PONTIFICIAE ACADEMIAE SCIENTIARVM DOCVMENTA

13

Study Week on:

THE IMPACT OF SPACE EXPLORATION ON MANKIND

October 1-5, 1984

CONCLUSIONS

PONTIFICIA
ACADEMIA
SCIENTIARVM

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMLXXXV

PRESENTATION

On October 1-5, 1984, the Pontifical Academy of Sciences held in the Vatican a Study Week on "The Impact of Space Exploration on Mankind", organized by Dr. V. M. Canuto, and chaired by Prof. M. G. K. Menon, Pontifical Academician.

The presentations and the subsequent discussions will be published as soon as possible in "Scripta Varia", which is the classical publication of the Pontifical Academy, and in co-edition with an international publisher. However, owing to the importance of the questions submitted to discussion, it was considered necessary to publish immediately and diffuse as much as possible the conclusions (by consensus) reached by the participants as a contribution of ideas for further action, and to call to the attention of the scientific community the results of this Study Week, which are so important since they involve the present and the future of all mankind.

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Introduction

The second half of the twentieth century has witnessed the beginning of space exploration by man.

Human understanding of the universe has been much advanced by close observation of other planets — Venus, Mars, Jupiter, Saturn, of the moons of these planets and our own as well, and by space observation of the cosmos unavailable from the earth. Orbiting telescopes and detectors operating in the ultraviolet, infrared, visible, x-ray and gamma-ray spectral ranges are offering a new, more complete view of the universe.

From the technological viewpoint, one of the most important achievements concerns the use of artificial satellites. After 27 years of experience with artificial earth satellites, we have however only a taste of the benefits humanity will receive from the exploration and utilization of space. Satellites have contributed to national and international security by providing assurance of no undetected launch of intercontinental-range ballistic missiles, as well as by helping to ensure that nations comply with their commitments under international or multinational agreements which limit the nature or number of tests of nuclear weapons or their delivery systems.

Space communications have included international telephone and point-to-point data communication, dissemination of television and radio signals for retransmission by terrestrial transmitters, and direct reception of such space broadcasts by the end user. Reliable communications to mobile users have been provided from space for civil and military users.

Satellite remote sensing provides continuous near-global environmental data as well as frequent information on local conditions and crops, available to any user. The global observation of the earth's gravity fields, of the ocean surface, and the details of the atmosphere, provides information on the structure and functioning of the earth's system.

For mobile users, not only communication but also accurate, flexible navigation capabilities are available from space, and enhanced safety is provided by the first-generation, satellite-aided search-and-rescue system, KOSPAS-SARSAT.

In summary, it may be said that satellites in their variety of uses, have provided mankind with new, powerful means of transporting information of all kinds on large and small scale from one part of the earth to another without the major constraints that often affect the terrestrial telecommunication network. In fact, the distance on earth between two ends of a satellite telecommunication link has no effect on the cost of providing the service. Moreover, satellites offer simultaneous access to a large number of stations, thus realizing a full communication network, in contrast with the terrestrial media, which are essentially able to link two single points and can form a network only through complex communications and switching nodes.

Following are the conclusions and recommendations that the participants of the Study Week have arrived at at the end of their discussions. They have been divided into three groups:

(1) Telecommunications Satellites.

(2) Space Technology.

(3) Future uses of Space.

Telecommunication Satellites

The participants of the Study Week noted that the future evolution and development of satellite telecommunication systems were bound to be increasingly affected in the future by non-technical issues.

Although technology will continue to evolve, the choice of systems, the extent of their coverage and the types of service they will provide are likely to be more a function of the context in which the sponsors of the systems want to use these, rather than what is technically achievable.

This evolution has given rise to new concerns which will need to be addressed in a systematic way if the interaction between the political, economic, technical, cultural, and last, ethical factors involved are to be adequately understood and discussed.

1) The present array of civil satellite communication systems for international, inter-regional and national use operates as a result of intergovernmental negotiations which, even if these were carried out separ-

ately, are to a greater or lesser extent interrelated but certainly fully coordinated from the technical and economic point of view.

This fact should be given its full importance and more attention should be paid to the possible consequences of actions non coordinated on an international basis which are likely to affect the use and operation of satellite communication systems, the operation of which is the result of international agreement, which reflects the broadest form of policy and interest.

2) Satellite telecommunication systems are capable of having considerable economic, social or cultural impact. They are furthermore likely to be conceived to have a life span of many years.

The effects of such systems will in most cases be felt over large areas and for long periods of time so that millions of people can be affected possibly to the extent of becoming dependent on such services.

Those responsible for establishing such satellite communication systems, especially when they provide services not available to the public by other means, should be aware of the political and social responsibility they incur.

3) The present evolution of satellite communication could place increased importance on the economic and social issues involved, especially as one cannot overlook the "public utility" aspect of some of the telecommunication services offered.

