UNITED
NATIONS

A

General Assembly

Distr.
LIMITED

A/AC.105/673
7 May 1997

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE
Fortieth session
Vienna, 2-13 June 1997

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

Report by the Secretariat

1. During the thirty-fourth session of the Scientific and Technical Subcommittee, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) and the International Astronautical Federation (IAF) organized, in liaison with Member States, a Symposium on Space Systems for Direct Broadcasting and Global Information Systems for Space Research to complement discussions within the Subcommittee on that theme. The Symposium was organized in accordance with the recommendation of the Subcommittee at its thirty-third session (A/AC.105/637, para. 192), which was subsequently endorsed by the Committee on the Peaceful Uses of Outer Space at its thirty-ninth session[1] and by the General Assembly in its resolution 51/123 of 13 December 1996.

2. The Symposium was the thirteenth to be organized by COSPAR and IAF during the annual meetings of the Scientific and Technical Subcommittee, the topic for each year being selected by the Subcommittee at its previous session. The Symposium was held on 17 and 18 February 1997, following the completion of 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 agenda of the Subcommittee. 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 thirty-fourth session of the Scientific and Technical Subcommittee. The annex is in English only. A list of the presentations and speakers is contained in the appendix to the annex.

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I. SYMPOSIUM ON SPACE SYSTEMS FOR DIRECT BROADCASTING AND GLOBAL INFORMATION SYSTEMS FOR SPACE RESEARCH

6. The primary functions of any broadcast medium are to provide information, entertainment and education. Radio was the primary mode of news broadcasting for a long time until the advent of television. But even today, some users still rely more on radio news than any other medium. Radio fulfils a very important social objective of broadcasting educational programmes, especially for school children. It also provides, sometimes even in an interactive way, special services such as counselling to farmers, industrial workers, women, youth and children.

7. Worldwide, the number of radio sets runs into the billions. But like the telephone and television, the number of radio sets per thousand head of population shows significant variations between States, depending on their economic conditions (from 1,050 in developed countries to around 180 in developing countries). There are certain countries where 30 per cent of the territory is not covered by any domestic radio station. Present-day radio systems are predominantly analogue and broadcast by terrestrial systems. Satellite systems are used mostly for wider programme distribution by rebroadcasting or to serve the cable head-ends. It will take some time before digital satellite systems take over, because the cost of the existing infrastructure have to be fully recovered and the cost of digital receivers will be high during the initial periods.

8. In India, studies on satellite digital sound broadcasting have been going on over the past few years. Since the inception of the Indian National Satellite (INSAT) system in 1983, the primary mode for radio programme distribution is via the satellite radio networking (RN) system. The cumulative monthly utilization of the satellite transponder for the 28 RN channels exceeds 13,000 hours. In spite of its extensive radio network, India, with its varied population and languages, is looking for ways of providing an adequate number of audio channels throughout the country.

9. The GSAT-1 satellite scheduled for launch on the first development flight of the Indian Geostationary Satellite Launch Vehicle carries two high-powered S-band transponders so that it can provide a total of 96 audio channels. The availability of such a large number of channels is expected to revolutionize the radio broadcasting scene in India. Apart from channels of general nature, dedicated channels for news, sports, different types of music, business information, development communications and other fields of interest are also feasible. The digital nature of the system could provide a host of data broadcast services, such as dissemination of lecture notes to students of Open Universities, distribution of electronic newspapers, information by utility agencies or downloading large volumes of Internet data.

10. The unprecedented exponential growth of the Internet, where the network size doubles every year, has created a similarly increasing demand for multimedia and broadcasting services. Because integrated video, voice and computer applications demand more bandwidth, the terrestrial infrastructure - optical fibre networks, Integrated Service Digital Network, advanced modulation techniques, compression and others - should substantially improve. This is also necessary for an optimal combination with emerging satellite systems, which are complementary to terrestrial systems and fundamental for the rapid global expansion of services. An experimental LAN interconnection satellite system is being developed by Joanneum Research and the University of Salzburg (Austria) under a contract of the European Space Agency (ESA). It can accommodate up to 64 active stations in a network with a maximum user rate of 2 megabytes per second.

11. Direct Broadcasting Systems (DBS) can significantly decrease the expense of delivering television programmes to the subscriber, particularly in large areas with low population densities, which is typical of the Russian Federation. Small terminals in connection with DBS satellites in geostationary orbit (GSO) are easy to use and offer more high-quality channels than terrestrial systems. The first satellite of the GALS system was launched by the Russian Federation in 1994 and the second in 1995. A new satellite, GALS-R16, which is under development for 1998-2000, should have 16 transmitting beams in the 18/12 gigahertz band. It is designed to serve mainly the European regions

of the country, and its active lifetime should be increased to 7 to 10 years. Up to 4 analogue and 32 digital television programmes can be distributed to individual receiver sets with antenna diameters of 50 to 90 centimetres.

12. In Japan, a commercial company providing test digital broadcasting and regular digital DBS services with almost 100 channels is in the preparation stage. Also, many broadcasting companies in Europe, Asia and South America are already providing or preparing digital DBS services. The first Koreasat satellite was launched into GSO position at longitude 116° east in August 1995 and the second in January 1996. Each Koreasat has three 27-megahertz, 120-watt DBS transponders and concentrated transmission beams at a frequency of 12 gigahertz. Therefore, within the territory of the Republic of Korea, a high-quality television signal can be received with only a 40 centimetre dish, and in neighbouring countries where many Koreans live, a 1 metre antenna is sufficient. The system could support a future data broadcasting service of up to 2 megabytes per second. This could provide for services like home shopping, remote education, electronic newspaper delivery, still pictures, game programmes and Karaoke. Furthermore, a high-definition television system (HDTV) is being developed for trial service in 1999 and for the 2002 World Cup.

13. Since the objectives of the Mission to Planet Earth (MTPE) of the United States of America are to expand scientific knowledge of the Earth system, to disseminate information and to enable the productive use of MTPE science and technology in the private sectors, networking and data-archiving systems are an inseparable part of that research endeavour. About 10,000 science and 100,000 non-science users will be searching through data obtained by an armada of international and national satellites, *in situ* platforms and many commercial providers. In addition to the main Earth Observation Data and Information System, MTPE will use different networks and archives to distribute and archive all relevant data. For example, a Global Observation Information Network will be established under a joint initiative between Japan and the United States to strengthen bilateral cooperation in information networks for Earth observation.

14. The objectives of the International Geosphere-Biosphere Programme (IGBP) research are to provide the foundation for determining how the Earth system functions and to develop practical predictive capabilities for effective policy responses. The exploitation of new opportunities to gather data on a global scale will be done through the IGBP Data and Information System (IGBP-DIS). The IGBP-DIS is not a conventional information system, and does not have large data sets or computer facilities. Its role is to identify key global data deficiencies for research on global change and to identify national or international agencies ready to implement remedial responses. Because of their global nature, space observations have represented a major focus of interest in IGBP-DIS.

15. The active involvement and contributions of developing countries to the study of global change is crucial. First of all, developing countries are causing significant environmental change. The size of their populations has an impact on the environment through deforestation, erosion of the soil caused by human activity, rural agricultural and other factors. Their economies are mostly based on natural resources, and their economic development strategies often assume rapid growth and low productivity. As a result, developing countries face serious global environmental problems such as a decrease in vegetation coverage, land degradation, natural disasters and pollution. They must therefore participate in programmes concerned with global change out of their own national interest and also to make their contribution to the international community.

16. China has made substantive contributions to studies of global change. The Chinese National Climate Committee was founded in 1987 and the Chinese National Committee for IGBP in 1988. A number of national institutions are conducting environmental research. Some of the specific ongoing research projects include: predictive study on trends in the life-supporting environment in China over the next 20 to 50 years; dynamic processes and prediction of trends in environmental changes in arid and semi-arid regions of China; research on global environmental change in Antarctica; the field experiment in the Heihe river basin on the interaction between the atmosphere and the land surface; experiments on ocean circulation in the tropical western Pacific; and studies on the formation, evolution and environmental changes of the ecosystem in the Qinghai-Tibetan plateau.

17. The World Wide Web has hitherto been used for the distribution of information and data (text, video and sound), and is beginning to be used also for software distribution and to computational capability. The Java programming language now offers the possibility of linking platform-independent software to Web pages. The software then runs on the client machine, using the Web browser in order to off-load the server. That eliminates all the problems related to the distribution of software to remote sites and its maintenance at such sites. The Hubble Space Telescope European Coordinating Facility started to use the Java programming language experimentally in order to make the Web more useful and efficient for astronomy. A long-term goal is to delegate tasks such as data calibration to the client machine at the user site.

18. The next step after the personal workstation seems to be the research station. It consists of a powerful local processor that is connected (via high-bandwidth networks) to other machines and to databases and knowledge bases. It has a configurable personalized user interface that allows access to all services and functions in a consistent and efficient manner. The emphasis is on visualization and conceptualization (model building). That can be realized through multiple screens, big screen projections (flight simulator), or video recorders.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Space debris

19. The French National Centre for Space Studies (CNES) continued its experimental observation of space debris using the 1.5 metre Schmidt telescope of the Observatoire de la Côte d’Azur. It should be able to detect 20 centimetre debris in GSO. The first study using photographic films and scanner were performed in 1996, and a camera with a charge-coupled device (CCD) has been tested in 1997. Optical observations of geostationary objects have also been made by the Communication Research Laboratory of Japan using the telescope of 1.5 metres in diameter with a CCD camera at Koganei, Tokyo.

20. Several Japanese study groups performed the post-flight analysis of the Space Flyer Unit (SFU), which was recovered by the United States Space Shuttle after 10 months in orbit. In total, some 20 square metres of exposed surfaces were available on SFU for analysis. A total of 337 impacts with diameters greater than about 200 micrometres have been observed in visual surveys, and 180 impacts in high-resolution surveys of selected surfaces. The diameter of maximum damage is about 13.4 millimetres, with an impact crater of 2.5 millimetres in diameter.

