenya, the GIS data were used within the framework of the FAO/PNUE project and in Morocco of the similar GEOSTAT project. The necessary calibration and correction of data (geometric, radiometric and atmospheric) was provided within the framework of the AGRIMA programme.

67. A pilot project to investigate the vegetation on the Maamora forest region (150,000 hectares) using SPOT data should result in a map (scale 1/50,000) of the forest changes and their statistical inventory. In principle, such inventories of vegetation, soil composition and moisture are perfect tools for further detailed desertification monitoring. The final goal is the development of the complex information system on desertification SID (Système d'information sur la désertification), enabling an integration, compilation and analysis of data diagnosing the local ecosystem. The first step towards this system is the project SAND (Space Assisted Network Against Desertification), proposed by the International Space University in Strasbourg, France.

J. Land cover studies using meteorological satellites in Brazil

68. Data obtained from NOAA environmental satellites are operationally used to provide assessment of weather information, land cover monitoring and forest fire outbreaks in Brazil. In the last few years, a number of studies concerned with land cover variables have been conducted at the Brazilian Institute for Space Research (INPE) using Advanced Very High Resolution Radiometer (AVHRR) data and other information from NOAA satellites. The aim of these studies is to monitor vegetation cover and forest fires to understand their effects on global change processes.

69. The knowledge of the state of land surface cover is important for understanding the energy exchange process and other fundamental physical processes which take place at the interface of land and atmosphere. In tropical countries like Brazil, vegetation covers a significant portion of the land surface and is an important source of sustenance for the whole population. However, in the last few decades, a significant portion of the Brazilian vegetation cover has been disturbed by humans to clear land for agriculture, settlements and other different purposes. Concerned with this problem, several studies have been carried out at INPE to obtain quantitative measurements, general pattern distribution, and seasonal changes in vegetation on a regional basis using AVHRR data. Also, a scheme to map forest fires was implemented.

70. An analysis of vegetation, soil and shade fraction images derived from AVHRR and NDVI vegetation data to monitor land cover over the State of São Paulo, south-east Brazil was performed recently. Six AVHRR images from 21 to 26 June 1993 were composed and used to obtain fraction images over the São Paulo State. The vegetation fraction component values were highly correlated with NDVI values and the vegetation fraction image showed a good agreement with a regional vegetation map derived from Landsat thematic mapper (TM) images. In general, the AVHRR-NOAA derived products have a potential to monitor urban islands, mapping vegetation on a regional scale and to differentiate forested from agricultural areas. On the other hand, visual analysis between false colour NDVI images and global vegetation maps shows poor agreement.

71. The analysis of NDVI monthly composites derived from AVHRR Global Area Coverage (GAC) data over the Amazonian region and neighbouring areas shows a significant seasonal variability of the following vegetation types: transition forest, corrado (savanna) and caatinga (semi-arid native vegetation) cover types. This feature is useful for monitoring vegetation types. Year to year variability of NDVI monthly data over north-eastern Brazil and the Amazonian region show strong influence of the El Niño Southern Oscillation events.

72. Forest fires have been monitored in Brazil since 1988 using meteorological satellite data. Basically, these fires are detected as pixels with very high brightness temperatures or low values of gray shades using AVHRR channel-3 data. This 3.8 micrometre channel is very sensitive to high temperature targets. In general, saturated pixels are associated with nominal temperatures around 320 K in this channel. However, even a fire front with a width of 50 metres could cause a response in a full resolution AVHRR image. From 1995/96, INPE operationally monitored mid- and late-afternoon fire outbreaks around the country from June though November. A total of 39,778 fire-pixels were detected in 1995 and 31,944 in 1996, using NOAA-12 data. Mato Grosso and Pará were the States which presented the highest incidence of fire pixels during the study period. They accounted for approximately 50 per cent of the total number of fires over the entire country.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Space debris environment and mitigation

73. The United States of America has the longest space debris mitigation experience. Its current policy was established by Presidential Decision Directive NSC-48/NSTC-8, National Space Policy of 14 September 1996. In August 1995, NASA's Office of Safety and Mission Assurance issued NASA Safety Standard (NSS) 170.14, Guidelines and Assessment Procedures for Limiting Orbital Debris. The Department of Defense (DOD) policies are defined in DOD Space Policy of February 1987 and in the United States Space Command Satellite Disposal Procedures of November 1997, and policies of the commercial sector in the Commercial Space Launch Activities act issued in 1994.

74. The United States space debris mitigation priorities are to make the spacecraft safe by eliminating all stored energy (propellants, pressurants and batteries), at the end-of-life; relocate the spacecraft to a disposal orbit (decrease the perigee of the low Earth orbit (LEO) to limit orbital lifetime to less than 25 years, and raise the perigee not less than 300 km above geostationary orbit (GSO) for GSO objects); and, when feasible, do the relocation before "safing" the spacecraft. Examples of recent operational procedures to minimize debris creation during the launching phase include the Delta launcher second stages executing depletion burns after executing the payload contact avoidance manoeuver; pressurants being vented and batteries left on open circuit; Centaur upper stages being vented at the end of mission and batteries left on open circuit; and, Pegasus XL launchers having been modified to provide for a depletion burn after payload deployment. All newly launched United States upper stages and spacecraft are modified to eliminate operational debris; retain captive separation devices; keep captive deployment and restraint devices; and disable pyrotechnic devices.

75. Regarding United States manned spaceflights, the Space Shuttle is being modified to have greater debris and meteoroid tolerance; the International Space Station (ISS) is shielded to withstand impacts of debris smaller than 1 centimetre in diameter; and collision avoidance manoeuvres are performed to avoid tracked objects both at launch and on orbit.

