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COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUB-COMMITTEE

Report by the Secretariat

1. During the twenty-seventh session of the Scientific and Technical Sub-Committee, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) and the International Astronautical Federation (IAF) organized a symposium on the subject of "The use of space technology in terrestrial search and rescue and in disaster relief activities". This symposium was organized in accordance with the recommendation of the Sub-Committee at its twenty-sixth session, in 1989, that this subject be fixed for special attention at the 1990 session and that COSPAR and IAF be invited to arrange a symposium on the subject. The recommendation was subsequently endorsed by the Committee on the Peaceful Uses of Outer Space and by the General Assembly in resolution 44/46 of 8 December 1989.

2. The symposium was the sixth to be organized by COSPAR and IAF during the annual meetings of the Scientific and Technical Sub-Committee, with the topic for each year selected by the Sub-Committee at the previous session. The symposium was held in two parts, on 27 and 28 February 1990, following the completion of debate in the afternoon meetings of the Sub-Committee during the first week of its session.

3. A special presentation was also organized by COSPAR on progress in its International Geosphere-Biosphere Programme (IGBP), in response to an invitation from the Sub-Committee endorsed by the Committee and the General Assembly. This was the fifth in an annual series of such progress reports to the Scientific and Technical Sub-Committee. The presentation was made on 2 March 1990.

4. In addition to these special presentations organized by COSPAR and IAF at the request of the Sub-Committee, 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 Sub-Committee. Several international organizations also made special presentations on their scientific and technical activities.

5. Many of the presentations, addressing the special theme selected for the 1990 session of the Sub-Committee, described the increasing role of space technology in dealing with disasters. The major development in this field in recent years has been in the use of small transportable Earth stations for emergency communications, enabling an otherwise isolated disaster site to communicate with any place in the world. Using simple and low-cost equipment, rescue teams can quickly order equipment and supplies, get advice from technical specialists and send and receive images and data. An example of such an application was the USSR/United States Telemedicine Spacebridge for medical treatment of victims of the Armenian earthquake and the Ufa train disaster.

6. Meteorological satellites for predicting and monitoring hurricanes and other storms have been used operationally for many years, and steady progress is being made in developing new analysis techniques. The decreasing size and cost of satellite communication Earth stations are greatly facilitating the wide dissemination of storm warnings to high risk areas, as exemplified by a programme in India. Remote sensing and geodetic satellites are being used to identify areas at high risk of floods, earthquakes and volcanoes, and to survey flooded areas. Climate monitoring and modelling are increasing the ability to predict and plan for droughts.

7. A major effort will be made in the 1990s, during the International Decade for Natural Disaster Reduction (IDNDR) to further develop methods of disaster reduction, using space technology among other means. Many international organizations such as the Office of the United Nations Disaster Relief Co-ordinator (UNDRO) and the World Meteorological Organization (WMO) and many national organizations will be co-operating in this effort.

8. The use of satellites for search and rescue is also becoming more widespread as more countries participate in the international COSPAS-SARSAT programme using USSR and United States polar-orbiting satellites. The use of geostationary satellites, as proposed by INMARSAT, requires somewhat more complex emergency transmitters, but offers the advantage of immediate communications. The availability and use of emergency position-indicating radio beacons is increasing and more ground stations are coming into operation around the world.

9. Under the co-ordination of COSPAR, many international and national agencies are participating in the International Geosphere-Biosphere Programme (IGBP), an ongoing programme to increase our understanding of the global environment. Global climate and environmental data are being collected by many countries and used to develop computer models for predicting global change caused by both natural and human factors, such as the greenhouse effect. Examples of national activities including space observations of the global environment include programmes in China, India, the Federal Republic of Germany, the USSR and the United States.

10. The United States, in co-operation with the European Space Agency, Canada and Japan, is planning an Earth Observation System to monitor the global environment from space. The System will include elements of the Space Station and polar-orbiting platforms, and is expected to begin observations in the late 1990s. Data will be available to users around the world.

11. The USSR is developing a Priroda module for the Mir space station and the Almaz system consisting of orbital platforms, relay satellites and ground facilities, both for the purpose of Earth observation. The Almaz system could be the basis for an international ecological laboratory.

12. Remote sensing for the development and management of natural resources is continuing to progress. Canada is developing its RADARSAT satellite for launch in 1994, providing an all-weather global observation capability. In Sweden, Landsat and SPOT data are being used both for national purposes and for international technical assistance activities, and plans are under way to use the ESA ERS-1 radar satellite.

13. A number of major space missions dedicated to planetary science and astronomy were successfully launched in 1989 and early 1990, promising a large amount of new data in the 1990s. The Magellan radar mapper was launched in May 1989 towards Venus, where it would start a detailed and comprehensive mapping programme in late 1990. The Galileo planetary orbiter and atmospheric probe was launched in October 1989 on a long and complex trajectory to Jupiter, where it would begin its observations in 1995. The Hubble Space Telescope, which was successfully launched in April 1990, will dramatically extend the ability of astronomers to see distant and faint objects. These three programmes were all led by the United States with the co-operation of other countries, and will provide data to the international scientific community. Other recent or planned United States space observatories include the Cosmic Background Explorer, the Gamma Ray Observatory and the Advanced X-ray Astrophysical Facility.

14. The annex below contains a more detailed summary of the scientific and technical presentations during the Scientific and Technical Sub-Committee. Because of the technical character of the material, the annex is given in English only. A list of the presentations and the speakers is contained in the appendix to the annex.

Annex

SUMMARY OF THE SCIENTIFIC AND TECHNICAL PRESENTATIONS IN THE SCIENTIFIC AND TECHNICAL SUB-COMMITTEE

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I. SPACE TECHNOLOGY FOR DISASTER PREDICTION, COMMUNICATIONS AND RESCUE

A. Disaster management and the International Decade for Natural Disaster Reduction

1. Between 1967 and 1987, 2.8 million lives were lost and property damage of $25-100 billion resulted from natural disasters that adversely affected more than 829 million people. There have been further tremendous losses since these figures were compiled by the United States National Research Council.

2. A single hazardous event can destroy crops, buildings, highways, ports and dams. It can also severely disrupt community lifelines - the systems that provide food distribution, water supply, waste disposal and communications locally and with the rest of the world. The Managua earthquake in 1972, for example, left more than 10,000 dead, 20,000 injured and three fourths of the city's population of 300,000 homeless. This single earthquake, with damages equal to a year's GNP, affected virtually the entire industrial production of Nicaragua.

3. Large segments of the world are vulnerable to rapid-onset disasters, and survivable communications are not available to most of these areas during the critical early phase of a disaster. There is also a growing realization that current disaster preparedness measures and response plans in many countries are inadequate to cope with the casualties and damage from catastrophic, or even "lesser" disasters.

4. Effects of such disasters may severely damage the fragile economic infrastructure of developing countries, especially the least developed, land-locked and island developing countries, and thus hamper their development process. Emergency health care and communications infrastructures, if present before a disaster, are frequently disrupted or rendered useless in the wake of a devastating event.

5. Early warning and quick re-establishment of communications are vital to mitigation and relief operations for all rapid-onset hazards, including earthquakes, floods, landslides, tsunamis, hurricanes, tornadoes, volcanic eruptions and wildfires. Predicting a major natural hazard can reduce its consequences; as a minimum, people will have time to protect life and property, and they may have an opportunity to relocate or reinforce their property. Relief operations can benefit from new mobile telecommunications, data networking and remote-sensing technologies that will be available world wide in the 1990s. Mitigation efforts for long-term hazards such as drought, insect plagues, desertification, and human-caused hazards such as ozone layer depletion, can also be enhanced by these technologies. There exists a wide gap between industrialized and developing countries in their capabilities to respond to natural disasters. They also differ significantly with respect to the effects of disaster: loss of life tends to be greatest in developing countries, property damage greatest in industrialized countries.

6. "Disaster management" is a comprehensive term which embodies all the activities carried out before, during and after a disaster. It is a useful concept because it emphasizes the fact that the actions and reactions in response to impending or actual disaster are all interrelated. There are three main elements to disaster management: preparedness, prevention and relief. Disaster preparedness seeks to minimize losses when disaster strikes, through measures such as disaster warning. In disaster prevention, we try to control these hazards: areas of potential hazard are identified and attempts are made to prevent events from becoming disasters. Finally, in disaster relief, we provide aid (hopefully as rapidly, effectively and efficiently as possible) once a disaster has occurred.

7. Satellite technology can make contributions to each of the three aspects of disaster management. Many of these contributions can be made with satellites and instruments currently in existence. Some will require modifications to existing capability or the development of new technology. Despite several decades of satellite development, the extent of operational use of satellites in disaster management is still limited, especially in contrast to the tremendous potential of this technology. Indeed, much of this potential has been demonstrated, often under actual or simulated operational conditions, but in only a few cases has the technology become a continued, integrated part of operational activities. Only two applications of satellite technology, storm warning and search-and-rescue, can be considered operational in the management of sudden disasters.

8. New and developing satellite telecommunications capabilities can aid in the mitigation of the devastating effects of natural disasters. New low-cost mobile communication technology by satellite, for example, will play a major role in reducing the devastating effects of natural disasters, complementing and enhancing existing terrestrial and regular satellite services. It will dramatically improve hazard prediction, risk assessment, disaster preparedness, early warning and onset and post-disaster relief operations. This low-cost service will soon be available to areas previously considered impractical or impossible to cover because of their location, terrain, weather or demography.

9. World-wide use of satellite technology for mobile communications will bring several advantages:

(a) Natural hazard mitigation experts even in remote areas, can use small, simple, and low-cost equipment;

(b) Emergency response and health care will be improved in areas and situations once considered impossible or impractical;

(c) Mobile satellite communications can be used by land, aeronautical, and maritime transportation industries.

In addition, local, regional and world-wide communications for rural or under-served areas will be significantly improved.

10. Recent space science has also improved our ability to measure and understand the physical, chemical and biological interactions of the Earth's magnetosphere,

atmosphere, oceans and land areas and to assess the importance of these interactions to global, physical and biogeochemical processes. Since the forecasting of natural hazards relies on either mathematical models or empirical understanding of physical phenomena, the ability to improve, update and build on these observations is critical. The accuracy of the models and observation techniques has improved, and thus the accuracy of prediction has improved. For example, from satellite observations of the Earth, it is now possible:

(a) To make three- to five-day world-wide weather forecasts over most parts of the globe, with accuracy and coverage never before possible;

(b) To monitor drought over large regions of the Earth, such as the African Sahel;

(c) To measure forest fires and deforestation over millions of acres of sparsely inhabited and wilderness terrain; and

(d) To use position-fixing satellites to measure the slow movements of the Earth's tectonic plates, potentially helpful for predicting earthquakes.

11. The General Assembly of the United Nations has designated the 1990s as an International Decade for Natural Disaster Reduction (IDNDR). The responsibility of the United Nations system is to promote international co-operation in the study of natural disasters of geophysical origin and in the development of techniques to mitigate risks arising therefrom, as well as co-ordinating disaster relief, preparedness and prevention.

12. The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) is the focal point in the United Nations system for the IDNDR activities, the objective of which is to reduce the devastating effects of catastrophic natural disasters. UNDRO is the specialized office of the Secretary-General for all disaster-related matters. One of its main functions is "to mobilize, direct and co-ordinate external assistance provided by the United Nations system in response to a disaster". UNDRO also promotes "pre-disaster planning as well as the study, prevention, control and prediction of natural disasters".