21. In the Defence Evaluation Research Agency of the United Kingdom of Great Britain and Northern Ireland, the Integrated Debris Evolution Suite Programme combines deterministic modelling of particles over 10 centimetres in diameter with stochastic modelling for particles below 10 centimetres. A semi-deterministic tool for the long-term analysis of the debris population is being developed under an ESA contact at the University of Pisa, Italy. The Nazarenko model developed in the Russian Federation provides spatial density and velocity distributions, on the basis of space catalogue data of the Russian Federation and the United States. At CNES, special emphasis is given to the impact of debris on fragile materials (glass, silicium), which can produce a great quantity of small particles (secondary impact). The mass of the secondary particles can reach 1,000 times the mass of the primary particles.

22. In Germany, the space debris modelling is financed by the German Ministry of Research and Technology and by the German Space Agency. The work has been carried out by the Institute for Flight Mechanics and Spaceflight Technology of the Technical University of Braunschweig (TUBS), IFR has developed the ESA Space Debris Reference Model (MASTER) under a contract of the European Space Operation Centre at Darmstadt. That model covers man-made debris and natural meteoroids (the distribution of meteoroids was modelled by the Max Planck Institute at Heidelberg, Germany.

23. Since 1990, government-sponsored cooperation between TUBS and the Johnson Space Centre of the National Aeronautics and Space Administration (NASA) led to fruitful discussions concerning the modelling approaches and

the results obtained by both parties using their own tools. The CHAIN model, developed initially in 1993 at TUBS, has been maintained and improved by the Johnson Space Centre, and the CHAIN European Extension (CHAINEE) has been produced at TUBS. The codes can be employed to identify the relative trends associated with specific mitigation policies, while higher fidelity assessments can later be performed by the EVOLVE model.

24. The United States orbital debris programme is designed to ensure safety of human space flight, to protect national assets and investments in space from orbital debris, and finally to ensure long-term protection of the space environment. The orbital debris engineering model (ORDEM) is used to compute the current and near-term orbital debris hazard for missions in low Earth orbit. For manned space shuttle flights and for a future International Space Station, the United States has initiated a special programme for pre-flight assessment of meteoroid and orbital debris risk and for post-flight damage assessment. A BUMPER computer code can determine the probability of specified damage levels caused by debris impacts, using relevant input and output specifications.

25. Measures to limit the generation of space debris must be developed and implemented on a multilateral basis by the space faring nations. The Japanese National Space Development Agency (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; disposition 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.

26. Strict mitigation measures are applied to all 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 the bolts should be trapped). The normal use of the upper stage should not generate other debris; solid propulsion in orbit is therefore 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.

27. 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 space debris research; and to identify debris mitigation options. The founding members were ESA, Japan, NASA and the Russian Space Agency. In 1995, China joined IADC and the British Space Agency, CNES and the Indian Space Research Organization did so in 1996. Formal meetings of the IADC are scheduled about once a year. All agreements of IADC are made by consensus.

28. In the Russian Federation, the consequences of a collision between decommissioned nuclear power sources (NPS) and space debris during their protracted stay in orbit are prime targets of research on radioactive, chemical and environmental contamination of outer space. The possible consequences of a collision between debris and reactor NPS launched into space and placed into sufficiently high orbit are: destruction of the reactor radiator reflector (beryllium); destruction of the radiation shield (lithium hydride); destruction of the liquid metal circuit and possible outflow of coolant (sodium-potassium); and destruction of the reactor NPS structural components with concomitant fragmentation of structural materials.

B. Use of nuclear power sources in outer space

29. To maintain specified thermal conditions and provide electrical power for small autonomous stations of the Mars 96 project, special radionuclide thermoelectric generators (RTGs) and radionuclide heat units (RHUs) based on plutonium 238 were developed. The heat units are universal (each with heat power of about 8.5 watts), so that they are also used as a primary source of heat for the thermoelectric changer of the RTGs. That has simplified the

safety design of both types of units, since the capsules with plutonium 238 are identical. The design and development of the units were performed in full compliance with the Principles Relevant to the Use of Nuclear Power Sources in Outer Space, adopted by the General Assembly in its resolution 47/68, and also with the national safety standards of the Russian Federation.

30. The Mars 96 space probe contained 18 RHUs with a total mass of plutonium dioxide of not more than 300 grams (270 grams of plutonium 238) and the total activity of about 4,700 curies. At each of the two small scientific stations, there were 2 RTGs (each containing a single RHU) and 2 RHUs for heating. Similarly, each of the two Mars penetrators contained one RTG (powered by two RHUs) and three RHUs for heating purposes. The electrical power for the main spacecraft should have been provided by conventional solar battery panels.

31. The capsules with radioactive material are specially protected to withstand an explosion and burning of the Proton space vehicle propellant with flame temperatures of up to 3,600 kelvin for 4,000 seconds; spacecraft atmospheric re-entry with the first and second space velocities (up to 11 kilometres per second); and impact with the Earth surface (including concrete and rocks) at velocities of up to 80 metres per second. In addition, plutonium dioxide (cermet) tablets are not dissoluble in freshwater and sea water (to a depth up to 10 kilometres) and in base or acid environments. The leak-proof capacity of the capsules has been confirmed by ground tests using model and full-scale RHU specimens and carried out by an inter-agency commission of experts.

32. The launching of the Mars 96 space probe with international scientific equipment on board for complex exploration of Mars took place on 16 November 1996 at 20.49 Universal Time from the Baikonur cosmodrome. The engines of the Proton launcher worked as scheduled; but while the first ignition of the special accelerating unit took place as planned, the second one failed, and the unit with the Mars 96 probe remained in a low Earth orbit. The automatic systems of the spacecraft performed the separation from the accelerating unit and ignition of its own engine, but that was not enough for a substantial increase in the orbit. The acceleration unit was precisely tracked in its low orbit and decayed on 18 November 1996 at 1.20 Universal Time over the Pacific Ocean, several thousand kilometres east of Australia (about 51° south and 168° west).

33. The tracking of the Mars 96 probe was not continuous, and the location of its decay was much more difficult to determine. After careful analysis of all available information, it was confirmed that the probe, including radioisotope capsules, had entered the atmosphere on 17 November 1996 at around 1.00 Universal Time at the end of its third revolution around the Earth. The probable fall zone was located in the Pacific Ocean, from 800 to 200 kilometres along the orbit, west of the coast of Chile. Its centre was at 25.1° south and 75.4° west.

34. After the aerodynamic destruction of the Mars 96 spacecraft and the RTG aluminium and steel structural components during the atmospheric re-entry, the capsules with plutonium dioxide fell within the fall zone of the fragments, in a practically unchanged form. Since there was no plutonium dioxide release into the environment, any possibility of radioactive contamination and radiological effects on the population was ruled out. Deposition of the RHU on the Pacific Ocean floor at considerable depth should be regarded as an ecologically safe disposal of a relatively small quantity of plutonium 238.

C. Remote sensing and global environment

35. The Committee on Earth Observation Satellites (CEOS) strongly pursues the development of the Integrated Global Observing Strategy in order to make more effective use of investments in this field and to support the worldwide demand for a complex set of instruments to collect and distribute relevant data and to create and distribute data products. The existing systems do not seem to meet the demand. User needs could be met more effectively through better inter-agency coordination and cooperation. A strategy should be developed to integrate inter-agency planning for cost-effective space-based systems, inter-calibration, compatibility of data delivery systems and the establishment of better links between the users and providers. The delivery of services should be designed to satisfy

social, economic and environmental needs of the users. Developing countries are recognized as both providers and users of data.

36. With the establishment of the Royal Centre for Remote Sensing (CRTS) in 1989, Morocco took an important step forward in the production of space information. CRTS 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 detection and geographic information systems. 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. CRTS is also organizing development of the first national experimental microsatellite with a payload of messaging and remote sensing equipment. The work is being carried out with the collaboration of the Berlin Technical University, which is providing the TUBSAT-C platform for the project. Installation of the component systems is expected to be completed in 1997.

D. Space medicine and materials science

37. The outstanding advancements in the crystallization of proteins in microgravity achieved during the last few years have raised hopes for the development of drugs that will eventually cure Chagas' disease, an infection endemic in most rural areas of Central and South America. Since 1984, a number of NASA Space Shuttle missions have carried out crystallization experiments and developed the necessary hardware. In February 1996, during the STS-75 mission of the Space Shuttle Columbia, the first medical experiment designed by Latin American researchers was carried out. For 16 days, crystals were grown of a specific enzyme connected to the parasite transmitting the disease. On the basis of the results achieved, new experiments were prepared for the STS-83 mission in April 1997. Participating scientists from Argentina, Brazil, Chile, Costa Rica, Mexico, Uruguay and the United States hope that using the rational design of drugs will result in the development of a new medicament against this silent but fatal disease.

E. Astronomy and planetary science

38. The Japanese Institute for Space and Aeronautical Sciences successfully launched the Very Long Base Interferometry satellite MUSES-B (renamed in orbit as HALCA - Highly Advanced Laboratory for Communications and Astronomy) by the new M-V launch vehicle on 12 February 1997. With the advent of the new launcher, Japanese space science entered a new area that should see more ambitious projects including lunar and planetary exploration. Five more spacecraft have already been approved for launch by the M-V: the LUNAR-A for the Moon Penetrator Mission (fiscal year 1997); the PLANET-B to Mars (fiscal year 1998); the ASTRO-E for an X-ray astronomy satellite (fiscal year 1999); MUSES-C for asteroid sample returns (fiscal year 2001); and ASTRO-F for infrared astronomy (fiscal year 2002).