76. The Japanese Society for Aeronautical and Space Sciences (JSASS) committee on space debris prevention design standards published the final report for the Japanese National Space Development Agency (NASDA) standards and design criteria in March 1996. Based on this report, NASDA established the NASDA-STD-18 "Space Debris Mitigation Standard" on 28 March 1996. The NASDA Standard includes the following mitigation measures: passivation of the spacecraft and the upper stages at the end of the mission; re-orbiting the spacecraft and upper stages at the end of the mission; disposal of objects in geostationary transfer orbit in order not to pose a risk to the geostationary orbit; minimizing the debris released during normal operations; and post-mission disposal of spacecraft from low Earth orbit.

77. NASDA has already implemented the draining of residual propellants and helium gas from the H-I/H-II second stage. The release of mechanical devices at satellite separation and solar paddle deployment has been avoided except in some particular missions, such as the separation of spent apogee motors for the geostationary meteorological satellites. In order to prevent unintended destruction of H-II second stages in space, the command destruct system is disabled immediately after injection into orbit and its pyrotechnics are thermally insulated to prevent spontaneous initiation. The measures adopted for NASDA programmes seem to be relatively inexpensive and have been proven to be very effective.

78. Strict mitigation measures are applied to all French space agency CNES launches. The basic requirement is to leave no more than one piece of passivated debris in orbit per payload. This means the upper stage of the launcher in the case of a single launch, and the upper stage with link structure in the case of a dual launch. The separation of the payload from the last stage of the Ariane 4 launcher should not generate any other debris (pyrotechnic separation should be "clean" and remains of pyro bolts should be trapped). The normal use of the upper stage should not

generate other debris; therefore solid propulsion in orbit is avoided and the end-of-life of the batteries and cells should not lead to explosions. To passivate the upper stage, pyrotechnic valves to empty the tanks and decrease the internal pressures are added.

79. During the development of a new Ariane 5 launcher, passivation requirements were taken into account in the early design phase. It was decided to provide for a direct controlled re-entry of the main cryogenic stage, even though it means the loss of 500 kilograms of deliverable payload to the geostationary transfer orbit. The passivation of the upper stage means provision of additional hardware (lines, nozzles, pyrotechnic valve) and reduction of internal pressure from 20 to 1 bar in 10 minutes after final injection burn. To avoid collision and pollution of the payloads, the upper stage should perform a dedicated attitude manoeuvre.

80. To avoid overcrowding the useful orbits with “dead satellites” and reduce pollution and collision risks, CNES is developing disposal procedures at the end of a satellite’s useful life. For low Earth orbits, de-orbit manoeuvres should induce a destructive re-entry of the satellite into the atmosphere. For GSO, manoeuvres are required to put the satellite on a graveyard orbit, typically 300 km above GSO. Software to predict potential collisions between the operational satellites and registered space debris and other related studies are also under development.

81. In connection with the introduction of large commercial satellite constellations in LEO, the impact of such a huge number of satellites on the space and space debris environment has been studied at different institutions, e.g. at the Defence Evaluation Research Agency of the United Kingdom and at the German Institute for Flight Mechanics and Spaceflight Technology of the Technical University of Braunschweig (IFR/TUBS). Interest has been mainly focused on the internal collision risk in case of a fragmentation within the constellation on the one hand and its contribution to the global debris evolution on the other.

82. Studies performed at IFR indicate that the first of these two problems seems to be negligible, given that the members of a constellation operate at the same altitude band, often in multiple, nearly polar-orbit planes that are phased in right ascension and intersect at high latitudes. Nevertheless, a collision of constellation members among each other is seen as extremely unlikely due to active satellite controlling by the ground stations during the operational lifetimes and intended de-orbiting strategies afterwards. Even in the event of fragmentation of one member as a result of a collision with an object of the background debris population, the additional flux imposed by this fragmentation cloud to the remaining satellites of the constellation is several orders of magnitude below the background.

83. The second problem, the impact of constellations on the overall debris evolution, is much more severe. The constellations planned for the future comprise up to several hundred satellites and consequently will contribute significantly to the accumulated in-orbit area within their altitude regime. In addition, most of these constellations will operate at an altitude between 700-1,400 km, which is currently the area of highest object density. Hence, the risk of a collision followed by complete disintegration of the target is increased to a comparatively high level. Most of the companies projecting such LEO constellations have agreed to include an end-of-life de-orbiting procedure into their system concept. But even in the ideal case that every satellite launched can be removed after its operational life, the collision risk is enlarged significantly due to the steady large number of operational satellites added to the background population.

84. The ESA *Space Debris Mitigation Handbook* is to be published shortly. Its purpose is to provide technical information on the space debris situation and guidance on how to avoid space debris in further spacecraft design and mission planning. This *Handbook* is intended to be used for these purposes within ESA and in the European industry as well as in space research planning. The *Handbook* has no regulatory character. However, if regulations were to be introduced in Europe by other documents, reference could be made to suitable paragraphs of the *Handbook*. An approach of this kind has already begun, with the drafting of the European Cooperation for Space Standardization (ECSS), where initial paragraphs on space debris are contained and later can include reference to the *Handbook*.

85. The *Handbook* is printed out as the product of an underlying software. The software controls the text as well as all graphical material, such as diagrams, sketches, tables etc. By making changes to the parameters of the underlying software, the *Handbook* can easily be updated according to technology and environment changes. The underlying software calls upon a set of computer codes and space debris environment models and produces the graphs in the *Handbook* (or updates thereof) in an automatic editing manner. A loose-leaf book edition is envisaged in order to update the copies of all users.

86. Specific programmes and techniques are being developed in the Russian Federation to avoid upper rocket stages from entering into orbit around the Earth. The spacecraft itself is inserted into its working orbit by means of an additional smaller booster module or apogee stage. Such techniques will be used operationally on the newly developed Zenit and Angara launchers. Work is under way to reduce the periods of time during which spacecraft and upper rocket stages remain in orbit in passive ballistic mode. In particular, the modernized Soyuz-2 launcher will be fitted with a passive braking system consisting of a deployable light construction on its upper stage, increasing its diameter to 10 metres. The orbital lifetime of the stage could be reduced this way by a factor of 5 to 6.