13. It is expected that many international organizations will respond to the IDNDR initiative, as well as States which have spacefaring capability and national organizations responsible for disaster management.

14. The United States National Aeronautics and Space Administration (NASA), for example, is considering participation in IDNDR by co-ordinating existing efforts carried out under the Land Resources and Weather and Climate Programmes as well as in the Geodynamics and Satellite Communications Programmes. The efforts that are directly and immediately related to IDNDR, include improvements in the ability to predict climate change and severe storms, and monitoring ocean surface conditions and regional to global scale biomass. In other cases, the role of space technology is less direct but still important, for example in predicting volcanic eruptions and earthquakes. In still other cases such as land-use classification, the necessary space technology already exists, but NASA could still make a substantial

contribution in the development of computer technologies, such as geographic information systems, and in technology transfer. The space research needs of IDNDR also conform to the recent NASA emphasis on interdisciplinary science, particularly with regard to Earth System Science and the IGBP; many of the objectives of these proposed programmes seem to be identical with, or very close to, the requirements of the IDNDR.

15. Separate studies carried out by NASA, the United Nations Office of the Disaster Relief Co-ordinator (UNDRO) and, more recently, the International Astronautical Federation and the Annenberg Foundation have explored the potential contribution of space technology to disaster management. These studies have uniformly concluded that this technology has much to offer, although they point out that it must be developed in close co-operation with disaster management agencies.

16. The studies conclude that space technology can make a contribution to a wide range of disaster management activities, but especially in terms of disaster warning. Research in some of the areas related to disaster preparedness has advanced to the point that operational application is rather straightforward (e.g., drought monitoring). Other applications, such as prediction of earthquakes and volcanic eruptions, are still in the research stage.

B. Weather-related disasters and WMO response under the IDNDR

17. The weather either causes or strongly influences 7 of the 10 major types of disaster as ranked by the number of human lives lost world wide from 1947 to 1980. Tropical storms, floods and thunderstorms occur frequently and affect hundreds of millions of people every year. Weather also contributes to many other life-threatening events, including the droughts which cause havoc in many parts of the world. Many of the responses to catastrophic earthquakes are also weather dependent, and disruptions of water courses often bring hydrological factors into play.

18. One of the most destructive weather systems found on Earth is the tropical cyclone which caused almost half a million deaths from 1947 to 1980. In the Western Pacific, tropical cyclones with winds exceeding 120 mph are called typhoons, while those in the North Atlantic, Caribbean, Gulf of Mexico and eastern North Pacific are called hurricanes. About 80 of these killer storms occur around the world each year, causing annual damage estimated at about $1,500 million. Over the past 30 years, the average annual death toll has been about 15,000. Drowning contributes heavily to the fatalities, especially through rare events such as the storm surge, which caused over 200,000 deaths in Bangladesh in 1970.

19. In the United States loss of life due to hurricanes has decreased, even though the population of the most-affected coastal regions has increased greatly. On the other hand, property damage has increased. Improvements in warnings and in community preparedness have been effective, but rapid economic development in those parts of the country most affected by hurricanes has offset the property-damage reductions. Data from China and Japan show that warning systems in those countries have also lowered the death tolls from typhoons.

20. Jamaica's experience with Hurricane Gilbert in September 1988 illustrates the changes that many countries have made over the years. Jamaica's national Meteorological Service has identified a number of factors which contributed to the lower death toll, among them the use of imagery from weather satellites and from Jamaica's weather radar and reports from ships, land stations and aircraft. Apart from the proof of the value of good warnings and good disaster-preparedness plans, lessons learned during Gilbert included the need to keep the general public and sensitive sectors of the economy aware of the threat from hurricanes; to continually upgrade the facilities and equipment of technical agencies, such as aging radar; to transmit warnings in language that will be easily understood by the population at risk; and to develop means of communication that will be more efficient and more reliable under disaster conditions.

21. While tropical cyclones are the most destructive storms in global terms, there are many other destructive storms. Indeed, each region of the Earth has its own weather peculiarities and presents its own problems to the meteorologists and hydrologists and to the national disaster-response organizations. Extra-tropical cyclones cause many weather-related disasters, including floods, thunderstorms, avalanches and landslides.

22. Severe winter storms, whose cold winds, snowfall and blowing snow can cause havoc over large areas, are a major hazard in many countries. At sea, gales accompanied by high waves often disrupt shipping, fishing and the operation of offshore oil facilities. In addition to losses at sea, the winds and waves can cause great damage and disruption to coastal regions when storms move inland. The heavy rainfall and high winds over land associated with extra-tropical cyclones also cause a great deal of damage.

23. Warnings with long lead times, and increased confidence in such warnings, allow Governments and industries to prepare for these events at many levels and permit the general public to adjust their activities to take into account the disruptions caused by these storms. The same applies to extreme events which are associated with the prolonged absence of storms: protracted periods of settled weather which may give rise to heat waves, cold snaps, or intensification of air pollution.

24. Thunderstorms often accompany tropical storms. Extra-tropical cyclones are also responsible for spawning many outbreaks of thunderstorms and tornadoes, number four on the list of killer natural disasters. Forecasts a few hours ahead can identify the regions in which thunderstorms are expected and whether or not some of them are likely to be accompanied by hail or tornadoes, but it is not possible to be specific about the individual storms until they have actually been detected. Weather radar is invaluable at that stage, as it is pinpointing local areas of excessive rain and hence the individual streams and valleys that might be hit by flash floods.

25. In some countries, tornadoes are a major killer. These extremely violent funnels of rotating air are very local, often having paths only a few kilometres or tens of kilometres long and 100 metres or so wide. However, destruction within that path is often virtually complete. In the United States in 1986, one tornado

caused over $25 million in damage to a coal-burning power plant. Another, with an intermittent path of only 2.4 km, killed 3 people, injured 10, and caused damage of nearly $500,000.

26. Because they are so local and because the individual funnels are often quite short-lived, it is not possible to forecast in advance where a particular tornado will occur. However, identification of the regions which should watch out for severe thunderstorms and tornadoes is improving steadily. The newest weather radars can detect the most violent thunderstorm cells, and indeed the tornado funnels themselves, as they develop. This greatly facilitates the identification of the zones in which people are especially at risk and allows the dissemination of short-term warnings.

27. Storm surges - the pile-up of water due to wind on the ocean surface - have caused tremendous loss of life in densely populated low-lying coastal areas, such as along the coast of Bangladesh. The Seasat satellite has already demonstrated the capability for accurately determining the wind field, and satellites such as Topex and ERS-1 will provide these data in the future, making it possible to provide advance warning of surges.

28. A study done by UNESCO in 1973 estimated that each year, in Asia alone, river floods damaged or destroyed about 4 million hectares of land and crops, and affected the lives and well-being of over 17 million people. It has been estimated that some 5 million Chinese lost their lives in floods between 1860 and 1960, including two of the three most costly natural disasters in terms of human life (the other being an extended drought and famine in India). During the period 1977 to 1984, at least 133 floods involving loss of life occurred in 45 countries.

29. Case studies in Canada, Japan, the United Kingdom and the United States have shown that flood forecasts and warnings can reduce damage by between 6 and 40 per cent. In principle, in the flood plains of large rivers, good hydrological forecasting services could reduce the damages from floods by up to 33 per cent. In practice, damage reduction in these large flood plains is more typically 10 to 15 per cent, but even this figure gives high benefit of cost ratios. For example, a 10 per cent reduction in damage in India would amount to about $250 million per year. Unfortunately, a recent WMO assessment indicates that, of those countries with a high risk of floods, some 15 have no warning system at all, and another 40 or more have an inadequate or only partial flood warning system.

30. The use of remotely sensed data for flood monitoring is basically for mapping. The problem is usually one of identifying a water/land boundary or delineating geological and geomorphic characteristics or determining land use with respect to flood plains. Both analysis of imagery and digital classification techniques have been used successfully. Delineation of land/water boundaries depends on the relative spectral characteristic of soil, vegetation and water. The very low reflectance of water in the near-infrared region of the spectrum makes this wave-band the obvious choice for identifying and measuring surface water. Microwave systems are also ideal for identifying land/water boundaries because the dielectric constant of water is considerably greater than that for soil or vegetation-covered soil. Unfortunately, microwave data are not generally available

except from experimental satellite or aircraft flights. Land use classification not only involves mapping the area of a given crop or cover but also requires identification of the specific crop or forest species. Multitemporal and multispectral data from Landsat and SPOT are nearly ideal for this use. In most cases, spectral bands in both the visible region and at least one of the infrared bands are needed for effective land use classification. The infrared band often can be used to infer stage of growth and general health of the crop.

31. The area inundated by floods and flood-plains can be mapped effectively with remotely sensed data. Satellite data such as those from Landsat and SPOT can be used to delineate flooded areas over an entire river basin but may have some limitations on small basins because of the spatial resolution. Black-and-white photography, infrared photography, thermal infrared data, multispectral scanner data and radar have all been used successfully to map the areal extent of flooding. For most approaches using remotely sensed data, determining areas of inundation depends upon measuring reductions in reflectivity caused by standing or flowing water, high soil moisture, moisture-stressed vegetation, and temperature changes. These effects last for some time after inundation and may be detected for up to two weeks or longer after the passage of a flood; thus acquisition of data exactly during the flood peak may not be necessary.

32. Cloud cover is frequently a problem in mapping floods with Landsat and SPOT data because the time of overpass may not provide a clear image during or shortly after the flood. The NOAA satellites have an advantage of more frequent coverage over the target area (twice daily). In spite of the coarser spatial resolution (approximately 1100 m versus 80 m for Landsat MSS, 30 m for the Thematic Mapper, and 20 or 10 m for SPOT), the NOAA satellite thermal infrared sensor has proved effective in measuring areas of flood inundation.

33. Satellite data can provide invaluable information on the extent and duration of flooding that can be used to plan and schedule relief and rebuilding efforts. The duration of flooding is useful for assessing the degree of crop damage as well as structural damage to buildings and transportation systems. In general, the extent of damage increases with the duration of inundation. Depth of inundation maps can be constructed from the areal extent of flooding mapped with satellites coupled with elevation contour maps or other ground-based elevation data. Unfortunately, depth of flooding cannot be measured directly by satellite.

34. Ideally, one would like to be able to predict floods days or even weeks in advance, but current remote-sensing technology cannot do this. The best that remote sensing can do is to monitor the progress and extent of flooding, and in large river basins, provide some warning of downstream flooding. Satellite data can be useful as inputs to hydrological models used to simulate and predict flood flows. In particular, the ability to predict accurately snowmelt floods can be improved with comprehensive snowmelt models. Also, future microwave systems should be able to measure soil moisture, which can be used in run-off models.

35. Future satellite systems may help to improve global circulation models and thus long-term weather forecasting. Also, there is some hope that spaceborne radars may be able to provide accurate, quantitative measurements of precipitation over remote areas.

36. New sensors planned for the near future and the Earth Observation System programme should be a valuable addition to the sensors available today. The most important of these will be a group of synthetic aperture radar satellites, starting with the launch of ERS-1 in 1991. The key for making these instruments useful for flood prediction and monitoring and for damage assessment is to develop communications links with satellite operators so that real-time data can be obtained when needed.

37. Explosive volcanic eruptions are often preceded by dilation (topographic expansion) of the flanks of the volcano (Mt. St. Helens bulged 100 metres before it erupted). This change in relief would be readily detectable by interferometric analysis of synthetic aperture radar data provided by future satellites. More precise (but spatially less dense) measurements will be possible using satellite-borne laser ranging systems now being designed.