39. The first ESA mission for the *in situ* study of a cometary nucleus environment and its evolution in the inner solar system is called Rosetta. It should perform a detailed exploration of the comet nucleus and its close environment and provide unique sample analysis capabilities, thus satisfying to a large extent the objectives of the original mission to collect samples from the comet nucleus.. The scientific payload of the Rosetta Orbiter was preselected and endorsed by the ESA Science Programme Committee at its meeting held in February 1996. The Orbiter payload comprises 11 investigations. Austria is responsible for the Micro-Imaging Dust Analysis System (MIDAS) experiment in cooperation with co-investigators from six other States. The MIDAS instrument is considered essential for the Rosetta mission, since, for the first time, it will provide the capability of imaging in three dimensions dust particles in the nanometre to micrometre range.

40. It has become clear that operational and spent spacecraft, as well as the larger pieces of trackable space debris, are the greatest contributors to trailing - the passage of an object across an astronomical telescopic field of view, which is recorded both photographically (during the deep space studies) and photometrically. The quality of deep space plates is degraded, photometric observations are lost, and there is an ever-present danger of damage to

sensitive detectors. In June 1996, the United States Naval Research Laboratory launched the TIPS experimental double satellite, the two components of which are connected by a four-kilometre-long tether. With such dimensions, TIPS can produce a smear rather than a trail, a smear that is comparable in size to the field of view of a CCD commercially available to professional and amateur astronomers.

41. It was announced in 1996 that the United Nations Educational, Scientific and Cultural Organization was moving away from the concept of the "Star of Tolerance" to mark its first 50 years of existence. It was supposed to be a system of two reflecting balloons, kept together by a two-kilometre-long tether in orbit at an altitude of 1,250 kilometres. Although, like TIPS, it would have been seen largely in twilight, it had the potential to appear in the dark sky and to be as bright as Sirius. Unfortunately, the concept might be revived as a millennial project. The launch of the project would send a disastrous message, namely, that advertising from space is considered acceptable. The firm stand taken by ESA against the project has been deeply appreciated by the whole astronomical community.

Notes

[1]*Official Records of the General Assembly, Fifty-first Session, Supplement No. 20* (A/51/20), para. 115.

*Annex**

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

CONTENTS

*This annex has not been formally edited.

I. SYMPOSIUM ON SPACE SYSTEMS FOR DIRECT BROADCASTING AND GLOBAL INFORMATION SYSTEMS FOR SPACE RESEARCH

A. Satellite Radio and Digital Audio Broadcasting

The primary functions of any broadcast medium are to provide information, entertainment and education. Radio was the primary mode of news broadcast for a long time until the advent of television. But even today some users still rely more on radio news than any other medium. The popularity of some radio channels is linked to their easy accessibility and the quality of their news coverage. In developing countries, radio is the major source of information for large segments of the illiterate, and it caters to communication needs in development, with broadcasts targeted for rural audiences on agricultural practices, agro-products, animal husbandry, health, hygiene and the like. Radio also fulfills a very important social objective of broadcasting educational programmes, especially for school children. The distance education system, which began in the ’60s, has adopted a multi-media approach to reach students. Radio also provides, sometimes even in an interactive way, special services such as counselling to farmers, industrial workers, women, youth and children.

Worldwide, the number of radio sets runs into the billions. But as with other elements of the communications infrastructure like the telephone and the television, the number of radio sets per thousand population shows significant variations between countries, depending on their economic status (from 1,050 in developed countries to around 180 in the developing ones). There are certain countries where 30 percent of the territory is not covered by any domestic radio station. The present day radio systems are predominantly analogue and broadcast by terrestrial systems. Satellite systems are used mostly for wider programme distribution by rebroadcasting or to serve the cable head-ends. It will take some time before digital satellite systems take over because the costs of the existing infrastructure have to be fully recovered and the cost of digital receivers will be high during the initial periods.

Advances in compression techniques and digital signal processing chips have enabled the introduction of compressed audio at bit rates significantly lower than uncompressed audio without decreasing the quality. Two distinct approaches related to digital sound broadcasting (DSB) coding and modulation methods have emerged. The Eureka 147 (ITU-R SYSTEM A) digital audio broadcast (DAB) system consists of analogue to digital conversion, compression through source coding, convolutional coding, data multiplexing, and time and frequency interleaving with differential modulation of a number of carriers. The main advantage of this system is that it is largely immune to multipath propagation effects because different carriers constructively enhance each other.

The second system, called IN-BAND (ITU-R SYSTEM B) digital audio radio (DAR) system and developed in the United States, is required to operate simultaneously with terrestrial frequency and amplitude modulated systems in the frequency channels allocated to the latter (this is why it is called "in-band"). The DAR services conform to the prevailing regulations on interference and power spectral density. Some of these systems use new source coding and bit reduction techniques, forward error correction, time and frequency interleaving and shaped guard band pulses. An auxiliary data channel is also provided. SYSTEM B is a single-channel-per-carrier system which can operate over a wide range of data rates. It allows a service provider to use only as much transmitter power and bandwidth as necessary for the selected service quality.

The world’s first operational terrestrial DAB was introduced in September 1995 and currently more than 25 pilot service trials and field tests at VHF and in L-band are being introduced in 13 European countries, with plans to begin pre-operational terrestrial services this year. Outside Europe, tests are being conducted in Australia, Canada, China, India, Mexico and the United States of America. It is expected that by 1998, when the initial DAB systems are established, about 100 million people will be covered in Europe using hardware from different manufacturers at hopefully affordable prices.

Satellite sound broadcasting (SSB) has been the subject of discussion over the past twenty years and has been viewed as the potential candidate for reaching the vast majority of people not adequately covered by either good quality audio or an adequate number of channels. A number of studies and experiments have been conducted, especially in Canada, France, Germany, Japan, United Kingdom of Great Britain and Northern Ireland and United States. In the early ’80s, the emphasis was on the use of analogue frequency modulation (FM), which required large-powered satellites or large on-board antennas to provide an adequate number of channels. During the ’90s, the emphasis shifted to digital techniques that did not demand as much power or antenna areas.

A logical extension of the terrestrial Eureka 147 system would be to consider the same scheme for satellite systems as well. Substantial space segment resources are required for the implementation of satellite DAB (S-DAB). To provide a sufficiently-high ground elevation angle in Europe, the proposed Archimedes system is considering an eight-hour highly elliptic orbit (inclination 63 degrees, altitude 26,800 to 1,000 km) instead of the geostationary orbit (GSO). The L-band satellite trials were conducted in Mexico in 1995 using the Solidaridad satellite in GSO and a number of technical parameters were established for fixed and mobile reception. Similarly, satellite trials using Eureka 147 DAB were carried out in Australia via the Optus-B satellite in 1995.

Digital Sound Broadcasting System B provides digital sound and ancillary digital data broadcasting for reception by indoor/outdoor fixed and portable receivers and also by mobile receivers. It is designed for either satellite or terrestrial emission. Several audio compression schemes have been demonstrated via the TDRS satellite in the 2.1 GHz band. The implementation of a variant of the Digital System B is being carried out by World Space Inc. of the United States. The proposed AfriStar (to cover Africa) is planned for launch in 1998, followed by AsiaStar (to cover some regions in Asia) and CaribStar (for the Caribbean, Central America and South America). Each satellite can support, through three emission beams, 288 audio channels at 16 KB/s. The target is to provide audio channels of acceptable quality to fixed and portable receivers for those segments of population not adequately covered by the present system.

In India, studies on satellite digital sound broadcasting have been going on over the past few years. Since the inception of the INSAT system in 1983, the primary mode for radio programme distribution is via the satellite radio networking (RN) system. The cumulative monthly satellite transponder utilization for the 28 RN channels exceed 13,000 hours. In spite of its extensive radio network, India, with its varied population and languages, is looking towards ways of providing an adequate number of audio channels across the country. The GSAT-1 satellite scheduled for launch on the first development flight of India’s Geostationary Satellite Launch Vehicle (GSLV) carries two high-powered S-band transponders so that it can provide a total of 96 audio channels. The availability of such a large number of channels is expected to revolutionize the radio broadcasting scenario in India. Apart from channels of general nature, dedicated channels for news, sports, different types of music, business information, development communications and others are also feasible. The digital nature of the system could provide a host of data broadcast services, such as dissemination of lecture notes to students of Open Universities, distribution of electronic newspapers, information by utility agencies or downloading large volumes of Internet data.

B. Satellite Multimedia and Broadcasting Services

The unprecedented exponential growth of the Internet, where the network size doubles every year, also created a similarly increasing demand for multimedia and broadcasting services. In Europe, there are over 22 million analogue television receivers, with 10 million digital receivers expected in the next three years. In the United States, 2.5 million digital receivers already exist and estimates for the end of the decade project 20 million units. Because integrated video, voice and computer applications demand more bandwidth, the terrestrial infrastructure—optical fibre networks, Integrated Service Digital Network (ISDN), advanced modulation techniques, compression and others—should substantially improve. This is also necessary for an optimal combination with emerging satellite systems, which are complementary to terrestrial systems and fundamental for the rapid global expansion of services.

For multimedia services, the use of the Ka-band (33 to 36 GHz) of the radio spectrum is steadily increasing. Since the United States’ initial application for use of the Ka-band in 1995, EUTELSAT has applied for 12 orbital positions in this frequency region and ASTRA for 10 positions over Europe and 11 over the American and

Asia/Pacific regions. Most of the Ka-band satellite systems utilize inter-satellite links and the typical subscriber terminal has a 60-70 cm diameter dish antenna. Typical data rates are 16 to 384 KB/s, but with larger dishes, rates up to 155 Mbps are possible. Since the protocols for data transmission on the Internet were designed for terrestrial networks, the introduction of GSO satellites with longer time delays and possibilities of errors during the signal fading will force their adaptation to these new conditions. This will enable efficient exploitation of the broadcast capacities of satellite systems, such as multi-casting web-based information (newspapers, magazines, stock exchange information), updating corporate databases, multi-casting e-mail or newsletters from head offices to branches, and distribution of new software. An experimental LAN Interconnection Satellite System (LISSY) is being developed by Joanneum Research and the University of Salzburg (Austria) under an ESA contract. It can accommodate up to 64 active stations in a network with a maximum user rate of 2,048 KB/s.