87. In order to prevent the booster module DM of the Proton launcher from entering into GSO, a technique is being examined for its insertion into an orbit located in the GSO plane, but at a higher altitude. The subsequent injection of the spacecraft into GSO would be performed by means of the on-board engine assembly which remains a part of the spacecraft body. Measures are currently being taken to remove spent spacecraft from GSO with a view to preclude any possible collisions. Such disposal measures involving the burn-up of residual propellant in the on-board engines are currently envisaged for spacecraft in the Ekran and Gorizont series. An analysis of the statistical data shows that the amount of residual propellant in the engine units makes it possible to increase the altitude of spent objects to 200 km above the GSO. In the development of future Russian geostationary spacecraft, the introduction of special on-board fuel capacity is envisaged, which will make it possible to increase the altitude of spent objects to more than 200 km above the GSO.

88. In the Russian Federation space programme, the following measures are envisaged for preventing explosions: passivation of spent rocket stages and space objects remaining in orbit, i.e. the release from tanks and gas bottles of propellants and pressurants that could cause their explosion even after a considerable period of time. It is proposed to fit the DM upper module of the Proton and second stages of Zenit launchers with appropriate equipment. Modifications of the on-board power-supply circuits of the Ekran satellite should improve its structural integrity and prevent accidental creation of debris due to electric faults.

89. The BUFFER computer program has been developed by the Russian Space Agency’s Central Engineering Research Institute and is now undergoing further refinement for the purpose of calculating the probability of non-penetration of the hermetic surface of spacecraft and orbital station modules. This program will be used to evaluate the effectiveness of, and choose optimum parameters for, the shielding of the Russian segment of the ISS. The accuracy of collision-risk evaluations and the reliability of the chosen design for the ISS shielding depends mainly on the precision of the space debris models in the particle-size range presenting the greatest hazard (1-10 cm). At present, the mathematical uncertainty with regard to the values of particle fluxes in this size range is a factor of up to 10. It is therefore essential to develop a more precise model of space debris environment in the ISS orbit on the basis of experimental data, mainly from the Mir orbital station long-term exposure surface detectors.

90. Russian specialists have compiled a catalogue of dangerous space debris approaches to the space station (several million approaches) and an algorithm for deciding whether to proceed with an avoidance manoeuvre. A chain of technological facilities has been established for this purpose. It is planned to organize an operational information service and to set up a hardware-software system to identify hazardous situations involving the predicted approach of orbital stations by larger space debris and avoid collisions. The work is under way to establish a special telecommunications system linking the command point with the space flight control centre.

91. The International Academy of Astronautics supports the position that there are several space debris mitigation actions that should be initiated immediately to ensure the future viability of space operations. They fall into two categories: those requiring minimal impact on the design and operations and those requiring significant changes in hardware or operations. Both categories of measures do not require development of new technology.

92. Category I comprises those measures that require no or limited changes to the design and cost impacts are in general minimal. However, they may imply changes in hardware and operations and some performance reduction may result. Category I measures include the following: no deliberate break-ups of spacecraft that produce debris in long-lived orbits; minimization of mission-related debris; passivation (venting, burning to depletion, and battery safing) of upper stages and spacecraft in any Earth orbit at the end of mission; for spacecraft and rocket upper stages below 2,000 km with excess fuel, at the end of operations, lower the perigee altitude to minimize the orbital lifetime; reorbiting of geostationary satellites to a disposal orbit (minimum perigee altitude increase 300 km above GSO); and upper stages and spent apogee booster motors used to move satellites from the transfer to geostationary orbit should also be inserted into a disposal orbit at least 300 km above GSO and freed of residual propellant.

93. Category II comprises those options that require either significant changes in hardware or operational procedures. However, no new technology developments are needed. Category II options are aimed at removing used upper stages and defunct spacecraft from orbit within Tmax years (the numerical value should be agreed on by consensus of all involved agencies), thus eliminating a major debris source. They include the following: removal after end of mission within Tmax years of all rocket upper stages and defunct spacecraft in orbits with an apogee below 2,000 km altitude; removal after end of mission within Tmax years of all rocket upper stages and spacecraft in geostationary transfer orbits, transfer orbits to 12-h orbits or other eccentric orbits with a perigee altitude below 2,000 km in altitude; and re-orbiting of upper stages and satellites at the end-of-life into a disposal orbit (as a temporary measure) for circular orbits above 2,000 km altitude.

94. The debris control measures in categories I and II can be carried out with existing technologies. According to the International Academy of Astronautics, the search for new mitigation methods, technical feasibility and cost-efficiency should be pursued further. Of great benefit for the space environment would be advanced propulsion capabilities and reusable launch systems, in particular reusable upper stages. Advanced propulsion techniques could lower cost for de-orbiting or render feasible de-orbiting from high-energy orbits.

95. In 1993, an Inter-Agency Space Debris Coordination Committee (IADC) was formally founded in order to exchange information on space debris research activities between member space agencies; to review progress of ongoing cooperative activities; to facilitate opportunities for cooperation in space debris research; and to identify debris mitigation options. The founding members were ESA, Japan, NASA and the Russian Space Agency (RSA). China joined in 1995, the British National Space Centre (United Kingdom), CNES (France), the Indian Space Research Organization (ISRO) in 1996, and the German Aerospace Research Establishment (DLR) in 1997. Recently, the Italian Space Agency (ASI) applied for membership.