38. The Total Ozone Mapping Spectrometer (TOMS) currently operating on the Nimbus-7 satellite can detect the sulphur dioxide emitted by explosive volcanoes. This information is of interest to airlines and their pilots in providing warnings of the possible presence of volcanic dust which can foul jet engines. In order to provide timely warnings, however, continuous observations from geostationary satellites would be required. It is also possible that the rate of sulphur dioxide release before the eruption may be indicative of an imminent explosive event.

39. The tragic human impact of drought and desertification in Africa has repeatedly drawn the world's attention since the good rainfalls in sub-Saharan Africa during the 1950s and 1960s gave way to a severe drought in 1972-1973. Since then the seasonal rains in the region have often been marginal at best, and devastating droughts afflicted large parts of the continent again in the early and mid-1980s. Although droughts in Africa have received the most publicity recently, droughts occur on all continents. Economic costs and loss of life can be immense: it has been estimated that droughts and famines in India during the period 1965-1967 took some 1,500,000 lives and caused economic losses of over $100 million.

40. The causes of droughts and other climatic variations are many, complex and still not fully understood. The disasters caused by droughts are also strongly affected by such diverse factors as agricultural practices, population density, and the ability of a country to provide alternative supplies of food, water and employment. However, society is making progress on a number of fronts in its attack on drought and desertification, and the atmospheric sciences are contributing in several ways.

41. One such contribution is an improved knowledge of recurring droughts in the past, over all drought-affected regions of the Earth. The recent droughts in Africa and elsewhere have been very severe but not, it appears, unique. As our knowledge of the past improves, so does our ability to provide information on the risk that a drought of a given severity will occur in the future. Such information can be very helpful in planning for drought-combating economic development as well as in developing emergency plans for the next drought when it occurs, as it inevitably will.

42. The World Meteorological Organization (WMO), the specialized agency responsible for international co-ordination in the fields of meteorology and operational hydrology, responded rapidly when the United Nations adopted a special programme to reduce loss of life, property damage and social and economic disruption caused by natural disasters.

43. The safety of life and the alleviation of damage resulting from natural disasters are major preoccupations of national meteorological and hydrological services, and this is reflected in the Second WMO Long-term Plan for 1988-1997. In addition, WMO has adopted as one of its priorities for the years ahead the improvement of warning systems for weather-related disasters. Thus, when the United Nations General Assembly decided to designate the 1990s as the International Decade for Natural Disaster Reduction (IDNDR), WMO agreed to take the lead with respect to tropical cyclones, floods, tornadoes and severe thunderstorms, other severe weather phenomena including major snowstorms, and avalanches and landslides. The organizations providing meteorological and hydrological services within each country are, of course, uniquely capable of assessing the special national susceptibilities to extremes in weather and climate and to floods and droughts. They will also have made special arrangements to respond to disasters within their national boundaries. Those individuals who have responsibility for some aspect of disaster response and who recognize a need for better liaison in the event of a disaster should contact their national meteorological, hydrometeorological, or hydrological authorities.

44. WMO's action plan under the IDNDR calls for emphasis on disaster reduction within the ongoing activities of the organization during the 1990s. These include the Tropical Meteorology Research Programme, the World Climate Research Programme, and research programmes dealing with forecasting on various time scales. These activities will continue and will undoubtedly make significant advances that will be relevant to the IDNDR.

45. However, given the 10-year span of the IDNDR and its emphasis on developing countries, the immediate problem lies in the application of existing technologies and procedures. The main thrusts of WMO activities will be to upgrade existing and establish new warning systems; initiate or accelerate actions to ensure adequate response to warnings; improve the number and quality of risk assessments that are available for disaster-prevention measures; and contribute to public information and education.

46. WMO programmes that are especially relevant to these priorities include the World Weather Watch (WWW), the Tropical Cyclone Programme, the Hydrology and Water Resources Programme, the Technical Co-operation Programme, and the Education and Training Programme. All of these have been in existence for many years. They will continue throughout and beyond the IDNDR, and their aims are essentially indistinguishable from the aims under disaster-reduction activities. Also relevant are proposals for Regional/Specialized Meteorological Centres serving countries in South-East Asia and those in and around the western part of the Indian Ocean.

47. In many developing countries, the two great impediments to improvements at the national level are a lack of knowledge of the appropriate technology and

methodology, and a lack of funds to install, operate and maintain the appropriate equipment and systems. The basic requirements if these impediments are to be overcome are: technical co-operation and developmental programmes with emphasis on technology transfer and institution-building; procurement and installation of equipment and facilities; and the development of human resources.

48. Medium- to large-scale projects of this nature cost several million dollars and usually take more than two years to complete. WMO will continue its efforts to increase the funds available to the Technical Co-operation Programme with special emphasis on disaster-reduction measures. It will also work to ensure that appropriate meteorological and hydrological support systems are included in all developmental projects.

49. In addition to its ongoing projects and programmes, WMO will attempt to complete three relatively low-cost projects which could contribute substantially to the goals of the IDNDR. These are as follows:

(a) System for Technology Exchange for Natural Disasters (STEND)

This project will be modelled on the highly successful Hydrological Operational Multipurpose Subprogramme (HOMS). The objective is to facilitate exchange of information on how meteorological and hydrological services can help to reduce the impact of natural disasters. The information in STEND would cover such things as instrument systems, other equipment, computer software, technical manuals, and a variety of guidance material.

As with HOMS, STEND will reply on inputs provided by national institutions with expertise and experience in specific topics. National focal points will channel information into, and distribute information from STEND. This will allow the system to operate with a very small international staff and a modest budget. Experience with HOMS suggests that it will be of great help to most countries, both industrialized and developing, and that it will be very cost-effective.

(b) Tropical cyclone warning system for the south-west Indian Ocean region

This project is designed to upgrade the tropical cyclone warning system for the south-west Indian Ocean. Based on the systems of the WWW, emphasis will be on the application of data from meteorological satellites, microcomputer technology, and the transfer of scientific knowledge so as to strengthen the capabilities of national meteorological services to provide tropical cyclone warnings for their countries. The upgrading will form part of the Regional Co-operation Programme of the Tropical Cyclone Committee for the South-west Indian Ocean, in accordance with the regionally co-ordinated co-operative plan established by that committee. This plan includes support to countries from a Regional Tropical Cyclone Advisory Centre in Réunion.

(c) Comprehensive risk assessment

The aim of this project is to demonstrate the power of modern methods in comprehensive risk assessment. It will focus first on the risk of flooding and the use of modern technology such as geographic information systems and remote sensing.

An international team of experts will undertake a demonstration project in a region of a developing country which is subject to a range of flood-related hazards, including as many as possible of the following: seasonal flooding and over-bank flow in large rivers; flash flooding resulting from convective storms; flooding of urban areas and flooding caused or aggravated by urban development; flooding in estuaries and coastal regions due to storm surge or a combination of storm surge and heavy rainfall; and the potential impact on these of anticipated future changes in climate in the region.

One of the important outputs of the project would be a number of techniques and technological reports presented in standardized forms suitable for inclusion in STEND. The project will also be used as a basis for training local experts and experts from other countries in the use of the technologies involved. There would, of course, be a comprehensive report on the causes, current risks and possible future probabilities of flooding in the region under study, along with an analysis and discussion of the combined risks.

C. Severe weather analysis in Taiwan

50. A high resolution satellite ground station was established by the Central Weather Bureau (CWB) of Taiwan in January 1981. The station can receive and process NOAA data and Japanese Geostationary Meteorological Satellite (GMS) data. Since 1981, satellite data have become an essential information source for weather prediction and research in Taiwan.

51. The system can receive the HR-FAX (high resolution facsimile) and LR-FAX (low resolution facsimile) from GMS, and the HRPT (High Resolution Picture Transmission) and APT (Automatic Picture Transmission) from NOAA satellites. Since January 1989, HR-FAX data have been replaced by stretched VISSR (Visible and Infrared Spin Scan Radiometer) data to increase the observational frequencies from three-hour to one-hour intervals. In order to receive the GMS stretched-VISSR data, CWB has upgraded its receiving and processing systems.

52. The new GMS stretched-VISSR receiving and processing systems were installed in August 1989. The functions of these systems include: (a) satellite data acquisition (real-time functions); (b) automatic image processing; (c) interactive data analysis and interpretation; (d) image data distribution; and (e) image data archive.

53. Severe weather frequently occurs in the subtropical region between the Eurasian Continent and the Pacific Ocean, a major monsoon area. In this area, there are three rainfall periods, the north-east monsoon period in winter, the Mei-Yu (Baiu or plum rain) period from mid-May to mid-June, and the typhoon period from July to October. Within these rainy periods, typhoons and other weather systems frequently produce heavy rainfall and even result in flash floods in Taiwan. The average annual economic loss due to meteorological disasters is probably more than $200 million.

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54. In summer and autumn, the Pacific high and Tibetan low are the major climatological surface pressure systems in the subtropical area. Typhoons form to the south of the Pacific high and are steered by the easterlies. Most typhoon tracks pass through the Taiwan area. The heavy rainfall produced by typhoons causes the most serious natural disasters among the three major rainfall periods. Therefore, accurate prediction and warning are the most important events in typhoon operations. The first step is to determine the present location of a storm centre in order to estimate the future track and intensity of the storm. Typhoons form over the oceans where conventional meteorological observations are not easily obtained. As the storm intensifies, ships avoid it, so the number of ship observations decreases. Meteorological satellites have therefore become the most important means of locating tropical storms.

55. Typhoon Sarah was one of the typhoons affecting the Taiwan area in 1989. It evolved from a tropical disturbance over the western Pacific Ocean at 1800 UTC on 6 September. After its formation, it moved westward and intensified. The movement of Sarah was first controlled by an intense convective cloud located to the south of it, then changed its direction to south-westward during the afternoon and late evening of 8 September. It made two loops over the ocean to the east of Luzon, then moved northward. It landed on eastern Taiwan and dissipated over the central mountain area. But a secondary typhoon centre formed over the sea to the east of south-eastern Taiwan after Typhoon Sarah landed. The secondary centre moved northward and continued affecting the Taiwan area.

56. Typhoon tracks like Sarah's are very rare in the region. If there were no timely high-resolution satellite images, it would be impossible to follow such a strange track. The CWB used hourly GMS images to issue updated typhoon news and warnings to the public and thus minimized the loss of lives and property.

57. The problems of forecasting and understanding the development, movement and dissipation of intense convective weather systems are complicated by the fact that conventional observations are too sparse to observe the life-cycle of such systems. However, many of the important mesoscale cloud features in the development and evolution of deep convection are detectable on satellite imagery. When images are viewed in animation, the movement, orientation and development of important mesoscale features can be observed. Satellite images are an unparalleled tool for better understanding mesoscale meteorological processes.

58. Large, long-lived and highly organized mesoscale convective systems (MCSs) frequently occur over the central and eastern United States during the warm months from March through September. Most of these weather systems develop in the afternoon, organize in the late evening and grow to maximum size after midnight, then persist until the early morning. They are believed to be the factors primarily responsible for nocturnal thunderstorms and maximum frequency of heavy rainfall in the central and eastern United States. They also frequently occur over subtropical China, the Yang-tze River and Japan during the Mei-Yu (Baiu, plum rain) period.