C. Direct Satellite Television Broadcasting in the Russian Federation

Direct Broadcasting Systems (DBS) can significantly decrease the expense of delivering television programmes to the subscriber, particularly in large areas with low population densities, which is typical of the Russian Federation. Small terminals in connection with DBS satellites in GSO are easy to use and offer more high-quality channels than terrestrial systems. The first satellite of the GALS system was launched by the Russian Federation in 1994 and the second in 1995. They have an expected operation lifetime of five to seven years and carry up to three transponders transmitting in the 11.7-12.5 GHz band. Receiving antennas in the European regions should have a diameter of 60 cm, in other parts of the territory up to 150 cm. To make the commercial system cheaper, broadcasting is in the analog form with frequency modulation.

A new satellite, GALS-R16, which is under development for 1998-2000, should have 16 transmitting beams in the 18/12 GHz band. It is designed to serve mainly the European regions of the country and its active lifetime should be increased to seven to 10 years. Up to four analogue and 32 digital television programmes can be distributed to individual receiver sets with antenna diameters of 50 to 90 cm. This satellite system will also be available to foreign users. The Russian Federation is performing studies on data compression regarding the most effective algorithms of picture compression conforming to the MPEG-2 standard.

D. Satellite Digital Television Broadcasting Systems

Digitalization, particularly new modulation and compression technologies, makes bandwidth utilization efficient and multi-channel DBS possible. The MPEG (Motion Picture Experts Group) standards were first published in November 1994 and modified in 1995. They specify all of the syntax and semantics of the data stream and decoding process, but not the coding process itself in order to allow future improvements. This technology can compress video data into less than 1/30th of the original and audio data into 1/6th of the original. Therefore, four to 10 television channels could be transmitted by a single 27 MHz transponder. At the same time, laser-disk-quality video and compact-disk-quality multichannel sound are possible. In addition, digital technology provides for easy interoperability with communications and computers so that multimedia integrated service and continuing improvements are possible. Among the benefits, there is the possibility of permanent storage of the programme into digital storage media, loss-less scrambling for pay television service and easy animation toward the virtual studio.

In Japan, a commercial company providing test digital broadcasting and regular digital DBS services with almost 100 channels is in the preparation stage. Also, many broadcasting companies in Europe, Asia and South America are already providing or preparing digital DBS services. The first Koreasat satellite was launched into GSO position at 116 East longitude in August 1995 and the second in January 1996. Each Koreasat has three 27 MHz, 120 Watt DBS transponders and concentrated transmission beams at 12 GHz frequency. Therefore, within the territory of the Republic of Korea, a high-quality television signal can be received with only a 40 cm dish and in neighbouring countries where many Koreans live, a one metre antenna is sufficient. The system could support future data broadcasting service up to 2 Mbps. This could provide for services like home shopping, remote education, electronic delivery of newspaper, still pictures, game programmes and Karaoke. Furthermore, a high definition television system (HDTV) is being developed for trial service in 1999 and for the 2002 World Cup.

E. International Networks and Satellite Data Archiving Systems for Mission to Planet Earth

Since the objectives of the United States Mission to Planet Earth (MTPE) are to expand scientific knowledge of the Earth system, disseminate this information and enable the productive use of MTPE science and technology in the private sectors, networking and data archiving systems are an inseparable part of this research endeavour. About 10,000 science and 100,000 non-science users will be searching through data obtained by an armada of international and national satellites, *in situ* platforms and many commercial providers.

MTPE Science Themes for 1996-2002 comprise: land cover and land use research; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; long-term climate (natural variability and change research); and atmospheric ozone research. In addition to the main Earth Observation Data and Information System (EOSDIS), MTPE will use different networks and archives to distribute and archive all relevant data. For example, a Global Observation Information Network (GOIN) will be established according to a joint United States-Japanese initiative to strengthen bilateral cooperation in Earth observation information networks. NASA is one of the participants from the United States and the goal of GOIN is to achieve comprehensive connectivity and interoperability among existing and planned networks.

The MTPE programme would also use the International Directory Network (IDN), sponsored by the Committee on Earth Observation Satellites (CEOS) Access Subgroup. The IDN provides open, on-line access to information on Earth science, space physics and other disciplines. It contains descriptions of data located in archives held by universities, government agencies and other organizations. NASA serves as the American Coordinating Node of IDN. Similarly, the CEOS Catalog Interoperability Experiment (CINTEX), designed to demonstrate interoperability through international data exchange, would be used in MTPE as well. A common interface, designed for access from Germany, Italy and United Kingdom to the EOSDIS, has already successfully demonstrated interoperability.

F. Data and Information System on Global Climate Change

The objectives of the International Geosphere-Biosphere Programme (IGBP) research are to provide the foundation for determining how the Earth system functions and to develop practical predictive capabilities for effective policy responses. Observations and models are key items in the process; existing and emerging knowledge has to be made available to all and properly disseminated. Therefore, IGBP has established mechanisms to define research priorities in global change, open traditional disciplinary barriers, and coordinate national efforts and resources. The exploitation of new opportunities to gather data on a global scale is critical in this process. This includes remote sensing from space, new ground-based initiatives and the use of information technology for data processing and dissemination. The objective of the IGBP-DIS (Data and Information System) Framework Activity is "to improve the supply, management and use of data and information that are needed to attain IGBP's scientific goals". This is achieved by carrying out activities leading to the generation of global data sets and ensuring the development of effective data and information systems for IGBP.

IGBP-DIS is not a conventional information system and does not have large data sets or computer facilities. Its role is to identify key global data deficiencies for global change research and to identify national or international agencies ready to implement remedial responses. Because of their very global nature, space observations have represented a major focus of interest in IGBP-DIS. Its structure consists of the Scientific Steering Committee, the Project office in Toulouse, France, and has three focuses: data set development; data management and dissemination; and data coordination and international context.

One of the new approaches in data retrieval takes into account that the user increasingly wants to broaden his/her data sources and get away from the focus on a single instrument (so-called data fusion). Also, the user wants to be in a position to quickly assess the availability of a wide range of data and products over a particular area and/or period of interest. To this end, "one-stop shopping" and "data harvesting" concepts are taken as starting points. Data harvesting means that metadata are automatically retrieved and assembled in a logical homogenous data base. This highly facilitates standard queries.

G. The Role of Developing Countries in Programmes on Global Environmental Change

The active involvement and contributions of developing countries to the study of global change is crucial. First of all, developing countries are causing significant environmental change. They have tremendous populations, which influences the environment (deforestation, human erosion of soil, rural agriculture, among others). Their economies are mostly based on natural resources and economic development strategies often assume rapid growth and low productivity. Because of this, developing countries have to face serious global environmental problems such as vegetation coverage decrease, land degradation, serious natural disasters and environmental pollution. Therefore, developing countries have to participate in global change programmes out of their own national interest and also to make their contribution to the international community.

China has made substantive contributions to global change studies. The Chinese National Climate Committee was founded in 1987 and the Chinese National Committee for IGBP in 1988. A number of national institutions are conducting environmental research. Some of the specific on-going research projects include: predictive study on trends in the life-supporting environment in China over the next 20 to 50 years; dynamic processes and prediction of trends in environmental changes in arid and semi-arid regions of China; global environmental change research in Antarctica; the Heihe river basin field experiment on the atmosphere-land surface interaction in western China; experiments on ocean circulation of the tropical western Pacific; and studies on the formation, evolution and environmental changes of the ecosystem in the Qinghai-Tibetan Plateau.

H. Software Packages and the Use of the World Wide Web

The ultimate goal of any research activity in space science (and science in general) is to generate a theoretical model, able to explain, in as simple as possible physical terms, the phenomenon being studied. To achieve this goal, a scientist needs data, data analysis software, display software; and modelling software. Most of these products, or at least some information on them, are available through the World Wide Web. The main problem of a researcher is how to select the optimal software and how to tailor it to particular needs. During the ’80s, data analysis was mainframe-based and computational resources were expensive. Therefore, the users pushed for uniformity with the aim of having a minimum number of data analysis packages in order to maximize the efficiency of the system. Later on, it was realized that as long as a full description of the package exists, the user was able to implement it and only standard interfaces were needed. This can best serve the users, but it is not possible to provide even a partially complete list of available software.

Until now, the World Wide Web has been used for the distribution of information and data (text, video, sound). The Web is beginning to be used also for software distribution and computational capability. It has already become possible to access computational services through the Web: parameters are entered at the client site, the computation is done at the server site and the results go back to the client. The Java programming language now offers the possibility of linking platform-independent software to Web pages. This software then runs on the client machine, using the Web browser as the runtime environment and off-loading the server. This eliminates all the problems related to software distribution to remote sites and maintaining it there. It also eliminates all installation problems; all that is needed is a good Web browser. The Hubble Space Telescope European Coordinating Facility (ST-ECF) started to use Java experimentally to provide astronomically useful functionality on the Web. A long-term goal is to delegate tasks like data calibration to the client machine at the user site.

However, the hardware and software market is still developing vigorously. For image processing, the bottleneck is not processing speed but input/output transfer rate. Low-cost co-processors are available for compute-intensive tasks. The most significant current development is the spread of computer networks on a global scale, and their application for tasks which were not initially envisaged. Computer networks are unexpectedly becoming indispensable for science activities like photocopiers and fax machines.