96. The IADC Working Group Chairs are elected to serve a term of two consecutive meetings. Each member (nation or organization) must be represented in the Steering Group and in Working Group 4 on mitigation. Representation in other Working Groups is desirable but not mandatory. Formal meetings of the full IADC are scheduled about once a year. All agreements of IADC are made by consensus and these voluntary mitigation measures have proven effective in both low and geostationary orbits. In the future, however, wide compliance with the full range of mitigation measures will be needed in order to avoid an uncontrolled growth of the debris population.

B. Russian segment of the International Space Station

97. The Russian Federation has accumulated significant scientific and technological experience in the field of manned spaceflight. The most recent is the 12 years of continuous operation of the Mir orbital station. From 1992 to 1997, there were 14 primary crew expeditions (numbers 11 to 24) and six visiting expeditions at Mir, involving

representatives of France four times, Germany twice, and several other ESA countries. The total duration of foreign cosmonauts staying at Mir during that period is over 600 days and the recent trend is to extend the duration of visiting expeditions from traditional 7-8 days to 20-21 days and incorporating foreign cosmonaut researchers into the crews of primary expeditions.

98. An important factor in developing and strengthening international cooperation in space is the Phase One of the ISS programme, which involves the docking of the United States Space Shuttle at the Mir station and long-duration stays of United States astronauts at the station. The priority in this programme is given to the basic research activities (including space medicine, biology and materials science) and testing the advanced technology and processing equipment. The most important is gaining experience in organizing long-term activities of international crew at the station, as the precursor to ISS.

99. The ISS will be constructed from modules and elements developed by Canada, ESA, Japan, the United States (the United States segment) and the Russian Federation (the Russian segment). The beginning of orbital assembly is planned for late this year and the ISS operational lifetime would be at least up to 2012. The Russian Federation involvement in the ISS partnership since December 1993 led to the improvement of the project and to the alleviation of some problems (technical as well as budgetary). For example, there were no means, until the recent redesign, for fuel transportation, station refuelling, appropriately improved crew life-support means for long-term flights and emergency return vehicles for the crew (the Shuttle orbiters do not have the capability for long-term parking at the station). The experience of operating the Mir station for 12 years is twice the initially perceived lifetime and will be used in the development of the ISS, including operations of such systems as thermal control, power supply, air purification, etc.

100. The Government of the Russian Federation has made all necessary commitments to allocate financial resources to support the activities in the ISS project to provide for successful implementation of its obligations. Though the project implementation requires significant financial expenditures, they might be compensated by managing semi-industrial production of various substances, materials, medicines and biocompounds. In the framework of the Science-NASA/RSA (Russian Space Agency) programme, more than 150 Russian research teams conduct extensive investigations to define the most valuable studies and experiments at the manned orbital stations. In 1996, the Mir-NASA programme consumed over 62 per cent of available crew activity time, about 65 per cent of total payload upward traffic and 63 per cent of total payload downward traffic to support the United States' science and technology investigations.

101. The RSA Science and Technology Advisory Committee (STAC) conducts preliminary appraisal and selection of proposals filed for the research and application investigations programme at the ISS's Russian segment. Foreign scientists also present their proposals. The STAC already selected over 170 proposals for scientific investigations and experiments and recommended them for implementation at the ISS. The ISS project is seen as a model of world community cooperation in implementing large-scale projects and consolidating scientific, technological and economic potential of different countries to solve the problems for the benefit of mankind.

C. Planetary research and astronomy

102. The Cassini spacecraft, in development since October 1989, is a cooperative endeavour of NASA, ESA and Italy's ASI. The mission will send a sophisticated robotic spacecraft equipped with 12 scientific experiments to orbit Saturn for a four-year period and to study the Saturnian system in detail. The ESA-built Huygens probe that will parachute into Titan's thick atmosphere carries another six scientific instrument packages.

103. Cassini is a follow-on mission to the brief reconnaissance of Saturn performed by the Pioneer 11 spacecraft in 1979 and the Voyager 1 and 2 encounters of 1980 and 1981. Those highly successful flybys produced volumes of new information, discoveries and questions about Saturn, its environs and its family of rings and moons. Those encounters, along with recent key findings from the Hubble Space Telescope and ground-based observatories,

continue to entice scientists who view the Saturnian system as a clue to the history of planetary and solar system evolution. The mission is named for two seventeenth-century astronomers. Italian-French astronomer Jean-Dominique Cassini (born Gian Domenico Cassini in his native Italy) made several key discoveries about Saturn between 1671 and 1684; he established that Saturn's rings are split largely into two parts by a narrow gap, known since as the Cassini Division. Dutch scientist Christiaan Huygens discovered Titan in 1655 and was responsible for many important Saturn findings.

104. Saturn is the second largest planet in the solar system. Like the other gaseous outer planets Jupiter, Uranus and Neptune, its atmosphere is made up mostly of hydrogen and helium. More moons of greater variety orbit Saturn than any other planet. These natural satellites range from Titan, which is larger than either Mercury or Pluto and nearly the size of Mars, to bodies so small that astronomers call them "moonlets". Although it is believed to be too cold to support life, haze-covered Titan is thought to hold clues to how the primitive Earth evolved into a life-bearing planet. It has an Earth-like, nitrogen-based atmosphere and a surface that many scientists believe probably features chilled lakes of ethane and methane (which may also pool in subsurface reservoirs). Scientists believe that the Moon's surface is probably coated with the residue of a sticky brown organic rain. Titan's orange haze chemically resembles smog, and it is thought to be composed of naturally occurring, smoke-like hydrocarbon particles.