A better understanding of the economic and social dependence, both existing and potential, of mankind on telecommunications, including satellite telecommunication systems needs further study.

Space Technology

The participants of the Study Week noted that while using space technology for various applications, there is a need to develop new *configurations* and *new ways* of integrating the *new technology* with the existing economic and cultural variables of society in different parts of the world. The problems of hunger, lack of facilities for basic education and health care, unequal opportunities for continuous learning and access to resources, *cannot* be solved through space technology alone, and certainly not through the use of a uniform version of the technological configurations evolved to meet the needs of affluent developed societies. One has to respect and build on the local talent and existing institutional infra-structure. Wisdom of the poor and the deprived is not inferior for the fact of being powerless; it should be integrated with the new knowledge and information and not drowned in a flood of standardized prescriptions from far away. The long reach of space communication should not lead to homogenization and indoctrination; rather it should open windows to the big wide world and enrich the living and action within the community, with the respect for political, economic, cultural and moral identities of all nations and people.

Fortunately space technology is now extremely versatile and flexible. While using it under different conditions obtaining on the earth, we need to, and can, use it in different ways. In some parts of the world, community receiving facilities may be used for information dissemination and education. Microprocessor-based modern techniques, and small ground stations may provide two-way communication between communities and between people and sources of vital information. Some of the new possibilities in this regard may not have been possible even five years ago.

Even while terrestrial services are being improved, some of the vital needs of modern industry, banking, transport, education, etc., could be quickly met through digital satellite systems, using customer-based ground stations if good end links are not available. Many developing countries can overcome their "last mile problem", namely the need for good terrestrial links and efficient switching systems, through some version of packet switching networks. In some circumstances, low rate data services could be established even before the telephone service, due to lower cost. Nevertheless, a cheap, efficient telephone system does remain a very desirable intermediate objective, as we move towards integrated services networks.

Some countries may decide to acquire their own satellite systems, while others might employ satellite capacity from an international common carrier or a neighboring state. The increasing success of international cooperatives in space systems is a positive factor in this regard.

Satellite remote sensing is proving to be an almost essential technology for locating, managing and caring for our renewable and non-renewable resources, particularly mineral exploration, agriculture, forestry and land use, even though the ultimate objectives are realized only after a great deal of additional work on the ground. The large view from above illuminates the relational aspects, so essential for environmental management, and understanding of the weather.

Even while the use of remote sensing expands, there is increasing concern amongst many countries whether the required data would be continuously available on an affordable and equitable basis and whether some vital information about their resources, derived by a few entities, may not be equally accessible to the countries concerned. In any case, the countries' central concern is related to having preferential rights to the strategic information of their respective territories and to making certain that the natural resources of space are exploited for the benefit of mankind. It is also necessary in this and other applications of space technology to be consistent with the concept of common heritage of mankind of Outer Space.

We urgently need to work towards a direction where the basic needs of the whole world in respect to weather and remote sensing services are assured through an appropriate mechanism. (Some of the existing mechanisms of international telecommunication systems may provide suitable examples in this regard).

For all uses of space, in communication, broadcasting, education, resources management, etc., it is essential to keep the focus on the ultimate objective, namely the well-being of all people, especially the poor, the isolated and the underprivileged.

The Pontifical Academy of Sciences might consider organizing a study group to explore how remote sensing and information systems could be best developed and used to assure food security, including aspects of production, distribution and protection of the poor from exploitation. The stratification of various land uses over large areas can best be done by satellite images. From these various land strata, crop fields can be efficiently sampled on the ground to provide precise estimates of total crop production. This information is essential for the poorer countries to understand their food needs.

The Future uses of Space

Progress in the exploitation of space for the benefit of humanity will depend upon the effective use of technology, organization, and management tools. One should consider the following observations:

Space Sciences

Space science has provided marvelous and inspiring insights and surprises. The braided rings of Saturn, the vulcanism of Io, and (it seems so long ago) the nature of the surface of the moon, of Mars and of Venus have provided a point to fix the imagination and a base for further conjecture. The space probe observation of Martian dust storms has contributed to the recognition that fires set by nuclear war on earth could lead to winter temperatures and perhaps consequences even more catastrophic than the direct effects of nuclear war.

Some fundamental experiments of physics and observations of cosmological relevance can be done only in space, and a truly scientific study of the effects of the zero-g environment on human health and performance is long overdue. Some science and perhaps some technology can be done more cheaply in space: the fabrication and operation of precision radio antennas of kilometer or multi-kilometer size, the construction and use of very large composite optical mirror systems and very-long-baseline interferometry. In addition, advanced technology for space services (communication, navigation, remote sensing) may have to be demonstrated or verified in space experiments before it can confidently be included in a worldwide system.