The next step after the personal workstation seems to be the research station. It consists of a powerful local processor which is connected (via high-bandwidth networks) to other machines and databases/knowledge bases. It has a configurable personalized user interface which allows access to all services and functions in a consistent and efficient manner. The emphasis is on visualization and conceptualization (model building). This can be realized through multiple screens, big screen projection ("flight simulator"), or through video recorders.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Measurements of Space Debris

The French space agency CNES continued its experimental observation of space debris using the 1.5 metre Schmidt telescope of the "Observatoire de la Côte d’Azur". It should be able to detect 20 cm size debris in GSO. The first study using photographic films and scanner were performed in 1996, and tests of a CCD camera have been conducted in 1997. CNES is also developing on-board debris detectors to be implemented on commercial satellites in order to get telemetry data on the flux of meteoroids and space debris in different orbit. The feasibility study prepared in 1996 was followed by qualification model and flight model development for a flight on the Mir station in 1999. A complex data base is under development using the results of in-orbit experiments to get a reference for the improvement and validation of space debris models and a catalogue of consequences of impact of particles on different materials.

Optical observations of geostationary objects have been made by the Communication Research Laboratory of Japan using the 1.5 m diameter telescope with CCD camera in Koganei, Tokyo. Objects as small as 20 cm can theoretically be observed at GSO altitudes. As a collaborative study with the National Space Development Agency of Japan (NASDA), similar observations have been conducted since 1992 using the Schmidt telescopes of the Kagoshima Space Centre (KSC) and Kiso Observatory of the University of Tokyo. Experimental radar observations of satellites have been successfully demonstrated using the 20 metre antenna at KSC as a transmitting station and the 64 metre antenna at the Usuda Deep Space Centre. By means of modern communications technology, objects as small as 2 cm at 500 km altitude can be detected. Debris observations have been made by the Middle and Upper Atmosphere (MU) radar which has an active phased array antenna 103 metres in diameter and peak output power of 1 MW. The greatest advantage of the MU radar is its beam steerability, which makes it possible to observe variations of the radar scattering characteristics of unknown objects for a period of 20 seconds and to observe in different directions almost simultaneously.

Several Japanese study groups performed the post-flight analysis of the Space Flyer Unit (SFU) which was recovered by the U.S. Space Shuttle after 10 months in orbit. In total, some 20 square metres of exposed surfaces were available on SFU for analysis. The main surfaces consist of multi-layer insulation (MLI), second surface mirrors and the painted alloy structure. According to the preliminary results, no significant outgassing or off-gassing have been detected. A total of 337 impacts with diameters greater than about 200 micrometers have been observed in visual surveys, and 180 impacts in high-resolution surveys of selected surfaces. The diameter of maximum damage is about 13.4 mm, with an impact crater diameter of 2.5 mm.

B. Modelling of Space Debris Environment and Risk Assessment

The measurement of space debris does not cover the total debris size distribution in all altitude regimes of interest. In many cases, measurements provide only statistical information (e.g. number of objects passing the beam of a radar antenna). In order to understand the dynamics of the debris population, it is essential to also analyse the time-dependent numbers of smaller objects. Finally, relying only on measurements is not sufficient to understand the sources and dynamics of the debris population and to analyse the risk for future missions. A detailed analysis of future scenarios and of the effectiveness of debris minimization and mitigation measures can be performed only by using space debris population models. The space debris environment is currently modelled in many countries.

In the Defence Evaluation Research Agency of the United Kingdom, the Integrated Debris Evolution Suite (IDES) combines deterministic modelling of particles over 10 cm size with stochastic modelling for particles below 10 cm. Altitudes covered are from 100 to 2000 km. Orbital situations can be computed in one-month time steps to predict possible collision events (including catastrophic, damaging or just surface erosion effects). A semi-deterministic code SDM/STAT, for the long-term analysis of the debris population, is being developed under an ESA contact at the University of Pisa (Italy). It has features similar to CHAIN and is based on the background population which is modulated by traffic and mitigation dependent overlay populations. The Nazarenko Model (CPS) developed in the Russian Federation is a semi-analytical, stochastic model for medium and long-term forecast of the LEO debris environment. It provides spatial density and velocity distributions, based on Russian Federation and United States space catalogue data.

In CNES, special emphasis is given to impact of debris into fragile materials (glass, silicium) which can produce a great number of small particles (secondary impact). The mass of these secondary particles can reach 1000 times the mass of the primary particles. A study group at the Institute for Space and Aeronautical Sciences of Japan (ISAS) studied the debris flux as a function of altitude and showed that it peaks at the altitudes of 1000 and 1500 km and that the flux in the year 2000 should be twice the 1982 value. Since no fragments have been tracked in GSO, even though there have been at least three explosions there, models are extremely important for understanding the dynamics of objects in this region. According to the study performed at Kyushu University, the estimated number of objects that regularly cross the geostationary band depends mainly on the explosion rate, followed by the rate of re-orbiting the satellite at the end of lifetime. Therefore, the passivation measures for spacecraft are necessary to reduce the possibility of explosion on GSO.

In Germany, the space debris modelling is financed by the German Ministry of Research and Technology and by the German Space Agency (DARA). The work has been carried out by the institute for Flight Mechanics and Spaceflight Technology (IFR) of the Technical University of Braunschweig (TUBS), Germany. Based on these activities IFR/TUBS has developed the ESA Space Debris Reference Model (MASTER) under a contract of the European Space Operation Centre in Darmstadt (ESOC). This model covers man-made debris and natural meteoroids (meteoroids distribution was modelled by the Max Planck Institute in Heidelberg, Germany). Since 1990, government-sponsored cooperation between TUBS and NASA Johnson Space Centre (JSC) led to fruitful discussions concerning the modelling approaches and the results obtained by both parties using their own tools. The debris models developed in Germany are concentrating on man-made objects larger than 0.1 mm; with respect to the risk posed to spacecraft, objects larger than 1 cm are of special interest.

For the purpose of long-term population modelling, the analytical computer code CHAINEE (CHAIN European Extension) was developed. This code describes the population and collision fragments up to an altitude of 2000 km using four altitude bins and six mass classes. The main advantage of CHAINEE is the extremely low computer time needed (approximately 10 seconds for a simulation of one hundred years); however, its low spatial resolution is a major disadvantage. Therefore, it is mostly a tool to analyse some basic effects of future scenarios. For detailed analysis, especially if a high resolution concerning the orbital altitude is required, a new tool called LUCA has been developed at TUBS. It combines the advantages of a high spatial resolution and a tolerable amount of computer time needed to run a simulation. In order to calculate the time-dependent collision risk, a special tool has been implemented, which analyses the geometry of the orbits of all population members and determines the probability that members of the population will have a collision. This tool is used once in a year of simulated time and guarantees that changes in the population properties are reflected in the collision probabilities. This ability is also an enhancement with respect to the modelling methodology compared to the former programmes used.

The United States orbital debris programme is aimed to ensure safety of human space flight, protect national assets and investments in space from orbital debris and finally to ensure long-term protection of the space environment. The orbital debris engineering model (ORDEM) is used to compute the current and near-term orbital debris hazard for low Earth orbit missions. The ORDEM91 model was baselined before the STS-80 flight, the ORDEM96 model is baselined on data starting with STS-80. It provides low Earth orbit debris flux levels and directionality as a function of particle size. It is based on the latest remote and *in situ* measurements of the near-Earth environment.

Because of the importance of the manned space shuttle flights and of a future International Space Station, the United States has initiated a special pre-flight meteoroid/orbital debris risk and post-flight damage assessment programme. A BUMPER computer code can determine the probability of specified damage levels caused by debris impacts, using relevant input and output specifications. In addition to the spacecraft configuration and mission profile, a concrete meteoroid/orbital debris environment model (e.g. ORDEM96) is part of the input data. As an output, probability of particle impacts from given size, probability of the impact damage (necessity of the window replacements, reinforced carbon-carbon and radiator impacts and probability of "critical" damage) are obtained regarding both meteoroid and debris particles.

There are different thresholds of "critical" damage: For example, the windows should be replaced if impacted by a 0.04 mm particle, a space suit could be penetrated by a 0.1 mm particle, an orbital radiator tube by a 0.5 mm particle, the reinforced carbon-carbon panels (as well as payload bay) by a 1.0 mm particle, the thermal protection system by a 3-5 mm particle and the orbiter crew cabin by a 5 mm or larger particle. Comparisons of the real and predicted replacements of the shuttle windows after the last nine flights show that the real replacements are 30 percent more frequent than predicted (the total of 63 is up to STS-80). Similar results have been obtained from data on the first repair mission to Hubble Space Telescope in December 1993. In general, the use of the BUMPER assessment process has reduced meteoroid/space debris damage on the shuttle and enhanced the safety of the shuttle missions.

Another computer code, EVOLVE, simulates historical and projected space operations, including satellite fragmentations, to create mathematical descriptions of the satellite population. It combines historical data with special purpose routines to simulate semi-deterministically the evolution of the orbital debris environment to the present. Then, Monte Carlo techniques are employed for investigations of future evolutionary characteristics under various debris mitigation practices.

Developed initially in 1993 at TUBS Germany, the CHAIN model has been maintained and improved by the JSC. CHAIN is a lower fidelity model employing the so-called "particle-in-a-box" technique to permit fast running, Monte Carlo simulations of the long-term evolution of the Earth's satellite population. CHAIN can be employed to identify the relative trends associated with specific mitigation policies, while higher fidelity assessments can later be performed by the EVOLVE model.

C. Space Debris Mitigation Measures

Measures to limit space debris generation must be developed and implemented on a multilateral basis by the spacefaring nations. The Japan Society for Aeronautical and Space Sciences (JSASS) committee on space debris prevention design standards published in March 1996 the final report for the Japanese National Space Development Agency (NASDA) standards and design criteria. 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; disposition 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.