105. The launch of the Cassini/Huygens spacecraft was performed successfully on 15 October, when the Titan IVB/Centaur rocket lofted the spacecraft onto the interplanetary trajectory that will deliver it into orbit around Saturn (as its first artificial satellite) almost seven years later, on 1 July 2004. Cassini's primary mission should conclude in July 2008. In manoeuvres called gravity-assist swingbys, Cassini will twice fly past Venus (26 April 1998 and 24 June 1999), then once each past Earth (18 August 1999 at a distance of 1,150 km) and Jupiter (30 December 2000) on its way to Saturn. The spacecraft's speed relative to the Sun increases as it approaches and swings past each planet, giving Cassini the cumulative boost it needs to reach its ultimate destination. On 6 November 2004, Cassini will release the disc-shaped Huygens probe towards Titan.

106. After a three-week ballistic free fall toward Titan, the 2.7 metre diameter battery powered Huygens will enter Titan's atmosphere, deploy its parachutes and begin its scientific observations. Data gathered during Huygens' 2.5-hour descent through Titan's dense atmosphere will be radioed to the Cassini spacecraft and relayed to Earth. Instruments on the descent probe will measure the chemistry, temperature, pressure, density and energy balance in the atmosphere. As the probe breaks through the cloud deck, a camera will capture panoramic pictures of Titan. Titan's surface properties will be measured, and more than 500 images of the clouds and surface will be returned. In the final moments of descent, a spotlight will illuminate the surface for spectroscopic measurements of its composition. If the probe survives landing—which should occur at a fairly low speed of about 25 km per hour—it may return data from Titan's surface, where the atmospheric pressure is 1.6 times that of Earth's and the temperature is -179° C. The exact conditions it will encounter are unknown; the probe could touch down on solid ground, rock-hard ice, or even splash down in a lake of ethane and methane.

107. During the course of the Cassini orbiter's mission, it will execute more than 40 targeted close flybys of Titan, many as close as 950 km above the surface. This will permit high-resolution mapping of Titan's surface with the Titan imaging radar instrument, which can see through the opaque haze covering that moon to produce vivid photograph-like images. The Cassini spacecraft, including the orbiter and Huygens probe, is the most complex interplanetary spacecraft ever built. Its sophisticated instruments are state-of-the-art and represent the best technical efforts of the United States and 16 European nations involved in the mission.

108. Because of the very dim sunlight in Saturn's orbit, solar arrays are not feasible. Electrical power is supplied to the orbiter by a set of radioisotope thermoelectric generators (RTGs), which convert the heat from the natural decay of plutonium-238, in the form of plutonium dioxide, to electricity for Cassini's systems. The same material is used in 117 radioisotope heater units (RHUs) placed on Cassini and Huygens to keep electronics systems at their operating temperatures. RHUs were most recently used on the Mars Pathfinder mission's Sojourner rover to keep

the system from failing during cold Martian nights. Huygens will draw its electrical power from a set of five batteries during its entry and descent into Titan's atmosphere.

109. Telecommunications with Cassini spacecraft during the mission will be carried out through the giant dish antennas of NASA's Deep Space Network, with complexes located in California, Spain and Australia. Cassini's high-gain antenna is provided by ASI. Data from the Huygens probe will be relayed to an ESA operations complex in Darmstadt, Germany. The overall mission is managed by JPL for the NASA Office of Space Science, Washington, D.C.

D. Availability of remote sensing data

110. The data from the Landsat spacecraft constitute the longest record of the Earth surface as seen from space. The new satellite, Landsat 7, is to be launched later this year not only to continue this record, but to add new possibilities. It will carry the Enhanced Thematic Mapper Plus (ETM+) providing panchromatic images with 15-metre spatial resolution, thermal infrared channel with 60-metre resolution and with the possibility of on-board radiometric calibration. At the same time, the ETM+ still provides data continuity with the Thematic Mapper (TM) that flew on Landsat 4 and 5.

111. The first Landsat, Landsat 1, was launched in 1972 in response to the possibilities of an expanded basis of Earth remote sensing following the early success of the TIROS and Nimbus series of experimental meteorological satellites. Its multi-spectral scanner (MSS) proved so valuable that a version of it has been flown on each of the first five Landsat missions. With the 1982 launch of the Landsat 4, the TM sensor was introduced. The TM was a significant improvement over the MSS, providing greater resolution in the visible and infrared regions (30 versus 80 metres) and three additional spectral bands. The Landsat 3 version of the MSS also was flown to ensure data continuity with the new sensor and to provide additional backup. The same payload was installed on Landsat 5, launched in 1984.

112. There was a fundamental shift in the United States policy toward Earth remote sensing in 1984. After intense discussion, focused on the roles of the Government and the private sector, the Land Remote Sensing Commercialization Act was adopted. The Earth Observing Satellite Company (EOSAT) was awarded a contract to operate the Landsat system for 10 years and to develop and build two new satellites, including the ground system. In May 1994, a Presidential Decision Directive was signed to further stabilize the Landsat Program. This directive clarified the roles of NASA and the United States Departments of Commerce, Interior and Defense. In particular, it charged NASA with assuming the previously shared responsibilities and with developing a strategy to maintain the continuity of Landsat-type data beyond Landsat 7.

113. While the NOAA will manage all Landsat 7 mission operations, the United States Geological Survey's Earth Resources Observation Systems (EROS) Data Center of the Department of Interior will maintain the national archive of existing and future Landsat-type remote sensing data within the United States and will make them readily available to federal and other users. The new organization should also improve access to the data collected by the network of international ground receiving stations. These data should be available to end users within 24 hours after their capture. Because the calibration of the data will be limited to only radiometric correction and first-order geographic registration to the digital image data, new opportunities will be open for value-added private providers. They will be able to furnish enhancements, interpretations and specialty products without fear that the Government would undercut their offerings.