59. To improve the understanding of MCSs and forecasting of the associated rainfall, scientists from Taiwan and the United States performed a Taiwan Area

Mesoscale Experiment (TAMEX). The TAMEX field experiment was conducted from 1 May to 29 June 1987. Thirteen intensive observational periods (IOPs) were documented during the field phase. The ultimate objective of TAMEX is to improve the accuracy of prediction of heavy precipitation that can lead to flash flooding. It is felt that this can be best accomplished by better understanding the complex mesoscale processes involved.

60. Cold surge, characterized by strong winds and low temperature, is the most significant winter severe weather in Taiwan. The most common cloud patterns occurring behind the cold outbreaks of polar air masses are open-and-closed cellular clouds. As this cold air moves off the continent, the cellular clouds form and align themselves with the movement of the air-mass. Wind speeds vary with the stage and shape of the cellular cloud patterns. Satellite images can be used to trace the movement of cold air-masses and estimate the low level wind direction and wind speed.

61. To further promote the use of space technology in severe weather forecasting in Taiwan, the following steps are proposed:

(a) Update data receiving and processing systems when satellite systems are changed.

(b) Establish an interactive computer "nowcasting" system to improve nowcasting and very short-range forecasting.

(c) Develop a rainfall estimation scheme based on hourly geostationary meteorological satellite images.

D. International satellite search and rescue systems

62. The need to improve search and rescue services has led to intense international interest in developing a global system using satellite technology to enhance the safety of life at sea and increase survivability from all types of distress situations. The United States, Canada and France jointly developed the SARSAT system (Search and Rescue Satellite-Aided Tracking) which is carried on the NOAA polar-orbiting meteorological satellites. The COSPAS system (Cosmicheskaya Sistyema Poiska Avariynich Sudov, Space System for the Search of Vessels in Distress) was developed by the Soviet Union and is carried on COSMOS series navigation satellites. The joint COSPAS-SARSAT Programme was formalized by a Memorandum of Understanding (MOU) signed in November of 1979. Interoperability between the two systems was thus established allowing all participating nations to use both systems to detect and locate distress beacons. Norway, Sweden, Finland, Bulgaria and the United Kingdom participated in the project to evaluate its effectiveness in their respective search and rescue areas of responsibility. At the conclusion of the demonstration and evaluation phase, the system was declared operational and the MOU of 1979 was superseded by a new MOU extending the programme to at least the year 1990 allowing time for a more permanent mechanism to be put in place. Under the terms of the MOU between the COSPAS-SARSAT Parties and the International Maritime Satellite Organization (INMARSAT), signed in October 1989, the COSPAS-SARSAT Parties have contracted with INMARSAT to maintain a permanent COSPAS-SARSAT secretariat.

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63. There are currently five satellites in the system, COSPAS 4 and 5 (also called Nadezhda 1 and 2) and SARSAT 2, 3 and 4. Mission Control Centers are operating in Canada, Chile, France, India, Norway, the Soviet Union, the United Kingdom and the United States. There are also operational ground receiving stations to support each of the centres.

64. By the end of this year it is anticipated that there will be 15 receiving sites operational, 1 each in Brazil, Chile, France, India, Norway and the United Kingdom; 4 in the Soviet Union; 3 in Canada; and 3 in the United States. Chile established an experimental station that provided limited service for several years and is now fully operational. Australia has installed a ground station in Alice Springs, which will be operational this year. Outside the four basic Parties, Ground Segment Operator agreements have been concluded with Norway, the United Kingdom, India, Italy and Venezuela. User State agreements have been signed with Bulgaria, Denmark, Sweden and Switzerland. The potential for enhancing search and rescue operations and thus reducing the expenditure of resources in carrying out these operations is the primary reason for increased international interest.

65. COSPAS-SARSAT is a satellite system designed to assist search and rescue operations, using distress beacons operating on 121.5 MHz or 406 MHz and providing alert and location data to Rescue Co-ordination Centres (RCCs). Its objective is to serve all organizations in the world with responsibility for search and rescue operations, whether at sea, in the air, or on land. There are at present three types of uplink units, namely Emergency Locator Transmitters (ELT) for use in aviation, Emergency Position-Indicating Radio Beacons (EPIRB) for maritime, and Land Mobile Satellite Beacons (LMSB) for use on land. These beacons transmit signals that are detected by COSPAS-SARSAT polar-orbiting spacecraft. The signals are relayed to COSPAS-SARSAT ground receiving stations termed Local User Terminals (LUTs), which process the signals to determine the beacon location. Alerts are then relayed, together with location data, via a Mission Control Center (MCC), either to another MCC or to the appropriate Search and Rescue Point of Contact (SPOC) to initiate search and rescue.

66. Doppler location (using the relative motion between the spacecraft and the beacon) is the most feasible means of locating these very simple devices. The frequencies currently in use are the 121.5 MHz aeronautical emergency frequency, also allocated to distress beacons, and the 406.0-406.1 MHz band exclusively reserved for distress beacons operating with satellite systems. The 406 MHz units are more sophisticated than the 121.5 MHz beacons because of the inclusion of identification codes in the message, but complexity is still kept to a minimum by the retention of the Doppler location concept. To optimize Doppler performance, a low-altitude near-polar orbit is used. The low altitude results in a low uplink-power requirement, a pronounced Doppler shift, and short intervals between successive passes. The near-polar orbit provides complete world coverage.

67. A single satellite, circling the Earth around the poles, eventually views the entire Earth's surface. The orbital plane, or path of the satellite, remains fixed, while the Earth rotates underneath. At most, it takes only one half a rotation of the Earth (i.e. 12 hours) for any location to pass under the orbital plane. With a second satellite, in an orbital plane at right angles to the first,

only one quarter of a rotation is required, or six hours maximum. Similarly, as more satellites are orbiting in properly spaced planes, the waiting time is further reduced. The COSPAS-SARSAT System is designed to have a constellation of four satellites to provide a short waiting time, but the system can still function with fewer satellites in the constellation, although with increased waiting time.

68. The Doppler location provides two possible positions for a beacon: the true position and its mirror image relative to the satellite ground track. This ambiguity is resolved by calculations that take into account the Earth's rotation. If the beacon's frequency stability is good, as in the case of 406 MHz beacons designed for this purpose, the true location is determined during a single pass. In the case of 121.5 MHz beacons, the ambiguity is resolved during the second pass, if not during the first attempt.

69. The detection and location of an aircraft crash or maritime distress is of paramount importance to the search and rescue teams and to the potential survivors. Studies show that although the initial survivors of an aircraft crash have less than a 10 per cent chance of survival if rescue is delayed beyond two days, the survival rate is over 50 per cent if the rescue can be accomplished within eight hours. Similar urgency applies in maritime distress situations, particularly where injuries have occurred. Furthermore, accurate location of the distress can significantly reduce both search and rescue costs and the exposure of rescue forces to hazardous conditions.

70. Operational use of COSPAS-SARSAT by search and rescue agencies started with the crash of a light Cesna aircraft in Canada, in which three people were rescued (9 September 1982). During its first six years of operation, the COSPAS-SARSAT System was used in 437 events and contributed to the saving of over 1,150 lives world wide. From these 437 events, 146 (33 per cent) were maritime, 274 events (63 per cent) were aviation, and the rest 17 (4 per cent) were land incidents. It is also worth noting that 70 per cent of maritime cases involved small sailboats or pleasure craft and almost all aircraft accidents involved general aviation aircraft (including helicopters).

71. The location accuracy of the 121.5 MHz system is 17 km, while that of the 406 MHz system (which operates in both the real-time and stored-data modes) is better than 5 km. The 406 MHz system was first tested on a global scale in November 1986 and has been used in 10 maritime incidents to date.

72. Both the Soviet Union and the United States have definite plans for the continuation of the space segment well past the turn of the century. Longer-range plans will be determined in the mid-1990s with the evolution of later generations of space hardware.

73. The introduction of geostationary satellites into the system is a real probability in the mid-1990s. Steps are currently being taken to place a 406 MHz system on board the next five Geostationary Operational Environmental Satellites (GOES) in the United States. Likewise, India and Japan are also planning to put instruments on their geostationary meteorological satellites. Discussions have also begun with EUMETSAT for incorporating a space and rescue

system on METEOSAT. The effort is being co-ordinated through a separate working group to ensure compatibility between the systems. If this constellation of geostationary satellites provides significant information to global search and rescue forces, it is foreseeable that the programme would be incorporated into COSPAS-SARSAT as a complimentary system.

74. The number of ground stations is increasing and will significantly reduce the wait times for the detection of those in distress. New stations are planned for the early 1990s in Japan, Venezuela, Singapore, Hong Kong, Italy, Spain, a second station in India, and possibly in South Africa and Argentina. In the United States, there are plans to replace the existing stations with a second generation and put them in more strategic locations. Plans call for stations in Hawaii, California, Texas, Puerto Rico, Alaska and possibly Guam.

75. The aviation community is showing significant signs towards heading in a similar direction as the maritime community. Most aircraft currently carry some sort of distress beacon, either an ELT or a portable radio/beacon in survival craft, both of which operate on 121.5 MHz. These signals are received by the satellite but are not always received by the ground stations. For the 121.5 MHz signals, the satellite must be simultaneously visible to both the beacon and a ground station, since there are no means of storing and relaying the signals to the next ground station that comes in sight of the satellite as there is in the case of the 406 MHz system. For this reason, ICAO is proposing that aircraft engaged in international flights should carry a 406 MHz beacon to assure global coverage.

76. In November 1988, the seafaring nations met within the International Maritime Organization (IMO) in London and agreed upon amendments of the International Convention for the Safety of Life at Sea (SOLAS), with regard to the Global Maritime Distress and Safety System (GMDSS). This new system is mainly based on satellites as a reliable means of distress communications. After 1 August 1993, all ships over 300 gross tons must be equipped with Emergency Position-Indicating Radio Beacons (satellite EPIRBs) with the capability of rapidly transmitting the identification and position of a vessel in distress.

77. In addition to the COSPAS-SARSAT system, which is already operational, IMO also accepted a proposed INMARSAT system using the 1600 MHz frequency band on the geostationary satellites which carry telephone and telex communications between ships and Coast Earth Stations (CES). Since geostationary satellites cover a third of the Earth's surface, three of them are able to provide continuous service for all navigable waters. Before the INMARSAT system can be considered operational, however, appropriate receivers and processors must be operating in each ocean region. An experimental receiving station has been in place at Goonhilly CES in the United Kingdom since 1986.

78. In 1982-1983, six countries compared their EPIRB technology using the same INMARSAT satellite under equal environmental conditions. Between Edinburgh and the North Cape, the EPIRB models were activated once a day from the Research Vessel Gauss. The signals were received at the Villa Franca tracking station near Madrid. The EPIRB of the Federal Republic of Germany demonstrated a performance of 99 per cent from the North Cape with a transmitted power of 50 milliwatts. As a

result of the trials, those specifications were recommended by the International Radio Consultative Commimttee (CCIR) for the 1.6 GHz frequency band, however, with an increased RF power of 1 watt.

79. At present two types of EPIRBs are available for use with INMARSAT satellites: the floatable beacon used by vessels over 300 gross tons, and the portable EPIRBs, also called Low Power Distress Transmitters (LPDTs) used by smaller vessels such as fishing boats or yachts. The transmitted messages of the two types are fully compatible. The floatable EPIRBs are positioned on the deck of a ship and connected to the ship's navigation equipment via a Data Entry Device which also operates the wireless magnetic coupler to the EPIRB. It can be initiated from the bridge, but if a ship is sinking, it floats up and transmits automatically.