The current NASDA Standard acknowledges that a plan for space debris mitigation control should be tailored for each programme, but requests each NASDA Project Manager to prepare a Space Debris Mitigation Plan, including an adequate rationale for items for which an exception is requested. Manufacturers are also requested to present a similar plan. Each plan is subsequently reviewed by the NASDA Safety Review Committee. An exception will be granted only under certain conditions; some projects currently well into their development cycle may be allowed to violate some requirement of the standard.

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. For example, the orbital life of the ETS-VI H-II second stage (1994-056B) was reduced to about seven months as a result of deorbiting. The stage re-entered the Earth’s atmosphere on 31 March 1995.

Strict mitigation measures are applied to all 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.

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 reentry 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.

From the German modelling studies, two mitigation measures can be identified. First, there is explosion prevention. Most of the historical unintentional explosions were due to the residual fuel of spent rocket bodies. Hence, passivation of spent rocket bodies by venting the residual fuel is appropriate to avoid self-triggered explosions. Prevention of collisions, in particular of those debris which generate most of the collisional debris, can only be performed by removing large objects from space. Spent rocket bodies and spent satellites are large objects with significant masses and areas. It can be seen from the models that substantial reduction of the population growth can be achieved this way, but there still would be a tendency toward a growing population.

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). In 1995, China joined IADC and the British Space Agency (United Kingdom), CNES (France) and the Indian Space Research Organization (ISRO) did so in 1996. 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.

D. Collisions of Nuclear Power Sources with Space Debris

In the Russian Federation, the consequences of a collision between decommissioned nuclear power sources (NPS) and space debris during their protracted stay in orbit are prime targets of research on radioactive, chemical and environmental contamination of outer space. The possible consequences of a collision between debris with a reactor NPS launched into space and placed into sufficiently high orbit are: destruction of reactor radiator reflector (beryllium); destruction of radiation shield (lithium hydride); destruction of liquid metal circuit and possible outflow of coolant (sodium-potassium); and destruction of reactor NPS structural components with concomitant fragmentation of structural materials.

Interaction of space debris with secondary liquid metal circuits and the resulting circuit destruction might lead to possible coolant drops into outer space. The investigation of these processes involve the character of the NPS motion around its centre of mass; the thermal state of the radiator and the circuit; the coolant overflow due to the punctured radiator and circuit components; the thermal state of coolant drops; and the probability of interaction with the radiator and subsequent radiator puncture.

The following pattern of coolant drop egress can be assumed. Immediately after tube destruction, coolant pressure inside the tube substantially exceeds external pressure, hence the coolant reaches a boil and splashes out in small portions. Calculations confirm that the condition whereby pressure is exceeded due to centrifugal forces is pertinent only to Cosmos 1900 and 1932 satellites transferred into high orbits in 1988. Destruction of their radiators or manifolds after collision with space debris can lead to coolant outflow from the secondary circuit and formation of sodium-potassium drops (which seems to be confirmed by some space debris observations). The lifetime of coolant drops with initial diameter from 5 to 20 mm in the 950-1000 km altitude range is 7.5 to 32 years. At the 900-950 km altitude range, the corresponding lifetime is four to 14 years. The evaporation time is much longer: 145 to 580 years.

The computed probability of a collision between space debris and the coolant circuit of one of the 28 reactors in orbit is one per year for particles of 1-1.5 mm in size and 7.10^{-3} to 2.10^{-3} events per year for 6-12 mm size. The former particles can make holes in the tube, but the coolant would outflow only after impact of the latter ones. Depending on the construction, seven NPS (Cosmos 1670 type) can be sources of sodium-potassium drops upon impact with particles over 6 mm size and nine NPS (Cosmos 1579 type) with the size over 12 mm.

E. The Use of Nuclear Power Sources in Outer Space

To maintain specified thermal conditions and provide electrical power for small autonomous stations of the Mars 96 project, special radionuclide thermoelectric generators (RTG) and radionuclide heat units (RHU) based on plutonium 238 were developed. The heat units are universal (heat power about 8.5W each), so that they are used also as a primary source of heat for the thermoelectric changer of the RTGs. This simplified the safety design of both types of units, since the ampules with plutonium-238 are identical. The design and development of the units were performed in full compliance with the Principles Relevant to the Use of NPS in Outer Space, adopted by the General Assembly in its resolution 47/68 of 14 December 1992, and also with national safety standards of the Russian Federation.

Each RHU has a carbon-carbon heat shield and contains about 17 grams of plutonium-238 dioxide having activity of 260 Ci in a special capsule. The inner part of the capsule shield is made of platinum-rhodium alloys and can absorb the helium created during the alpha-type decay of plutonium-238. The external shield is made of extremely hard alloys of tantalum and wolfram with a special cover layer of other high thermal resistance materials. Therefore, each capsule has more than double shielding against thermal and mechanical shock disturbances.

The capsules could withstand an explosion and burning of the Proton space vehicle propellant with flame temperatures up to 3600 K for 4000 s; spacecraft atmospheric re-entry with the first and second space velocities (up to 11 km/s); and impact with the Earth surface (including concrete and rocks) with velocities up to 80 m/s. In addition, plutonium dioxide (cermet) tablets are not dissoluble in the fresh and sea water (to a depth up to 10 km) and base or acid environments. The leak-proof capacity of the capsules has been confirmed by ground tests using model and full-scale RHU specimens and carried out by the inter-agency commission of experts.

The Mars 96 contained 18 RHU with total mass of plutonium dioxide not more than 300 g (270 g of plutonium-238) and the total activity of about 4700 Ci. At each of the two small scientific stations, there were 2 RTGs (each containing a single RHU) and 2 RHUs for heating. Similarly, each of the two Mars penetrators contained one RTG (powered by 2 RHU) and 3 RHU for heating purposes. The electrical power for the main spacecraft should have been provided by conventional solar battery panels.

The launching of the Mars 96 space probe with international scientific equipment on board for complex exploration of Mars took place on 16 November 1996 at 20.49 Universal Time from the Baikonur cosmodrome. The engines of the Proton launcher worked out after 583s as scheduled. After 6 minutes, a special accelerating unit engine was ignited for 100s. As a result, the unit and the Mars 96 probe were injected into a circular parking orbit around the Earth. These events were observed and controlled from the ground. After 51.5 minutes of orbital flight, near the equator and outside the visibility of the Russian ground tracking stations, the engine should have been ignited for the second time to provide an additional velocity of 3,146 m/s. After that, the Mars 96 probe should have separated from the unit and by the use of its own engine acquire an additional 536 m/s needed for entering the interplanetary orbit towards Mars.

However, while the first ignition of the accelerating unit took place as planned, the second one failed and the unit with the Mars 96 probe remained in a low Earth orbit. The automatic systems of the spacecraft performed the separation from the accelerating unit and ignition of its own engine. According to the telemetry data, it worked for about 6s and provided a velocity impulse of 10 m/s. This was not enough for a substantial increase of the orbit and moreover, the impulse was given in a wrong direction. The acceleration unit was precisely tracked in its low orbit and decayed on 18 November 1996 at 1.20 Universal Time over the Pacific Ocean, several thousand kilometres east of Australia (about 51 degrees South, 168 degrees West).

The tracking of the Mars 96 probe was not continuous and the location of its decay was much more difficult to determine. After careful analysis of all available information (telemetry, tracking and aerodynamic modelling), it was confirmed that the probe, including radioisotope capsules, entered the atmosphere on 17 November 1996 around 1.00 Universal Time at the end of its third revolution around the Earth. The probable fall-zone is located in the Pacific Ocean, 800 to 200 km around the orbit, west of the coast of Chile. Its centre is at 25.1 degrees South and 75.4 degrees West. In addition to the notification of the incident to the United Nations, representatives of Argentina, Bolivia, Chile and Peru were informed on 28 November 1996 of the circumstances of the accident. A special commission was set up to investigate all its aspects, including the reasons for the failure. The commission recommended an increase in quality control during all stages of production of the accelerating unit and cleared it for the use in future launchings of the Proton booster into highly-elliptical and geostationary orbits.

After the aerodynamic destruction of the Mars 96 spacecraft and the RTG aluminium and steel structural components during the atmospheric re-entry, the capsules with plutonium dioxide fell within the fall-zone of the fragments, in a practically unchanged form. Since there is no plutonium dioxide release into the environment, it rules out any possibility of radioactive contamination and radiological effects on the population. Deposition of the RHU in the Pacific Ocean floor at considerable depth should be regarded as an ecologically-safe disposal of a relatively small quantity of plutonium-238.

F. International Cooperation in Space Research and Applications

The Committee on Earth Observation Satellites (CEOS) strongly pursues the development of the Integrated Global Observing Strategy (IGOS) in order to make more effective use of investments in this field and to support the world-wide demand for a complex sets of instruments to collect relevant data, distribute them and create and distribute data products. The existing systems do not seem to meet the demand. User needs could be met more effectively through better inter-agency coordination and cooperation. Strategy should be developed to integrate inter-agency planning for cost effective space-based systems, inter-calibration, compatibility of data delivery systems and by establishing better links among the users and providers. The delivery of services should be aimed to satisfy social, economic and environmental needs of the users. Developing countries are recognized as both providers and users of data.

CEOS encourages data providers to make additional investments in calibration of measurements and validation of derived geophysical products and to extend data acquisition benefits to a broader user community. It recognizes *in situ* observations as a necessary complement of space-based observations and the need to develop data assimilation programmes to maximize the value of both types of data. A framework for private sector data providers and value-adding companies should intersect with publicly supported agencies. In general, an IGOS will demand new heights of mutual responsiveness between communities whose members measure phenomena of the Earth surface and atmosphere, and communities whose members make use of this information.