114. The Russian Federation government, in the spirit of openness, decided in 1992 that imagery from the Russian defence satellites can be used for civilian purposes. Space imagery has the same characteristics as aero-cartographic imagery, but is substantially cheaper and covers wider areas, including remote regions. The Russian defence satellite imagery is available as monographic (areas 40 by 160 km with 2-metre details) and stereographic (areas 200 by 300 km with 10-metre details). The geographic location of the imagery is also provided with high accuracy. On a

commercial basis, the archive data can be provided or a new imagery of the given area ordered. For the time being, the catalogue of existing data is not open to public search. The data are provided either as an original film, copy of the negative, print, digital data on magnetic media or computer-ready compact disc.

115. If requested, the data could by corrected for different effects and processed information like high-scale digital orthographic maps (scale up to 1/4,000), digital elevation models (with step 100 metres and guaranteed accuracy of 10 metres in elevation) or high-scale topographic and thematic maps (digital/hard copies) supplied. Even more sophisticated and user-specific products are offered. For example, a three-dimensional model of Bangkok city was developed using a single satellite image—the height information (with an accuracy of 2 metres) has been obtained from the length of the shadows of buildings and from the geometry of their side walls.

116. Since the Russian Federation’s defence cartographic and topographic organizations cannot operate at the world market directly, a specialized agency, called Rosvorouzhenie State Corporation, is acting as a mediator. Its purpose is to deal with all international business regarding the military and specialized technology, as well as with licences, services and provision of information involving the military area. It is exporting 90 per cent of the Russian military-related technology, cooperating with over 50 countries and has representation in 33 countries. It also plays an important role in the conversion of military technology to peaceful purposes.

E. Cooperation in remote sensing applications

117. Rangelands occupy nearly 80 per cent of the Moroccan territory and cover about 30 per cent of the nutritional requirements of the national livestock. They are located in fragile ecosystems and have been subject to strong degradation for many years, due to environmental stress (arid climate, poor soils, strong erosion, overgrazing and demographic expansion). These ecosystems need rigorous management and frequent monitoring. The Geostat-Morocco project was conducted to develop a methodology based on remote sensing and GIS techniques, and will provide regular rangeland acreage estimates both quickly and cost-effectively. The feasibility project Geostat-Morocco was conducted jointly by the Royal Centre for Remote Sensing (CRTS) Morocco, Scot Conceil of France and several other Moroccan and French partners.

118. Complete and repetitive coverage of rangelands with high-resolution imagery is not feasible due to high cost and volume of data. Therefore, an approach which combines statistical modelling and remote sensing data was adopted for this project to assess rangeland acreage at national level with reasonable accuracy (93 per cent). The developed methodology consists of three main steps: a technical study at the national level, using GIS for rangeland zoning; a detailed thematic feasibility study on three test sites for vegetation mapping; and a statistical study to set up a suitable sampling plan and an extrapolation model.

119. It would be possible to use satellite systems with a large field of view, such as the NOAA-AVHRR for inventory and monitoring, but such a system has a low spatial resolution and it is difficult to characterize sparse vegetation with a spatial-temporal variability. The use of high resolution as in the case of Landsat thematic mapper (TM) and SPOT multispectral data allows for a better identification of rangelands despite the difficulty of distinguishing (from the signal) between the contribution of vegetation and soil. An approach, similar to the one used in Europe for agricultural statistics gathering, combining high-resolution satellite data (SPOT scenes) over a small number of sites and statistical modelling, was adopted for the Geostat project to assess rangeland acreage with reasonable accuracy and affordable cost.

120. The first step of the project is rangeland zoning, which allows the concerned territory to be subdivided into homogeneous zones according to specified criteria (soil types, land cover, climate, etc.). Using the existing cartographic documentation and GIS technology, the zoning map was produced with seven homogeneous strata by overlaying three different types of information: a bioclimatic map, an agro-pastoral map and a soil map. Other information was integrated in the database, such as population, hydrography, administrative boundaries and a SPOT grid.

121. The second step consists of a thematic study on three SPOT sites representative of the main rangeland regions in Morocco: Oujda, Khenifra and Ourzazate provinces. The detailed thematic study has resulted in natural vegetation characterization and mapping. The automatic analysis, based on supervised classification and ground truth, was conducted on the first two sites using only two SPOT scenes, because the vegetation coverage was very high (7 and 5 classes were identified respectively at those two sites with an accuracy of 84 and 83 per cent, respectively). The study at the Ouarzazate site was more complex because of the low vegetation coverage and high seasonal variability. In this case, the study was based on photo-interpretation and ground-based observations allowed the possibility of establishing a relationship between the predominant vegetation species and the corresponding surface classes. Thus, 10 surface classes were identified, three of which were vegetation species, with an accuracy of 85 per cent.

122. The last step in the project focuses on a statistical study in order to set up a suitable sampling plan and build up an extrapolation model, The objective was to assess rangeland proportion or total rangeland area at the country level. In order to facilitate the statistical study, the two thematic maps were simplified to the following nomenclature: steppic rangelands, agricultural lands and bare soil. The statistical modelling allowed for the definition of a sampling plan composed of 30 SPOT scenes distributed within the different strata and each scene contained 30 segments of 4 hectares (200 x 200 metres) each. In Morocco, the proportion of rangelands in the studied area was estimated at 40 ± 7 per cent with 95 per cent probability.

123. The results of the Geostat project are very encouraging in terms of vegetation mapping and statistical inventory. After the success of the feasibility study, it is possible to look forward to the operational implementation of the project. Naturally, the methodology developed in the frame of the Geostat-Morocco project could be applied in other counties of the Mediterranean basin, the Middle East and other regions of Africa, Asia, America and Australia. The Geostat project deals with rangeland inventory and monitoring and is also directly related to desertification monitoring problems and the consequences for natural resources and the environment, which are of prime importance for many regional and international organizations.