80. The LPDT uses a cable connection to the navigation system and is manually activated. The device can float, but normally transmission should be from on board a ship or inside a life-raft, close to the people to be rescued. Its dimensions are 38 x 12 x 25 cm and its weight is about 5 kg, so it is easy to carry. In addition, a radar transponder is built-in as an efficient means of homing. LPDTs also have acoustic signals to the user, different tone sequences indicating the status of the transmission and giving warning in case of performance degradation.

81. Since 1986, 12 EPIRBs for the INMARSAT system have been tested on various vessels in the Atlantic between the Arctic and the Antarctic at latitudes up to 80 degrees (north of Spitzbergen). The message transfer time was always less than five minutes and all received messages were error-free owing to the use of an efficient error correcting code. In total, 2,258 transmissions were received, with only 9 missing without explanation, a rate of success of 99.6 per cent. The demonstration confirmed what had already been found in the Trials Programme: the safety margin using 1 watt instead of 50 milliwatts is a factor of 20 and results in an extremely reliable message transfer within a few minutes, even in extreme weather conditions. The transfer times of the INMARSAT system thus fall significantly below those of the COSPAS-SARSAT System. Furthermore, there is no need for additional receiving stations or satellites because they already exist. The INMARSAT system is therefore not only rapid and reliable but also economic.

82. At present, an operational receiver-processor is being developed co-operatively by industries in Finland and the Federal Republic of Germany. When four are installed around the world, the INMARSAT system will become operational. All nations, especially those which have a Coast Earth Station, are invited to operate such a receiver-processor and support this humanitarian concern by forwarding immediate alerts, thus improving safety at sea.

E. The use of space technology for search and rescue operations and for disaster relief activities in India

83. The Government of India decided to promote, participate in and contribute to the development of an international Satellite-Aided Search and Rescue Programme for maritime, aviation and land distress alert detection and position location in April 1986. This programme was an inter-agency effort, with the Department of Space/Indian Space Research Organisation as the co-ordinating agency, and with the active involvement of the several user agencies. An Inter-Agency Steering Committee co-ordinates and guides the development of the integrated national programme.

84. As part of the international Satellite-Aided Search and Rescue (COSPAS-SARSAT) network, an Indian Local User Terminal (LUT) along with a Mission Control Center (MCC) has been established at Bangalore and declared operational from 1 October 1989. Any distress signal from a ship or aircraft is picked up by an orbiting COSPAS/SARSAT spacecraft, which relays it instantaneously to the LUT. The LUT then processes the signal and identifies the location of the beacon. This location information is immediately passed on to the appropriate Rescue Co-ordination Centre (RCC) for search and rescue operations. The Indian LUT/MCC facility is capable of receiving and processing distress beacon signals in the 121.5/243/406 MHz frequency bands and providing position location on a real-time basis over a significant part of the Indian Ocean area. India is the first country in Asia to establish such a system.

85. Recognizing the locational advantages of the Indian LUT, which could serve a number of countries in the Indian Ocean area in search and rescue operations, the COSPAS-SARSAT Organisation has requested the Indian MCC to provide distress-alert services to the following countries: Bangladesh, Indonesia, Kenya, Malaysia, Maldives, Singapore, Somalia, Sri Lanka, the United Republic of Tanzania and Thailand.

86. India is planning to set up a second LUT in Lucknow (northern India) in mid-1990 to provide better coverage of the north-eastern area. India is also incorporating a Search and Rescue Payload in its second-generation INSAT spacecraft, the first of which is scheduled for launch in 1990-1991. This would be a major contribution from India towards the space-segment for the international Satellite-Aided Search and Rescue Programme. Efforts for indigenous development of emergency beacons operating in the 406 MHz band are in an advanced stage in ISRO as well as in Indian industry.

87. Natural disasters like cyclones and floods demand urgent responses and emergency relief to the affected population. Satellites have been used for establishing communication links between isolated areas and relief centres at short notice during many natural disasters in India. Earth terminals which are airliftable and which could be set up in a few hours to establish voice communication links with other parts of the country have been successfully developed and are in use.

88. India has also introduced a national disaster warning service using the INSAT system. As certain coastal areas of India are particularly prone to cyclones and suffer considerable damage every year, a unique selectively addressable cyclone disaster warning system (DWS) using a relatively narrow-band C/S-band carrier on a satellite broadcast service transponder has been set up in selected areas on the eastern coast of India. In the current demonstration phase, some 100 DWS receivers are installed. Simple S-band (2.5 GHz) receivers, which are an adaptation of direct satellite television receivers in the INSAT system, are designed for continuous operation in rural coastal environments and are tuned to specific codes, which are assigned to particular locations. Cyclone warnings are issued by a Regional Cyclone Warning Centre in Madras on the basis of INSAT (VHRR) weather data as well as cyclone radar data and selectively addressed to the concerned receiver or group of receivers in the area concerned. The receivers are automatically activated to provide audible alarms to alert people in the neighbourhood to listen to the radio for emergency information. There are plans to expand the system to add more disaster-warning receivers and uplinking facilities in other cyclone-prone coastal areas of the country. The experience in India with this system shows that lives can be saved through specific and timely warnings of impending disasters like cyclones through the use of space technology.

89. Initiation of appropriate relief activities in disaster situations depends upon availability of timely and accurate information. Space technology with its synoptic observation capability can be used to provide objective information rapidly to assist the relief activities. Remote-sensing data from space has been used in India and elsewhere to produce maps depicting the areas affected and the extent of damage to agricultural crops as well as humans and livestock. The information on wet areas, standing water, sand cast areas, damaged agricultural lands, marooned villages, canal systems and drainage patterns can be delineated from the space images.

90. For assessing, predicting and continuously monitoring drought conditions in India, a vegetation index derived from the polar meteorological satellites, along with supplementary information on rainfall and surface water conditions, are used to generate fortnightly drought bulletins to assist administrators in each district. Assessment and early warning of agricultural drought conditions are used to help farmers adjust their agricultural practices to drought situations.

F. Experience with the telemedicine spacebridge to the Armenian and Ufa disaster regions

91. The earthquake which occurred in the Armenian SSR on 7 December 1988 caused over 150,000 casualties as well as widespread destruction. NASA, under the auspices of the United States/USSR Joint Working Group on Space Biology and Medicine, made an official offer on 12 December, to the Government of the USSR to provide humanitarian aid in the aftermath of the tragedy. Soviet authorities accepted NASA's proposal for organizing consultative medical aid involving leading United States medical institutions and specialists via space telecommunications.

92. Subsequently, Soviet and United States health officials, physicians and communications specialists exchanged visits in order to better understand the available medical capabilities of each country. This also gave the United States consultants a chance to see first-hand the earthquake damage and extent of casualties. This led to the signing of a Protocol and Implementation Plan for the Spacebridge, which began operations in early May 1989 and was to terminate in late June. However, owing to another tragedy, the Ufa train accident of 4 June with over 1,200 casualties, NASA and its Soviet counterparts agreed to extend the Spacebridge until 28 July in order to consult on the victims of that disaster as well.

93. Although the Spacebridge to Armenia and Ufa was of unprecedented scope, telemedicine has been used on a limited scale in various parts of the world since 1971. The first experiment in telemedicine was conducted in Alaska under the auspices of the Indian Health Service (part of the United States Public Health Service responsible for providing health care to native Alaskans). Faced with the problem of servicing scattered small villages in remote regions and thwarted by the lack of reliable communication channels in the bush, the agency turned to telemedicine in the hope that consultation on a regular basis would improve village health services.

94. Similar medical assistance was given to appropriately equipped merchant ships at sea via the MARISAT system, which routes requests for diagnostic help to a hospital in New York City. Another project used the experience gained in the Apollo/Skylab programme to serve the 10,000 inhabitants scattered over the 11,000 sq km Papago region. And in 1985, the NASA ATS-3 satellite was used to help the victims of the Mexico City earthquake. Within 24 hours after the disaster, the satellite was on the air and was used extensively by the American Red Cross and the Pan American Health Organization.

95. Immediately after the Armenian earthquake, INMARSAT, working with its Soviet signatory MORSVIAZSPUTNIK, co-ordinated the establishment of a network of 16 portable Standard A satellite terminals. These portable terminals fit into two suitcases and were capable of transmitting audio, data, fax and telex. INMARSAT provided free use of satellite channels. In a truly international effort, the terminals came from around the world: four from the United Kingdom, including one from the Kent Fire Department that was sent to Armenia with a rescue team from that town; three Mobil Oil terminals from the Persian Gulf under registry of the United Arab Emirates; and eight units from the United States, including four from the Dade County (Florida) fire and rescue unit which sent a crew to Armenia, and terminals provided by COMSAT and modified to allow communication with the INMARSAT MARECS and the Soviet VOLNA satellite systems.

96. Communications commenced on 4 May after equipment, transported by Aeroflot from the United States to Yerevan was installed and operational. Operations continued until 28 July, when Spacebridge was officially terminated. Leading specialists from the Uniformed Services University of the Health Sciences (Bethesda, Maryland); the University of Maryland Institute of Emergency Medical Services System (Baltimore, Maryland); the University of Texas Health Science Center (Houston, Texas); and the Latter Day Saints Hospital and University of Utah

(Salt Lake City, Utah) acted as consultants for Armenian physicians for three months. After the train accident near Ufa in June 1989, it was decided to establish a temporary teleconferencing studio in Ufa, where numerous burn cases were being treated, and to connect this studio to the Yerevan-United States teleconferencing network, which had already been operating for two months.

97. Communications between Armenia and the four United States medical centres used international and domestic satellites as well as land lines. AT&T, Intelsat and Comsat arranged to donate satellite time free of charge, and STARS of Houston, Texas, provided an earth station that was transported to Yerevan by Aeroflot. The communications system allowed for two-way voice, one-way colour video (Armenia to the United States) and two-way fax capabilities.

98. Communications were conducted according to a daily calendar listing the subjects to be discussed. The United States medical centre with the most expertise on the subject in question led the exchange for that day, although the other three centres were always invited to join at any time, and two or three centres were on the air almost every day. In general, the consultations took place as scheduled, although the schedule was modified in case of unforeseen events or the unavoidable absence of clinicians or patients. Frequently, the patient was present and was examined in front of the camera; X-rays, computerized tomography and ultrasound studies were usually available as well. A lively exchange would then ensue, with particular emphasis upon patient management.

99. During the Ufa transmissions, slow-scan black and white video was used rather than colour video. With slow-scan, a still picture of the patient is transmitted every 20-40 seconds, with no colour and no movement. Although not as effective as colour video, the consultants could still get an idea of the patient's condition.

100. There were 31 conferences, each about four hours long, involving a total of several hundred physicians. Cases were presented across most medical and surgical specialties. In order to determine the effect of the consultations, a questionnaire was sent to the Republic Diagnostic Center. It was found that of the 210 patient consultations, Armenian physicians used the discussions with United States consultants to alter their diagnosis and treatment in approximately 25 per cent of cases. Furthermore, many of the cases presented were representative of many patients, and the consultative advice on that case was extended to others.

101. Following Spacebridge, NASA Headquarters Life Sciences Division hosted a United States/USSR meeting in Washington to review the operation. Major recommendations put forth by the participants were:

(a) A Spacebridge telecommunications system should be available for world-wide deployment in cases of disaster;

(b) A permanent subgroup under the auspices of the United States/USSR Joint Working Group on Space Biology and Medicine should be formed for the purpose of developing telemedicine procedures in space as well as finding national or international organizations to continue Spacebridge for earthbound disasters;

(c) A teaching curriculum should be developed for training health care professionals in this area.

II. THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME (IGBP)

102. The goal of IGBP is to develop a proper understanding of the various Earth system processes and their interlinkages in order to develop forecasting capabilities for future trends and to take corrective actions to protect the sensitive environment and ecology that sustain life on Earth.

103. The major tasks of the IGBP as defined by the International Council of Scientific Unions (ICSU) will be:

- Collecting and analysing data to identify the natural processes that lead to global change and those resulting from such changes;

- Incorporating, in predictive models, the nature and extent of past changes, an understanding of couplings between biogeochemical processes and the physical and climate system, and all available information on current and anticipated anthropogenic impacts.

104. The United States Mission to Planet Earth programme, building on earlier research programmes and encompassing the proposed Earth Probes and the Earth Observing System (EOS), is a major NASA contribution to the United States Global Change Research Programme. It will provide comprehensive global observations of Earth to reveal how the processes that govern global change interact as part of the Earth system. This understanding is critical to the development of models for predicting future environmental change. With a continuing, comprehensive data set from EOS, it will be possible to update and improve the models so that they can provide the vital information needed concerning environmental change on local, regional, and global scales.

105. The total cost of EOS is estimated to be $17 billion through the year 2000. The cost of EOS platforms and payloads is commensurate with other large observing programmes, such as the four Great Observatories of NASA's Astrophysics Programme. Typically with satellite programmes, NASA has allocated about 70 per cent of the funding for spacecraft hardware and 30 per cent for ground-based activities. For EOS, however, in recognition of the large data volume and the need for a comprehensive science programme, NASA will allocate 40 per cent for spacecraft hardware and 60 per cent for ground-based activities, including data and information processing, distribution and evaluation.

106. NASA began conceptual studies for EOS in 1982, and co-ordination with the European Space Agency (ESA), Japan and Canada was initiated in 1986. Present plans call for two series of polar-orbiting platforms: EOS-A and EOS-B. The 15-year observational period will be achieved using three identical satellites per series, each with a five-year design lifetime.

107. ESA is planning two series of polar platforms, with a climatological and terrestrial focus respectively, and Japan is planning one polar platform. Both NASA and NOAA will provide sensors for these platforms. Additionally, NASA is planning to provide earth observation sensors as attached payloads on the Space Station.

108. A group of 41 sensors from the United States, Canada, Japan and Europe have been selected as candidates for flight on EOS. The EOS-A series is tentatively planned to focus on atmospheric sounding and surface imaging, with specific sensors to be selected in October 1990. The EOS-B series is planned to include sensors capable of extending the observations made by the Upper Atmosphere Research Satellite (UARS) and TOPEX/Poseidon missions; sensor selection for EOS-B will occur one year later.

109. Platform size for EOS has been chosen to accommodate atmospheric sounding and surface imaging sensors, a grouping which maximizes the complementary use of simultaneous observations and minimizes atmospheric-induced uncertainties. The satellites will be launched into polar orbit from Vandenberg Air Force Base on Titan-IV rockets.

110. An EOS platform will accommodate a payload of up to 3,500 kilograms and can supply up to 3.2 kilowatts of power to the payload. This platform is twice the size of UARS and can supply about four times the power; it will accommodate 12 to 14 instruments.

111. The need for global coverage every one to three days dictates a sun-synchronous orbit with a quasi-two-day repeat; a 705 km altitude and 98.2 degree inclination orbit meets this need. It will have a 1.30 p.m. local equator-crossing time.

112. The Synthetic Aperture Radar (SAR), which cannot be efficiently accommodated on the EOS series of platforms, is planned for flight on a dedicated satellite in 1999. Its orbit will have a 620 km altitude and similar equator-crossing time; this will provide frequent opportunities for simultaneous observations by the SAR and EOS platforms.

113. The EOS Programme has put a major emphasis on the Data and Information System (EOSDIS). EOSDIS is to acquire a comprehensive, global, 15-year data set, to maximize the utility of this data set for scientific purposes, and to facilitate access by the research community. In addition to data processing, archival and distribution facilities, EOSDIS includes capabilities for command and control of the spacecraft.

114. The development of EOSDIS will be initiated immediately by building on the existing infrastructure within the research community. Its architecture will be open and distributed, so that it can evolve with advances in computing and networking technology. The near-term objectives are to support the analysis of both existing data and data that will come from the near-term pre-EOS missions. In this way, the research community can gain valuable early experience in preparation for the future large volume of EOS data. Archived data sets, in addition to those

from the EOS satellites, will include complementary *in situ* and satellite data. EOSDIS will also involve the United States Geological Survey, NOAA, the National Science Foundation and other agencies.

115. There will be two types of data products, standard and specialized, with standard products to be generated and archived at Active Archive Centers. The target time for the availability of engineering-level products is within 48 hours of collection, and the target for derived geophysical products is within 96 hours. Specialized products will be generated by individual investigators and made available to EOSDIS for archiving and distribution.

116. The EOSDIS policy specifies that all data and derived products be available to all interested users. Research users in the United States and participating countries will pay only the nominal cost of data reproduction and delivery, and will be required to publish their results and to make available supporting information, including methods for analysing data. Research users in other countries may propose co-operative projects and "in kind" contributions (i.e., provide similar access to satellite, aircraft and surface-based data) in exchange for access to EOS data on similar terms. Access to the raw data stream will be provided to operational agencies for forecasting purposes. NASA will provide for the commercial distribution of data on a non-discriminatory basis to all other users.

117. The USSR, recognizing the urgent need for integrated international monitoring of global ecological processes, is offering to the international scientific community the use of a specialized remote sensing and ecology module, Priroda (Nature), which will be part of the Mir orbital station. This module will support a variety of active and passive remote-sensing instruments operating within the frequency range from microwaves to visible light for simultaneous high-resolution monitoring of various land, ocean and atmospheric phenomena, including ocean currents, surface and internal waves, snow and ice layers, large-scale atmospheric circulation, vegetation state, geology, hydrology and natural and anthropogenic influences. The total mass of instruments currently under development in the USSR is about 4,000 kilograms. Since the maximum mass of the module's payload is 5,000 kilograms, there is still capacity for foreign instrumentation. The precision of the orientation and stabilization of the scientific module will be better than 1.5°, and during prescribed intervals up to 0.25° precision should be possible. The orbital inclination of 51.6° and the altitude of 350-400 kilometres will allow coverage of almost 95 per cent of the Earth's surface.

118. In addition to the Priroda module, which will be part of the Soviet manned orbital station programme, all interested States, research organizations and firms, scientists and experts are invited to consider adding their own scientific instruments to the "ALMAZ" ("Diamond") system. The system will consist of the "ALMAZ" multi-purpose orbital platform, relay satellites and ground receiving and data-processing stations. The ALMAZ orbital station is to be launched by the Proton rocket into orbit with an inclination of 73° and an altitude of 300 to 600 km. The total mass of the station will be 18,500 kg, while that of scientific payload will be up to 4,000 kg. The working space in the station will be 90 cubic metres, with a power supply of 2.4 kW, and 15-20-minute peak loads up to 7.5 to

10 kW. The expected active lifetime of the station is two to three years. The pointing accuracy will be 10-15 arc minutes, with a stabilization of 3-4 arc minutes, and pointing accuracy of the instruments of 1 arc minute. The temperature within the working compartment can be controlled within the range of 5° to 30° with 1° accuracy.

119. The first experimental "ALMAZ"-series station (Cosmos-1870) was in orbit for two years, from 25 July 1987 to 30 July 1989. The purpose of the launch was to test the construction of the station and component systems and how the station interacted with ground control, data-collection and data-processing stations. The station carried a synthetic aperture radar with a resolution capability of 25 metres. Tests of the station were completed successfully. A large amount of radar information was obtained for use in geology, oceanography, cartography, geophysics, ecology, agriculture and forestry. A data bank has been established, which may be consulted by interested States and organizations. The launch of the second "ALMAZ" station is planned for the second half of 1990. The station is complete, and is undergoing ground tests. It has been fitted with a more sophisticated radar with a resolution of 15 metres, and a three-band scanning radiometer system. The launch of the third "ALMAZ" station is planned for 1994.

120. The "ALMAZ" station can be used as the basis for an international environmental-monitoring space laboratory, which might carry the following remote-sensing apparatus: a high-resolution radar system; a multiband radiometer system; a scatterometer operating in the 5.7 centimetre range; a high-precision radio altimeter (accurate to 10 centimetres); a high-precision infrared radiometer; an ultraviolet scanner; a multiband, multichannel scanning lidar instrument. Other equipment can also be installed. In the future, "ALMAZ"-series stations may be designed to enable other spacecraft to dock with them and, if necessary, allow cosmonauts to visit the station, check on the equipment and carry out maintenance and repair work.

121. The participation of the Federal Republic of Germany in the major international geoscientific programmes on global environmental change, such as IGBP and the World Climate Research Programme (WCRP), involves the work of more than 300 researchers in 22 institutions concerned with climate, environment and the conservation of our natural resources. Most of the space projects carried out by the Federal Republic of Germany in this field involve international co-operation through the European Space Agency (ESA), international satellite organizations and national space agencies as well as through direct bilateral co-operation with individual countries.

122. Reception, processing and distribution of environmental data are provided by the Deutsches Fernerkundungsdatenzentrum (DFD, German remote-sensing data centre). This centre also stages regular training courses with international participation, including participants from the developing countries. The European contribution to global meteorological observations is co-ordinated by EUMETSAT, located in Darmstadt, Federal Republic of Germany.

123. In the framework of international Antarctic research, the Federal Republic of Germany is preparing to establish a station for the direct reception of data from

the European remote-sensing satellite ERS-1 over the Antarctic region. This station will be erected near and in co-operation with the Chilean O'Higgins Station.

124. The following are the priorities of the Earth Observation Programme of the Federal Republic of Germany:

(a) Improvement of weather observation and forecasting using METEOSAT data;

(b) Observation of the oceans and polar regions using ERS-1 (and its follow-up project ERS-2) with synthetic aperture radar and other sensors;

(c) Land observation for mapping and other purposes using the following sensors: the aerial survey camera on the first Spacelab mission in 1983; the multispectral scanner (MOMS) on the United States Space Shuttle in 1983 and 1984 and on the German Spacelab D-2 mission in 1992; an imaging radar system (X-SAR) developed in co-operation with the United States and Italy for comprehensive radar signature research. In addition, a joint project on the observation of tropical rain forests is being prepared by DLR and the Brazilian space agency INPE;

(d) Development of sensors for measuring the concentration of atmospheric trace gases and the global radiation balance;

(e) Preliminary studies for the development, between 1994 and 1998, of an environmental research satellite, including sensors for measuring changes in the atmosphere and in coastal waters, in order to close gaps in international data;

(f) Participation in the development of the polar platforms as part of the international effort "Mission to Planet Earth". This complex system is to provide ongoing data for global environmental research as well as operational meteorology;

(g) Contributions to the maintenance and extension of the EARTHNET data reception and distribution network.

125. China has also joined the global change and IGBP activities and established national committees to promote national research in these areas. Both activities are focused on global environmental change and are to be co-ordinated as part of ISY.

126. Projects in these areas are using space technology, in particular remote sensing, for monitoring desertification, forest resources, glacier and snow cover in high mountain areas, land cover, lakes and swamps, sea surface temperatures, ocean currents, and atmospheric parameters.

127. Remote-sensing data include those received from NOAA satellites, the Chinese meteorological satellite FY-1, and from Chinese middle to high altitude airborne remote-sensing systems. With data from 50 ecological observation stations and more than 100 monitoring sites for nature preservation, a multi-level data system will be realized.