The development of IGOS should be gradual to accommodate a variety of data policies and voluntary commitments, but at the same time it should contain some measurable benchmarks for gauging the progress of implementation. The structure of IGOS should satisfy a formal set of users' data requirements for continuity of data provision (coverage and characteristics); minimization of data gaps; maintenance of the long-term data record; reduction of unnecessary duplication of instruments; development of partnerships between data users and data providers for definition and complementary funding of observing programmes; and a high level of political support. The Task Force on Planning and Analysis, established in 1994, has already collected user requirements and defined a database structure to conform with data availability. The CEOS meetings provide a key forum to address the space component; an IGOS Strategic Implementation Team was established at CEOS's 10th plenary meeting in November 1996 in Canberra (Australia). The work of the Task Force will be continued and expanded by an Analysis Group. An international peer review of pilot projects should begin in 1999 and an operational system, based on the lessons learned, would be established after that.

During a meeting at the Vienna International Centre in February 1997, the representatives of Bulgaria, Greece, Poland, Romania, Slovakia and Turkey agreed to establish a network of space science and technology education and research institutions for central eastern and south-eastern European countries. The activities of the network would be in the harmony with the relevant work of existing institutions in Europe and would be open to international cooperation. The objective of the network will be to promote, by space specific multidisciplinary and interdisciplinary methods, higher level capacity building in the region; develop future specific regional space education, research and applications projects; and develop joint space scientific and operational programmes and benefit from them at the regional level. A study on the technical requirements, design and operation mechanism and funding of the network will be prepared by the experts in cooperation with the United Nations Office for Outer Space Affairs.

Satellite communications, which makes it possible to collect, transmit, disseminate and exchange information among all the regions of the world, could be of particular use to developing countries, especially in the rural areas, which tend to be isolated and lack communications infrastructures. Satellite communications increase domestic, regional and national traffic and have a substantial impact on national economies. A number of projects are currently being implemented in Europe and Africa for information exchange using satellites, and the installations involved could be used for the Mediterranean region, such as:

- COPINE, proposed by the United Nations Office for Outer Space Affairs and the World Health Organization, which aims to establish a network of satellite telecommunications stations for information exchange on the environment, education and medicine between Africa and Europe;

- MEDSAT, a project directed by France, involving the launch of a communications satellite to cover the Mediterranean basin (Morocco, Tunisia and Egypt are potential southern partners);

- EAST, another project announced by France, involving the launch of a powerful geostationary satellite over central and eastern Europe and North Africa to provide telephone and data transmission services;

- COSMO/SKYMED, a project directed by Italy, involving a constellation of small satellites to observe the Mediterranean basin; and

- FUEGO, a project directed by Spain, involving a constellation of small satellites for the management and monitoring of forest fires in the Mediterranean basin.

With the establishment of the Royal Centre for Remote Sensing (CRTS) in 1989, Morocco took an important step forward in space information production. 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 spaceborne remote detection 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. The aim of the projects is to generate the information needed for development.

There are currently stations for receiving Earth observation data from the METEOSAT meterological satellite, mainly in the National Department of Meteorology (DMN). A NOAA meteorological satellite data receiving station has also been set up in the DMN for meteorological studies. Another station of this type is planned for CRTS to receive satellite radiometric data, which is useful for agriculture, forestry and oceanography. Management of scarce water resources in Morocco is extremely important. In order to access data from other Earth observation satellites, the CRTS has concluded contracts with international image distributors: SPOT IMAGE in France for Spot data, EURIMAGE in Italy for NOAA, Landsat, ERS data *etc.*

The CRTS is also organizing development of the first national microsatellite, experimental in nature, which will be launched into low Earth orbit, with a payload of messaging and remote sensing equipment. The work is being carried out with the collaboration of the Berlin Technical University (TUB), which is providing the TUBSAT-C platform for the project. Installation of the component systems is expected to be completed in 1997.

G. Space Medicine and Materials Science

Chagas’ disease, also called American trypanosomiasis, is an infection caused by a parasite, the flagellate protozoan Trypanosoma cruzi, transmitted to humans most often by an insect carrier (particularly by a bloodsucking bug called "vinchuca" in Chile), but also transmitted by some other indirect ways (i.e. through blood transfusions and organ transplants or through the handling or ingestion of the blood and meat of infected animals). The disease is endemic in most rural areas of Central and South America, and causes local swellings, fever and prostration. When the disease enters a chronic stage, it can affect the heart, and may end in death, especially in children. To date, no known drug cures the T. cruzi infection at this chronic stage. According to the World Health Organization (WHO), 20 million people are infected in a territory that spans from the Southern United States to the end of the Patagonia. Every year, 80,000 people die, and 250,000 are infected.

The outstanding advancements in the crystallization of proteins in microgravity achieved during the last few years has opened a light of hope towards the development of medical drugs to eventually cure Chagas’ disease. Since 1984, a number of NASA Space Shuttle missions have carried out crystallization experiments and have developed the necessary hardware. As a result, crystals of numerous proteins have been grown in space, having a higher quality and a bigger size than those grown on the ground, subject to Earth's gravity. One of the biggest advances concerning crystal growth in the microgravity environment in space has been the introduction of a new method, called "vapour diffusion using hanging drop". This method has allowed for the crystallization of innumerable macro-molecules in space, particularly of proteins.

The bigger size and the higher quality of space-grown crystals make them particularly appropriate for the study of their three-dimensional structure by means of high-resolution analysis with X-rays diffraction. This technique, "computer molecular modelling," is performed with the help of modern computer software. The knowledge of the three-dimensional structure of protein molecules is essential in order to determine their mechanisms of action and their biological functions, and subsequently to develop new drugs able to interact with these bio-molecules in a specific, desired way. This process is known as "rational design of drugs".

In February 1996, during the STS-75 mission of the Space Shuttle Columbia, the first medical experiment designed by Latin American researchers was carried out. For 16 days, crystals were grown of Tripanotion Reductase, a specific enzyme of the T. cruzi. Based on the results, new experiments were prepared for the STS-83 mission in April 1997. The aim was to grow, in a microgravity environment, crystals of the parasite's other enzymes (11 different proteins in 80 crystallization chambers), in order to determine their molecular structures. Participating scientists from Argentina, Brazil, Chile, Costa Rica, Mexico, Uruguay and the United States hope that using the rational design of drugs will result in the development of a new medicament against this silent but fatal disease.

H. Astronomy and Planetary Exploration

The Japanese ISAS successfully launched the Very Long Base Interferometry (VLBI) satellite MUSES-B (renamed in orbit as HALCA - Highly Advanced Laboratory for Communications and Astronomy) by the new M-V launch vehicle on 12 February 1997. The M-V is a solid, three-stage rocket with an optional kick stage. It is about 30 metres long, with a diameter of 2.5 metres, and total mass about 140 tons. It can carry an approximate two-ton payload into low Earth orbit. With the advent of this new launcher, Japanese space science entered a new area, namely a stage which foresees more ambitious projects that include lunar and planetary exploration. Five more spacecraft have already been approved for launch by the M-V: the LUNAR-A for the Moon penetrator mission (fiscal year 1997); the PLANET-B to Mars (fiscal year 1998); the ASTRO-E for an X-ray astronomy satellite (fiscal year 1999); MUSES-C for asteroid sample returns (fiscal year 2001); and ASTRO-F for infrared astronomy (fiscal year 2002).

Despite a large amount of data collected by the Apollo and Luna missions, the structure and composition of the lunar interior is still poorly understood. The planned LUNAR-A mission will send three penetrators from the lunar orbit onto its surface. The penetrators, each having a cylindrical shape with a frustum nose of 80 cm long and 12 cm in diameter, will hit the surface at a velocity of about 300 m/s and penetrate two metres deep (two will be aimed to the near side of the Moon, a third to the far side). The penetrators will constitute a seismic and heat flow measurement network in order to better understand the origin and evolution of the Moon.

The PLANET-B is the first Japanese mission to Mars and is due for launch in July 1998. After an interplanetary cruise, it should enter the orbit around Mars with periapsis as low as 150 km. This is where the interaction of the solar wind with the Martian atmosphere could be most effectively studied. The on-board camera and radiometer will provide information on the global atmospheric conditions near the surface. Other instruments should provide data on magnetic fields, the vertical structure of the atmosphere and plasma, high energy particles, surface temperature, and images of the surface and dust storms. The spacecraft should operate in areocentric orbit for at least two years after insertion in 1999.

The ambitious first launch of the M-V in the 21st century will carry an asteroid sample return mission, MUSES-C, to the near-Earth asteroid Nereus. The mission should be launched early in 2001 and will arrive back on Earth in January 2006. Since Nereus seems to be one of the most primitive bodies in the solar system, the mission should provide a better picture of the early history of the solar system. The astronomical mission ASTRO-E (a successor to the Advanced Satellite for Cosmology and Astrophysics (ASCA) satellite launched in 1993) will be equipped with soft and hard X-ray telescopes to cover a very wide energy range. The ASTRO-F infrared astronomy satellite should explore the riddles of galactic evolution, interstellar objects, brown dwarfs, dark matter in the Universe and other topics, using a complex of instruments, cooled by a new mechanical cooling technique which has rapidly progressed in the past decade as an auxiliary cooler. This should substantially prolong the mission lifetime in comparison with previous infrared astronomy satellites.

The first ESA mission for the *in-situ* study of a cometary nucleus environment and its evolution in the inner solar system is called Rosetta. The main Orbiter spacecraft is developed, operated and fully funded by ESA, with the exception of the scientific payload, which is under the responsibility of the Principal Investigators. To enhance the scientific capabilities of the mission, the Orbiter will carry one Lander called the Surface Science Package. The Rosetta project is ready to enter Phase B with system and subsystem design and analysis to be completed in the third quarter of 1998. The spacecraft is scheduled to be launched in January 2003 by an Ariane 5 launcher. It will employ three planetary gravity assist manoeuvres (Mars in August 2005 and Earth in November 2005 and November 2007) to acquire sufficient energy to rendezvous with the comet Wirtanen in May 2012. After each Earth assist, an asteroid fly-by is planned (asteroid Mimistrobell in September 2006 and Shipka in October 2008).