124. At the University of Concepción in Chile, a multidisciplinary programme PMPR for remote sensing has been developed since 1993. It comprises research and development of the acquisition of digital information, *in situ* spectrography, and aerial and satellite remote sensing. A catalogue of NOAA satellite images in seven spectral bands over the territory between 15 and 59 degrees South and 95 to 55 degrees West was established. There are about two pictures per day since October 1994 in this database. According to an agreement with NASA, direct ground reception of OrbView-2 satellite SeaWIFS (Sea-Viewing Wide Field Sensor) data on aerosols and ocean colour and biology to monitor concentrations of sea phytoplankton is projected. Within the framework of PMPR, research is also being pursued in the field of geographic information systems applications for forestry, fisheries and urban monitoring.

F. Satellite Health Access for Remote Environment Demonstrator

125. The SHARED Project (Satellite Health Access for Remote Environment Demonstrator) is a pilot platform based on ESA's Direct Inter-establishment Communications Experiment (DICE) system to support remote health-care infrastructure, proposed by the Scientific Institute San Raffaele, and coordinated by Telbios (San Raffaele Biomedical Science Park and Alenia Aerospazio), ESA, ASI and the Italian army. The SHARED mission is to set up and operate on a trial basis a laboratory for re-engineering health-care delivery through the use of information and telecommunications technologies, including the space segment. Participating institutions in Bologna, Bucharest, Milan, Rome, Sarajevo and Tirana are connected through the Integrated Service Digital Network (ISDN) and also through the SHARED network by the Eutelsat geostationary satellite.

126. The goals of the first phase of the project were to form a group of end users familiar with a multimedia telecommunication platform used for telemedicine applications; identify the user requirements and constraints for telemedicine by means of a pragmatic approach; and catalyse the involvement of satellite communication technology in telemedicine applications. Very important is the humanitarian aspect of the project, because it involves also

support for the Military Field Hospital and the Clinical University Centre in Sarajevo, Idi in Tirana and Hospital V. Babes in Bucharest.

127. The support to humanitarian missions has provided an ideal utilization platform for the DICE Telemedicine system. Operated in a remote and underserved area, it has required a fast set-up of the communication facilities without relying on existing terrestrial communication infrastructure. The operational environment of the hospital has not required the adoption of health-care models strictly specialized for military applications. Telemedicine was found to be a perfect complement to balance the lack of specialized medical expertise available in a field hospital. The involvement of civilian medical personnel has shown great potential in supporting continuing medical education. According to the trial responses, telemedicine does contribute to breaking the professional isolation experienced by physicians working in remote areas.

128. From 16 September 1996 to 31 December 1997, there were 560 hours of telemedicine sessions, 260 hours of teleconsultation sessions, 180 cases were treated to support the Clinical Centre of the Sarajevo University, 10 doctors were involved in telemedicine sessions in Milan, 8 in Rome, 15 in Sarajevo and 8 in Tirana. Medical disciplines covered were ophthalmology, orthopaedics, pathology and dermatology. In February 1998, within the framework of the SHARED 2 phase, establishments in Bucharest, Bologna, Rome and three hospitals in urban areas were added. The future permanent European Telemedicine Network (EUROMEDNET) might consist of 20 satellite connected sites and many more locations accessible through the ISDN Gateway. To make this network operational, sponsoring support is being sought from the European Commission, ESA and ASI, as well as from different humanitarian organizations and local sponsors.

G. Space and education

129. Space education activities have been one of the missions of the French space agency (CNES) since its founding in 1962. The main objective of these activities is to foster space studies by young enthusiasts and to give rise to scientific vocations. The first stage, which started in 1962, promoted the creation and activities of youth scientific clubs to secure the building of micro- and mini-rockets. Since 1976, efforts were undertaken to introduce understanding and use of satellite imagery in pedagogical activities (the use of Landsat images) and since 1987, the French Ministry of Education supported pedagogical experiments to introduce satellite remote sensing in the courses of three educational disciplines. In 1991, an official agreement between CNES and the Ministry was signed to develop training courses for teachers, support and enlarge pedagogical experimentation in high schools and support the production of pedagogical documents (booklets, video, multimedia).

130. The present activities of CNES still involve the support of the youth clubs (launchings of small model rockets up to 3 kilometre altitude, stratospheric balloons with 20 kilogram payload up to 14 km, and experiments with microgravity in Airbus A300 0G plane). Over 2,000 youngsters participate in such activities each year. For primary and secondary schools, CNES is producing small monothematic books and videos with simple approaches on different space activities (e.g. tectonic plates viewed by satellites, activities of primary schools related to human spaceflight, what is the space technology for etc.).

131. CNES also regularly organizes short training courses to create awareness of space activities at the institutes for initial training for teachers (IUFM) and summer universities for more detailed education in the field of space physics, applications of Earth observation, etc. A high standard of the summer university is guaranteed by a scientific committee, close cooperation of scientists and teachers during the workshops and by the use of new educational technologies. Visits to space and aeronautic companies form an important part of the programme. The courses are also open to French-speaking foreigners.

132. The workshops give teachers different examples relevant to the theme of the main conferences and provide pedagogical approaches for a possible reuse of the theme in their class and also helps them to use new technology tools with high technology contents. Some themes studied in the general course on space sciences and technologies

are: state of the art in rocket technology, space and sciences of the Universe, human flights, oceanography, land use and management with remote sensing data. The next summer school will be organized in Tunisia in 1998. Main themes of general conferences include: Mediterranean climate and meteorology, Mediterranean land ecosystems, environment and urbanization, desertification and management of water resources. The workshops will deal with such issues as examples of meteorological events in the Mediterranean basin, monitoring of Mediterranean vegetation by remote sensing, dynamics of Tunisia, desertification processes in the south of Tunisia and problems of irrigation.