128. To provide analysis, evaluation and prediction of changes in the environment, the National Environmental System of China and the Natural Resources Information System of China will be established. These programmes should contribute substantially to international co-operation in this important field of research.

129. India, with its diverse environment and eco-systems and with an economy closely linked to the monsoon, has several urgent problems, including drought, desertification, floods, deforestation, pest infestation and land degradation. These are closely linked with the weather and climatic changes on the one hand and with the environmental and ecological effects of human interactions on the other. Owing to the large population and the consequent pressure on resources, it is imperative that studies be undertaken to understand the local and regional processes and their linkages with global environmental processes. For example the monsoon performance and the associated rainfall in the Indian region is known to be correlated with Pacific Ocean temperature anomalies and with pressure anomalies over the southern hemisphere. The monsoon rainfall may also be affected by large-scale deforestation, albedo changes, aerosols and greenhouse gases.

130. The following problems are of particular relevance to India:

(a) Changes in monsoon strength or pattern due to CO_2, dust, deforestation, and urbanization;

(b) Migration of climatic zones, too rapidly to be followed by natural vegetation and crops;

(c) Increased snow-melt, upsetting the hydrological cycle and leading to floods and wastage of water;

(d) Increased frequency or strength of tropical cyclones, especially in the Bay of Bengal;

(e) Sea-level rise, causing inundation of low-lying coastal tracts and islands, higher storm surges, more salinity-ingress and changes in estuary dynamics;

(f) Increased frequency of severe summers, causing heat strokes, lower work efficiency and greater evaporation loss from surface water bodies;

(g) Changes in wind patterns that might render present industrial locations unusable;

(h) Continuous review of policies related to the movement of people and materials along Himalayan borders may become necessary in view of greater snow-melt and slush, changes in glaciers snow-line or vegetation and changes in rain-patterns;

(i) Ozone destruction and related biological effects;

(j) Overgrazing, soil erosion and desertification.

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131. Considering the diverse aspects of the geography of India, with deserts in the north-west, snow-covered mountains in the north, large rivers and flood plains in the central parts, and cyclone-prone areas on the east and west coasts, studies related to climatic and ecological impacts on a long-term basis need to be undertaken as part of the geosphere-biosphere programme (GBP).

132. Several projects are under formulation for the Indian National Geosphere-Biosphere Programme, under the following four themes:

(a) Climate modelling and sensitivity studies;

(b) Atmospheric constituents and radiative/chemical effects;

(c) Land-air interaction and terrestrial ecosystems;

(d) Ocean-atmosphere interaction and marine ecosystems.

133. The projects undertaken in the above categories will be designed to generate long-term records of various parameters related to the earth-atmosphere system and to provide information on trends. The modelling efforts will focus on local interactions, which can be linked to the regional and global models that will become available as the IGBP proceeds. The organizational details, such as spatial distribution, frequency and precision of measurement, will be developed so as to be compatible with those of the international programmes. Development of a denser and higher-precision data network will be explored in order to bring out regional-level anomalies. It is hoped that as the IGBP emerges, these details will become clear.

134. The National GBP is to establish linkages with the global programmes being pursued by the International Council of Scientific Unions in which a number of national space institutions are participating. Several countries are already developing or carrying out their national programmes. One major mode of interaction within the IGBP will be through joint experiments. Exchange of data, development of global models, standardization of data reduction and processing techniques and hosting of international workshops are other possible modes. The international co-operative programmes in the area of the geosphere and biosphere is expected to receive additional focus as a result of the designation of 1992 as International Space Year (ISY) and initiation of activities under the common theme "Mission to Planet Earth".

135. In the context of ISY, the Indian Space Research Organization made a proposal to the Space Agency Forum for International Space Year (SAFISY) to undertake an international programme called PEACE (Protection of Environment for Assuring Cleaner Earth). The PEACE mission would involve the use of polar-orbiting satellites carrying a variety of payloads for monitoring the environment, and a set of geographically distributed institutions and ground stations for data acquisition and processing, located in both developing and developed countries.

III. REMOTE-SENSING PROGRAMMES WITH EMPHASIS ON APPLICATIONS FOR DEVELOPING COUNTRIES

136. RADARSAT is an advanced remote-sensing satellite being developed by Canada, with NASA providing a launch in 1994 as a United States contribution to the project. The main payload instrument is a powerful and versatile synthetic aperture radar (SAR) with many modes of operation. In near-polar sun-synchronous orbit (altitude 792 km, period 101 minutes, inclination 98.50°), the SAR can image anywhere across a 500-km-wide primary swath and a further 300 km is accessible with reduced performance. Spatial resolution can be better than 10 m, and in the SCANSAR mode, the complete 500 km swath can be covered at lower resolution. Specific areas can be "revisited" every day north of 71.5° N and at least once every three days between 50° and 71.5° N. Using advanced computers, the SAR will produce high-resolution images regardless of weather or light conditions. Other instruments being considered for RADARSAT are an advanced along-track scanning radiometer and an advanced radar altimeter designed for operation over land as well as water (a similar instrument on the SEASAT and ERS-1 satellites provided data only over oceans).

137. Scientists have already shown SAR to be effective in mapping ice distribution and locating large icebergs. This application will be used in the first year-round monitoring of conditions along Arctic sea routes. SAR's sensitivity to soil moisture and vegetation offers new opportunities in crop assessment and forest operations. Geological exploration will be enhanced through the use of stereo data from RADARSAT. The measurement of ocean surface features with RADARSAT will aid in fisheries management, marine transportation and offshore drilling.

138. Since its inception, RADARSAT has benefited from the collaboration of international partners, notably the United States, which is providing the launch. Close liaison in the planning of RADARSAT has been maintained through the Co-ordinating Committee on Earth Observation Satellites, whose members include the United States National Aeronautics and Space Administration and National Oceanographic and Atmospheric Administration, the European Space Agency, Japan, India, Brazil, the United Kingdom, the Federal Republic of Germany and Italy. In addition, several other countries have expressed interest in receiving RADARSAT data.

139. Although developed primarily for Canadian needs, RADARSAT can also provide resource information for the rest of the world, particularly the developing regions. RADARSAT's international partners will have equal access to the satellite's instruments to obtain data over any part of their territory. Moreover, RADARSAT data will be supplied to numerous international organizations and working groups that have already agreed on the exchange of world-wide information in such areas as oceanography, meteorology and the environment.

140. In Sweden, remote-sensing activities combine research, development and application. The scientific community is using the technique successfully and has contributed substantially to the development of techniques and methods. At the same time the field of applications is growing steadily and forms the basis for expanding commercial activities.

141. The Swedish National Space Board (SNSB) is the governmental agency responsible for national and international space efforts in Sweden, including all aspects of remote sensing. The responsibilities of the Board in remote sensing include policy decisions, initiating research, development and other activities, and distributing research grants for these activities. The technical implementation of the space and remote-sensing programmes is generally contracted on an annual basis to the State-owned Swedish Space Corporation (SSC).

142. Over the years, airborne and ground-based sensors have been developed as well as digital equipment for image processing. In the area of sensors, Swedish industry, in collaboration with industry in the Federal Republic of Germany, has developed synthetic aperture radar (SAR) antennas for remote-sensing satellites.

143. The Swedish national remote-sensing programme uses data from several remote-sensing satellites, especially SPOT and Landsat. A major project at the Swedish University of Agricultural Science aims at data assimilation for updating forestry maps, including methods which identify different types of forests by their spatial and spectral characteristics, using interactive data interpretation or expert systems. Other projects are under way at the Department of Physical Geography of the University of Stockholm, including classification of vegetation using SPOT and other data. Satellite data are also used for creating a new Swedish topographical map and for updating clear-cut areas, roads and other features in forest areas.

144. Several digital imaging systems have been developed in Sweden and are now used for the development of new methods for digital image processing. Among the projects in this area are classification of clouds and ice surfaces and detection of lineaments for geological applications. Digital image analysis is a component of most remote-sensing projects.

145. In the preparation for the utilization of the European Earth Remote Sensing Satellite ERS-1, to be launched in 1991, a comprehensive experiment on ice observations has been carried out in Sweden, with the participation of several research groups. Ice observation is an area where relatively little has been done so far but it has a great relevance in northern countries. In particular, routing of shipping in the Baltic Sea under ice conditions is a possible application of ERS-1. The ongoing analysis of data includes applications of synthetic aperture radar, radar altimetry and scatterometry as well as studies of ice and snow properties including ice ridges. A continuation of this preparatory work is the large-scale ESA project PIPOR (Programme for International Polar Ocean Research) with a large number of scientists involved.

146. The Swedish satellite operations facility and sounding rocket range ESRANGE near Kiruna is situated north of the Arctic Circle at a latitude of about 68° N. It is operated by the Swedish Space Corporation. The geographical position offers several unique advantages. For satellite control and operations, the location north of the Arctic Circle gives two to three times more frequent access to polar-orbiting satellites than is possible with stations at lower latitudes. Thanks to the location, 11 out of 14 daily passes of all Earth observation satellites in polar orbits are visible from Kiruna. Data is received from LANDSAT

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MSS (Multi-Spectral Scanner, since 1978), LANDSAT TM (Thematic Mapper, since 1983), SPOT 1 and 2 (1986; 1990) and MOS 1 and 3 (Marine Observation Satellite, since 1987; 1990).

147. A letter of intent between Glavkosmos in the Soviet Union and the Swedish Space Corporation was signed in the fall of 1989, covering reception, archiving, processing and distribution of data from the Resurs and Okean remote-sensing satellites. Sweden has also enjoyed long-term co-operation with France in the SPOT programme. The Swedish SPOT receiving and processing station in Kiruna is one of the two main stations receiving data from all parts of the world through the on-board tape recorders. This means that Sweden has an archive containing global satellite data. Today the archive consists of about 400,000 SPOT scenes.

148. For many years, Swedish organizations have co-operated with remote-sensing organizations and users of remote-sensing imagery in developing countries. The main agency is the Swedish Space Corporation which has carried out more than 60 projects in 40 countries in close co-operation with end users. Examples of Swedish remote-sensing co-operation with developing countries are Indonesia, the Philippines, the United Republic of Tanzania and a number of other countries in Africa.

149. Assessment of natural woodlands in Tanzania using SPOT satellite data is a project supporting two ongoing UNDP/World Bank studies. About 50 SPOT scenes have been processed and interpreted for the study. The end-products will be land cover maps and 175 SPOT satellite image maps. These will be used for woody biomass inventory, and the result will be an assessment of available wood-fuel resources.

150. An inventory of Philippine natural resources was conducted using 190 multi-spectral scenes from the SPOT satellite, as part of a World Bank project lasting from April 1987 to April 1988 and covering 300,000 square kilometres. The project mapped 25 land cover classes, produced 43 pairs of satellite image maps and transparent thematic interpretation overlays corresponding to existing maps of the Philippines. Subsequently, the Swedish Space Corporation was contracted by NAMRIA (the Philippine National Mapping and Resources Information Authority) to produce 28 topographical maps at a scale of 1:50,000 based on SPOT data.

151. For Indonesia, Sweden has undertaken the task to deliver SPOT imagery covering the country with both multispectral and panchromatic data. Efforts have been made to plan the satellite programming to take account of the persistent cloudy conditions.

152. In 1989, the African Development Bank (AfDB) used remote sensing for the first time to carry out an environmental impact analysis. The Swedish Space Corporation delivered the imagery and provided consultancy services. During 1990, AfDB will carry out about 10 similar projects in African countries with the help of the Swedish Space Corporation.