The comet rendezvous manoeuvre is currently scheduled to occur approximately 4.8 astronomical units (AU) from the Sun and is aimed to match the spacecraft orbit with the comet so that the relative velocity is reduced to about 100 m/s. The rendezvous will be followed by a drift phase of three to six months as the spacecraft slowly closes on the comet. After that, there should be enough power from the solar array to bring the spacecraft to full operational status and acquire the comet with the on-board navigation camera. The final manoeuvre would then be completed and the spacecraft placed in a mapping orbit. The nominal operations on the comet are expected to commence approximately 3.25 AU from the Sun through to perihelion, a period of about one year. Early in the operational phase, the landing sites for the Lander will be selected and its separation and delivery accomplished. The Lander will nominally operate on the surface of the nucleus for several months, while the Orbiter will orbit or escort the nucleus to carry out scientific operations with its payload.

The scientific objective of the Rosetta mission is to investigate the origin of the solar system by studying the origin of comets and to study the relationship between cometary and interstellar material. It will provide for the detailed exploration of the comet nucleus and its close environment and will provide unique sample analysis capabilities, thus satisfying to a large extent the objectives of the original comet-nucleus sample-return mission.

The scientific payload of the Rosetta Orbiter was pre-selected and endorsed by the ESA Science Programme Committee at its February 1996 meeting. The Orbiter payload comprises 11 investigations and one radio science investigation using the on-board spacecraft telecommunications system. They comprise remote sensing (four experiments), composition analysis (four), nucleus large-scale structure (one), dust flux, dust mass distribution (one), and comet plasma environment and solar wind direction (one). The Lander payload consists of a complex of investigations which will characterize the comet surface and sub-surface (a total of nine experiments).

Austria is responsible for the MIDAS (Micro-Imaging Dust Analysis System) experiment on the Rosetta Orbiter (in cooperation with co-investigators from six countries). MIDAS is dedicated to the micro textual and statistical analysis of cometary dust particles. It is based on the technique of atomic force microscopy which has made rapid progress in recent years after the discovery of the principle in 1986. Textural and other analysis of dust particles will be performed in the size range of 4 to 5000 nanometres. The MIDAS instrument is considered essential for the Rosetta mission as, for the first time, it will provide the capability of imaging in three dimensions dust particles in the nanometre to micrometre range. This size range covers the building blocks of pristine interplanetary and cometary particles, i.e. the silicate core particles (100-200 nanometres), refractory organic mantle (about 10 nanometres) and possible crystalline structure of the material. The instrument will collect and image particles irrespective of their shape and electrical conductivity. It should perfectly complement the data on the chemical composition obtained by other instruments such as the Cometary Secondary Ion Mass Spectrometer (COSIMA).

I. Adverse Environmental Effects on Astronomy

It has become clear that operational and spent spacecraft, as well as the larger pieces of trackable space debris, are the greatest contributors to "trailing": a passage of an object across a telescopic field of view, which is recorded both photographically (during the deep space studies) and photometrically. The quality of deep space plates is degraded, photometric observations are lost and there is an ever present danger of damage to sensitive detectors. The phenomenon is not new, but with the launch of multi-satellite systems such as Iridium now and, perhaps, Teledesic in the future, there is likely to be a considerable growth in the population of both active and spent satellites. Also, the issue of radio interference produced by Iridium satellites at 1612 MHz with astronomical OH maser emission remains unresolved, despite the very considerable efforts of the Inter-Union Committee on the Allocation of Frequencies to obtain a resolution through the International Telecommunication Union (ITU).

In June 1996, the United States Naval Research Laboratory launched the TIPS experimental double satellite, the two components of which are connected by a four kilometre-long tether. The announced objective is to test survivability of the 2.5 mm diameter tether in orbit at 1000 km altitude, because tethers are believed to be fragile in respect of small debris impact. A tether 4 kilometres long subtends an angle of 14 minutes of arc and has the 6th magnitude - just visible to the naked eye. With these dimensions, TIPS can produce a smear rather than a trail - a smear which is comparable in size to the field of view of a CCD commercially available for professional and amateur use. Since some astronomical observations should be performed during astronomical twilight, TIPS is a hazard for observational optical astronomy. For example, observations at the beginning of April of the appulse of an early type star and the comet Hale-Bopp with the Keck Telescope had to be planned so as to not coincide with the passage of the TIPS satellite.

It was announced last year, that UNESCO was moving away from the concept of the "Star of Tolerance" to mark its first fifty years of existence. It was supposed to be a system of two reflecting balloons, kept together by a two kilometre long tether in an orbit at 1250 km altitude. Although, like TIPS, it will be seen largely in twilight, it has a potential to appear in the dark sky and to be as bright as Sirius. Unfortunately, the project might be back, this time as a Millennial Project. The putative launch of this project would send a disastrous message: that advertising from space is considered acceptable. The firm stand taken by ESA against this project was very warmly appreciated by the whole astronomical community.

Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

I. SYMPOSIUM ON SPACE SYSTEMS FOR DIRECT BROADCASTING AND GLOBAL INFORMATION SYSTEMS FOR SPACE RESEARCH, ORGANIZED BY COSPAR AND IAF

The first session of the symposium, "Direct broadcasting systems", was co-chaired by Mr. K. Doetsch, representing IAF, and Mr. G. Haerendel, representing COSPAR. The second session of the symposium, "Global information systems for space research, was co-chaired by Mr. K. Doetsch, representing IAF, and Mr. K. Kasturirangan, representing COSPAR.

"Global Perspectives of Satellite Radio and Digital Audio Broadcasting," Mr. K. Kasturirangan
Indian Space Research Organisation (ISRO), India.

"Multimedia and Broadcasting Services via Satellite," Mr. O. Koudelka, Technical University Graz, Austria.

"Current Status of Satellite Direct Television Broadcasting in Russia", Mr. Y. B. Zoubarev, State Radio Research and Development Institute, Russian Federation.

"Satellite Digital Television Broadcasting Technology and the Koreasat DBS System," Mr. J. S. Chae, Electronic Communications Research Institute, Republic of Korea.

"International Networks and Satellite Data Archiving Systems in Support of Mission to Planet Earth," Mr. R. Schiffer, National Aeronautics and Space Administration (NASA), United States.

"Software Packages Including the Use of World Wide Web (WWW) for Research Purposes in Space Science," Mr. M. Machado, Commissión Nacional de Actividades Espaciales, Argentina.

"Data and Information System on Global Climate Change (IGBP-DIS)," Mr. J.-P. Malingreau, Joint Research Centre of the European Commission.

"The Role of Developing Countries in Global Change and Establishment of a Global Information System," Mr. Zhou Chenghu, Chinese Academy of Sciences, China.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

"Scientific and Technical Aspects of the STS 78 Mission" (video presentation), Mr. J.-J. Favier, spationaute, Centre National d'Etudes Spatiales (CNES), France.

"Software Packages Including the use of World Wide Web for Research Purposes in Space Science," Mr. R. Albrecht, European Space Agency.

"Space Activities of Developing Countries: Technical Possibilities and Perspectives," Mr. M. M. Kabbaj, Royal Centre for Remote Sensing (CRTS), Morocco.

"Space Debris Research in France in 1996," Mr. F. Alby, Centre National d'Etudes Spatiales (CNES), France.

"Integrated Global Observation Strategy," Mr. G. Brachet, Centre National d'Etudes Spatiales (CNES), France.

"Research on Developing Medicaments for Chagas' Disease through Protein Crystallization in Microgravity Conditions," Ms. S. Sepulveda, Universidad de Santiago de Chile, Chile.

"Network of Space Science and Technology Capability Building Centres in Central Eastern and South Eastern Europe," Mr. M.-I. Piso, Romanian Space Agency, Romania.

"Mars 96 Mission," Mr. V. I. Lisitsin, Russian Space Agency, Russian Federation.

"Japanese Space Science in 1997," Mr. Y. Matogawa, Institute of Space and Astronautical Science (ISAS), Japan.

"Austrian Contribution to the Cometary Probe Rosetta," Mr. K. Torkar, Austrian Academy of Sciences, Austria.

"Some Topics of Space Debris Research in Japan," Mr. S. Toda, National Aerospace Laboratory, Japan.

"German Space Debris Modelling Activities," Mr. J. Bendisch, Technical University Braunschweig, Germany.

"Orbital Debris Modelling in the United States of America," Mr. N. Johnson, National Aeronautics and Space Administration (NASA), United States.

"Inter-Agency Space Debris Coordination Committee (IADC)," Mr. G. M. Levin and Walter Flury, on behalf of IADC.

"NASDA Space Debris Mitigation Standard," Mr. A. Kato, National Space Development Agency (NASDA), Japan.

"Space Shuttle Program Pre-Flight Meteoroid/Orbital Debris Risk and Post-Flight Damage Assessments," Mr. G. Levin, National Aeronautics and Space Administration (NASA), United States.

"Modelling the Orbital Debris Population," Mr. R. Crowther, Defence Evaluation Research Agency (DERA), United Kingdom.

"Modelling of the Space Debris Environment and Risk Assessment," Mr. W. Flury, European Space Agency.

"Collision of Nuclear Power Sources with Space Debris." Mr. V.S. Nikolaev, Ministry of Atomic Energy, Russian Federation.

"Nuclear Power Sources on Board of Mars 96 Spacecraft," Mr. A. Pustovalov, Russian Academy of Sciences, Russian Federation.

"Management of Water Resources in Developing Countries," Mr. D. El Hadani, Royal Centre for Remote Sensing (CRTS), Morocco.

"Adverse Environmental Impacts on Astronomy," Mr. D. McNally, International Astronomical Union.