133. CNES is also supporting educational experiments prepared by the Ministry of Education. Before introducing new educational concepts and know-how into the courses, the Ministry conducts corresponding pilot projects. Since 1988, there have been two experiments on remote sensing data and education in the field of physics, geology, geography and biology. In particular, CNES had helped in providing data access, training of experimental teams and produced booklets and CD ROMs from the pedagogical results. Also, in cooperation with the German space agency DLR, two teams of high school students are working on the theme of evolution of landscape in border regions and evolution of the shore line in French Guiana.

134. Training and education in space science and technology is extremely important for developing countries. A thorough analysis of the existing programmes in industrialized countries is necessary in order to use their experience for training in the development and sustainable use of space technology. It was realized that there is also a need for liberalization of training and individual initiatives in order to fulfil the requirements of the emerging market. The main limitations in the developing countries are: space industry is almost non-existent; a lack of awareness among decision makers; a lack of established activities in order to sustain training; insufficient infrastructure; and problems with the employment of graduates.

135. With the establishment of the CRTS in 1989, Morocco took an important step forward in applications of space-related technology. The Centre is responsible, among its different space-related tasks, for distributing satellite images and centralizing the national records of satellite data and data from projects using space-borne remote sensing and geographic information systems. A number of projects using these techniques are currently in progress or being set up in Morocco in response to needs in the areas of natural resource inventory and management, environmental protection and land development.

136. Training and education activities form an important part of the CRTS activities. They are performed in cooperation with international regional and national institutions. Cooperation with the United Nations-advocated regional centres for space science and technology education will be essential (the regional centre in Morocco should be inaugurated in 1998). Cooperating national centres in the Mediterranean region are the National Authority for Remote Sensing and Space Sciences in Egypt, the Royal Jordanian Geographic Centre, the Centre for Remote Sensing and Space Science in the Libyan Arab Jamahiriya and the National Centre for Remote Sensing in Tunisia, among others.

137. New facilities of CRTS would provide necessary infrastructure for remote interactive training, video-conferencing and lectures and practical work with modern equipment. In addition to university-related activities and short- and longer-term training of specialists, due attention should be paid also to public education. It involves regular contacts with local press and provision of reliable media information in general, as well as organization of short workshops for decision makers and senior executives (e.g. on operational remote sensing applications in agriculture, fishery and urban planning). This should increase general information and awareness of practical applications of space technology in the economy of developing countries.

Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Symposium on Scientific and Technical Aspects and Applications of Space-based Meteorology, organized by the Committee on Space Research and the International Astronautical Federation

The first session of the Symposium, on technical aspects of space-based meteorology, was co-chaired by K. Doetsch, representing IAF, and G. Haerendel, representing COSPAR. The second session of the symposium, on scientific aspects and operational applications of space-based meteorology, was co-chaired by J. Ortner, representing IAF, and J. L. Fellous, representing COSPAR. The presentations included the following:

"The World Weather Watch programme, present and future aspects", R. C. Landis, World Meteorological Organization

"The Meteosat second generation and Metop programmes", A. Ratier, EUMETSAT

"NOAA GOES and POES meteorological applications", L. Enomoto, National Oceanic and Atmospheric Administration, United States of America

"Chinese meteorological satellites", Huang Hanwen, China National Space Administration, China

"Applications of satellite meteorology to monitoring and predicting the east Asia monsoon", Hyo-Sang Chung, Republic of Korea

"Climate variability: the 1997/98 El Niño", H. Grassl, The World Climate Research Programme

"Scientific aspects and applications of the Tropical Rainfall Measuring Mission and its follow-on mission", E. Im, Jet Propulsion Laboratory, National Aeronautics and Space Administration, United States of America

"Disaster management using Indian remote sensing satellites", G. M. Nair and K. Kasturirangan, Indian Space Research Organization, India

"Meteorological systems for desert monitoring", M. Kabbaj, Centre royal de télédétection spatiale, Morocco

"Land cover studies using meteorological satellites", N. J. Ferreira, Instituto Nacional de Pesquisas Espaciais (INPE), Brazil

B. Other scientific and technical presentations

"Development and applications of the meteorological satellites in China", Tong Qingxi, China

"Mitigation measures for satellite constellations", R. Crowther, United Kingdom of Great Britain and Northern Ireland

"Orbital debris mitigation policies and practices", J. Loftus, United States of America

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"Space debris mitigation", S. V. Koulik, Russian Federation

"Space debris mitigation", J. Bendisch, Germany

"Space debris mitigation", N. Johnson, Inter-Agency Space Debris Coordination Committee

"Space debris mitigation", J.-M. Contant, International Academy of Astronautics

"Space debris mitigation", W. Flury, European Space Agency

"Space debris mitigation in France", F. Alby, France

"Space debris mitigation efforts in NASDA", A. Kato, Japan

"Space debris mitigation", M. Yakovlev, Russian Federation

"UNISPACE III Conference", K. R. Sridhara Murthy, India

"International Space Station—perspectives of cooperation", A. B. Krasnov and V. Borisov, Russian Federation

"Cassini mission", R. Wilcox, United States of America

"Remote sensing", R. Hernández, Chile

"Landsat 7", C. Wooldridge, National Oceanic and Atmospheric Administration, United States of America

"Use of imagery from Russian defence satellites for the purpose of international cooperation", V. V. Shalyguin, Russian Federation

"Austria on global monitoring", L. Beckel, GEOSPACE, Austria

"Project Géostat", M. Ait Belaid, Centre royal de télédétection spatiale (Royal Centre for Remote Sensing), Morocco, and N. Gargir, Scot Conseil and Centre national d'études spatiales (CNES) (French National Centre for Space Studies), France

"Training and education in space technology", A. Layachi, Morocco

"Satellite Health Access for Remote Environment Demonstrator (SHARED) project", A. Mason, Italy

"Space and education", M. Vauzelle, France

"Programmes for young people", N. Verdier, France