IV. PLANETARY EXPLORATION AND ASTRONOMY

153. 1989 was an important year for planetary exploration. The first-ever flyby of Neptune, with its system of rings and moons by the Voyager 2 spacecraft completed its exploration of the four large planets. Voyager 2 is now flying out of the solar system into interstellar space, following Pioneer 10 and 11 and Voyager 1. All four spacecraft remain operational and continue to transmit new scientific data from that distance. With the Neptune encounter, all the planets in the solar system (with the exception of Pluto) and their moons have been studied at a reconnaissance level.

154. Two new spacecraft launched in 1989 initiated the next generation of planetary missions, marking the beginning of what promises to be a very active exploratory period. These were the Magellan and Galileo spacecraft launched from the United States Space Shuttle in May and October, respectively. A co-operative project between the United States and the Federal Republic of Germany, Galileo will need one flyby of Venus and two of the Earth to gain the necessary velocity and will arrive at Jupiter in December 1995. Shortly before its arrival, Galileo will separate into two parts: an instrumented probe, which will descend into the atmosphere of Jupiter to make direct measurements for more than one hour; and the main orbiter, which will study the planet's atmosphere, magnetosphere and system of moons and rings during its expected 22-month lifetime. The Galileo scientific team includes specialists from Canada, France, the Federal Republic of Germany, Sweden, the United Kingdom and the United States.

155. The Magellan radar mapper was launched into space on board the United States Space Shuttle Atlantis in May 1989. About seven hours after the launch of the Shuttle, and after careful checks of the interplanetary probe, Magellan was released from the payload bay of the Shuttle and deployed its solar panels. After the Shuttle had manoeuvred to a safe distance away, the upper stage rocket on Magellan fired, sending the spacecraft on its 15-month trajectory to Venus.

156. On 10 August 1990, Magellan will use its own propulsion system to enter into an elliptical orbit 250 to 8000 km above Venus with a period of 3.15 hours and an inclination of 86 degrees to the planet's equator. Unlike most earlier space probes, the 3,550 kg three-axis-stabilized Magellan carries only one scientific experiment: a synthetic-aperture radar (SAR) operating at the single S-band frequency of 2.385 GHz. It will perform three functions: collect imaging data of the surface of Venus; acquire altimetric data of the planet's topography, and measure the thermal emissions from the surface. The swaths of imagery will be 17 to 28 km wide, with the most detailed coverage located beneath the lowest point of the orbit, about 10 degrees north of the equator. Since Venus rotates slowly, the spacecraft will investigate overlapping strips of surface from one orbit to the next.

157. After the low-altitude portion of each orbit (measurements can be made for 37 minutes per orbit), the spacecraft will pivot and use the same 3.7 m antenna to transmit its data to Earth. By computer analysis of the radar echo characteristics, such as strength, polarization, time delay, and Doppler shift of frequency, reconstructed pictures of the planet's terrain will be generated that

should resolve details as small as 250 metres across. The altimetric structure of the terrain will be described with 30 metres accuracy. During one Venus year (243 Earth days), about 90 percent of the surface will be covered. At the conclusion of this primary mission, however, the spacecraft should still have enough manoeuvring fuel to repeat the entire mapping sequence several times. This will give scientists a chance to complete parts missed earlier, or to study selected terrain more intensively.

158. In addition to the planetary exploration programme, the United States also has an ongoing space astronomy and astrophysics programme. Its aim is to examine the universe in all wavelengths of the electromagnetic spectrum, from the shortest gamma rays to the longest radio waves, in an effort to understand its origin, present structure and future evolution. This programme has a long tradition of international co-operation. Among the most important results were those obtained by the International Ultraviolet Explorer, a co-operative project between the European Space Agency, the Science and Engineering Council of the United Kingdom, and NASA, which has completed more than a decade of operation. Another successful programme was the joint United States/Netherlands Infrared Astronomy Satellite, which scanned more than 90 per cent of the sky in four infrared bands.

159. Although cosmic background radiation, believed to be a remnant of the early big bang fireball, has been studied intensively for 25 years, extremely precise measurements have been available only since the launch of the Cosmic Background Explorer (COBE) satellite in November 1989. The main instrument measures the difference between the spectrum of the sky and that of a reference source over a range of wavelengths from 0.1 to 10 mm. The observations revealed that the measured spectrum is that of a perfect blackbody with a temperature of 2.735 K to an accuracy of better than 1 per cent. This means that this spectral shape has not been distorted during the 15 billion years since the big bang.

160. The most awaited space astronomy instrument, the Hubble Space Telescope (HST) was successfully launched from the Space Shuttle Discovery on 25 April 1990. Designed to be operated as a remote-controlled international multi-purpose observatory, it will look 7 times deeper into space (the volume of the observable universe will therefore expand by 350 times), resolve objects 10 times smaller (up to 0.1 arc seconds) and image objects 50 times fainter (down to the 28th or 29th astronomical magnitude) than those detected by the best ground-based observatories. Within our own solar system, for example, the HST will provide Voyager-quality images of the clouds in the atmosphere of Jupiter and will show details on Pluto almost as well as the naked eye can see on the Moon. It should be possible to determine whether globular clusters near the centre of our galaxy contain massive black holes. The telescope is also expected to image individual stars in distant galaxies. At great (cosmological) distances, HST should provide the first clear images of newborn galaxies forming, colliding and evolving in the aftermath of the big bang.

161. The 11,600 kg Hubble Space Telescope has a cylindrical, 13.3 m long and 4.3 m wide, main body with two 11.8 by 2.3 m flexible roll-out solar panels providing electrical power. Other support systems include communications, data management, thermal control, and pointing and attitude control. Star sensors can

locate positions in the sky to within 0.01 arc second and hold that pointing without varying more than 0.007 arc second for as long as 24 hours. The main instrument, the Optical Telescope Assembly (OTA), consists of a 2.4 m diameter reflecting Cassegrain-type telescope employing a Ritchey-Chretien folded optical system with a 340 mm secondary mirror located inside the prime focus. The primary mirror required over 4 million man-hours of work and is configured to an accuracy of one fifty-thousandth of a millimetre. In the focal plane of the OTA, five instruments can use the light focused by the telescope: the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS), the High Speed Photometer (HSP), the High Resolution Spectrograph (HRS) and the Wide Field/Planetary Camera (WF/PC).

162. The HST programme is a result of co-operation between the United States and the European Space Agency, which is providing the FOC instrument and the satellite's solar arrays, as well as some staff for the Space Telescope Science Institute. This long-term institution has been established in Baltimore to co-ordinate world-wide use of this unique astronomical instrument. In return for its participation, ESA has received 15 per cent of the total observing time for astronomers from its member States. The HST has a minimum design life of 15 years, made possible by Shuttle servicing missions to replace elements and undertake refurbishment or repairs as necessary. Up to 90 per cent of the elements can be replaced in orbit.

163. The HST is only the first in a set of complementary Great Observatories, which are currently under development. The next observatory to be launched will be the Gamma Ray Observatory (GRO), scheduled for the Shuttle at the end of 1990. The Advanced X-Ray Astrophysics Facility (AXAF) is expected to be launched in the mid-1990s. The Space Infrared Telescope Facility (SIRTF), which will make both optical and infrared observations, is in the conceptual design phase now.

164. Two other important astrophysical missions are scheduled for launch this year. The first is the Astro-1 Spacelab mission which is to be operated by the Shuttle astronauts/astronomers for 9 or 10 days. Astro's four telescopes are connected to the orbiter via ESA Spacelab hardware and are dependent on the Shuttle for power, communications and pointing. They are the Hopkins Ultraviolet Telescope (HUT), the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), the Ultraviolet Imaging Telescope (UIT), and the Broad Band X-ray Telescope (BBXRT). The next satellite, ROSAT (Roentgen Satellite), is scheduled for launch by an expendable Delta rocket this year to study soft X-ray emissions from different celestial sources. This mission will be the result of international co-operation between the Federal Republic of Germany, the United Kingdom and the United States. After a half-year X-ray survey of the entire sky, ROSAT is to be used as a space observatory by the international astronomical community for specific observational programmes.

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Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

I. SPECIAL PRESENTATIONS ORGANIZED BY COSPAR AND IAF

Symposium on Space Technology for Disaster Prediction, Communications and Rescue, Session 1, Tuesday, 27 February. Chairman: Mr. Burton Edelson, Co-Chairman IAF Committee for International Space Year.

Introduction, Mr. James Harford, Vice President, IAF.

Overview, Mr. Louis Walter, NASA Goddard Space Flight Center, United States.

Communications during Disasters, Mr. Wilbur Pritchard, W. L. Pritchard and Co., United States.

Severe Floods, Mr. Ted Engman, (co-author Mr. A. Rango), United States Department of Agriculture.

Symposium on Space Technology for Disaster Prediction, Communications and Rescue, Session 2, Wednesday, 28 February. Chairman: Mr. George Ohring, Chairman: COSPAR Commission on Space Studies of the Earth's Surface, Meteorology and Climate.

Introduction, Mr. A. J. Somogyi, Member, COSPAR Bureau.

Droughts, Mr. Louis Walter, NASA Goddard Space Flight Center, United States.

Severe Storms, Mr. Shui-Shang Chi, State University of New York at Buffalo (co-authors Mr. George C. Lee and Mr. Ching-Yen Tsay).

Search and Rescue, Mr. James T. Bailey, National Oceanic and Atmospheric Administration, United States.

COSPAS-SARSAT: Status and Future Developments, Mr. Valery Bogdanov, V/o Morsviazsputnik, Union of Soviet Socialist Republics.

Progress Report on the International Geosphere-Biosphere Programme, Friday, 2 March. Chairman: Mr. A. J. Somogyi, Member, COSPAR Bureau.

The IGBP Programme, Dr. S. Ichtiaque Rasool of NASA, on behalf of COSPAR.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

The Use of Space Technology for Terrestrial Search and Rescue and Disaster Mitigation, and India's Geosphere-Biosphere Research, Dr. M. G. Chandrasekhar, Indian Space Research Organization.

Participation of WMO in the International Decade for Natural Disaster Reduction, Mr. Donald Hinsman, World Meteorological Organization.

Distress Alert System Using the INMARSAT Satellites, Dr. Walter Göbel, Space Research Institute of the Federal Republic of Germany.

The Telemedicine Spacebridge, Dr. Arnold E. Nicogossian, NASA, United States, and Academician O. Gazenko, Academy of Sciences, Union of Soviet Socialist Republics.

NASA's Educational Programmes, Mr. Frank Owens and Ms. Elaine Schwartz, NASA, United States.

Space Shuttle Mission to Launch the Magellan Spacecraft, Mr. Ron Grabe, United States Astronaut.

NASA's Space-based Astronomy Programmes, Dr. Alan Bunner, NASA, United States.

Venus Radar Mapping Mission, Dr. Gordon Pettengill, Massachusetts Institute of Technology, United States.

Swedish Remote Sensing Programme, Dr. Marianne von Glehn, Swedish National Space Board, Sweden.

Remote Sensing, Dr. Krishna Rao, National Oceanic and Atmospheric Administration, United States.

International Priroda-Almaz Programme, Mr. Yuri Grigoriev, Union of Soviet Socialist Republics.

Radarsat Project, Mr. Shabir Ahmed, Canadian Space Agency, Canada.

Ocean Remote Sensing and the United States Earth Observing System, Dr. Stan Wilson, NASA, United States.