Without recommending specific missions or even fields, we express our admiration for the results of planetary and space science thus far, and the feeling that a substantially larger component of research on space science and technology is warranted to speed the availability of new space services.

Benefits from Space Explorations

A) The spectacular achievements of space exploration have not as yet fully contributed their potential to the reduction of poverty, of illiteracy, or to the improvement of public health among the poorer nations of the world, or to improving food production and food security. Not only must developing countries participate in the acquisition of information and technology for weather forecasting, detection of new mineral resources, water management, and improved communication, but major efforts must be made in providing means to ensure that the benefits of economic and human development are actually available to the vast numbers of people in need.

To this end, regional mechanisms of cooperation could aid the realization of these benefits, and nations and international and multinational organizations should encourage the establishment of such mechanisms as appropriate.

B) To ensure the continual availability to all nations of the benefits of space exploration and exploitation, and to preserve the contribution to international security and national security made by existing satellite systems and those which might augment them, it is essential to prevent a spiral of competitive deployment of weapons in space.

To this end, an international treaty is required, with the purpose of banning the placement and testing of *all* weapons in outer space, on the moon, and all other celestial bodies, and in banning tests of anti-satellite weapons, wherever located. The necessity for an eventual international multilateral agreement should not delay an urgently needed bilateral agreement to this end between the two leading space powers.

Decision Procedures

In order to provide benefits of human and economic development to people throughout the world, one must select *missions*, to be fulfilled by technological *approaches*, with appropriate choice of reliability and response time. The choice of mission, approach, and performance must be guided by efficiency — both near-term and long-term. It is important to do the research, development, and analysis required to make these judgments, including generic work not associated with a commitment to a particular mission.

Tradition provides a candidate (traditional) approach, but it must not be allowed to define or limit the technological candidates for accomplishing a particular mission or to define the missions themselves.

Development has provided and experience has demonstrated the utility of manned reusable spacecraft for satellite launch and in-orbit repair; it has also provided a basis for unmanned launch, rendez-vous, resupply in various orbits and for large and small payloads.

Key Directions for Better Performance

a) Burgeoning capability for computation and signal processing based on the last decade's progress in microprocessors to give ten-million to 1,000-million operations per second in a few microchips;

b) the application of microprocessors and microwave integrated technology to flexible communication systems such as phased-array antennas which can make possible efficient satellite communication systems and appropriate space information relay (and especially satellite-to-satellite relay) by radio or laser link. Just as the Tracking and Data Relay Satellite (TDRS) is replacing many ground stations, so can the output of low-earth-orbiting satellites be made available more economically by radio relay via geostationary satellite. INTELSAT space cross-links would be valuable and, for instance, search-and-rescue satellite signals can be acquired by low-earth-orbit satellites and relayed by a geosynchronous-orbit satellite whose phased-array antenna occasionally looks at the SARSATs and requests the transmission of any stored signals;

c) the use of telecommunication to provide more effective linkage of scientists in their laboratories with experiments or observing facilities in orbit;

d) the increasingly powerful augmentatoin of human ability by local computing power and instruments;

e) the perfection of reliable reusable transportation of people and things to and from orbit, and, complementarily, the availability of automated or remote-managed orbital resupply, repair, or adjustment;

f) the evolution of a capability for cost-benefit analysis, project management, system engineering and design choice which can provide a more solid groundwork than intuitive choice — among potential applications as different as remote data communications and vehicle monitoring — while retaining the possibility of accepting and evaluating proposals of intuition and genius;

g) the experience of productive collaboration in which real decisions are made and real hardware and capabilities created — such as the INTELSAT cooperative and the Canadian provision of the remote-manipulation arm for the U.S. space shuttle.

Recommendations (General)

a) For a given mission, an informed choice should be made as to the proper mix of human intelligence and machines, and the optimum location of the human furnishing the intelligence.

b) Society must choose among a homogeneous system in which all obtain the same communications service at the same price; a heterogeneous system in which concentrated users obtain a better service or lower cost; and a heterogeneous system in which there is internal or external subsidy.

c) Planning for an evaluation of accomplishing a *set* of missions must consider the options of a large space station on the one hand, in comparison with a set of smaller satellites on the other. Such analyses must include the unconstrained application of feasible technologies such as satellite-to-satellite communications, reusable or expendable launchers and re-entry vehicles, manned or automated docking and resupply, and the like. The benefits and costs of international collaboration must also be considered, with likely net benefit for collaboration in the planning and technology phase, as well as in operation.

d) Much research and development would be justified and should be performed to provide additional options for reduction of cost in performing space tasks now feasible and in providing new and competitive technological options (e.g. robotics, expert systems, and artificial intelligence) for accomplishing new tasks.

e) As for manned space flight, each person traveling to space and returning safely is testament to the magnificent achievement of the men and women who have created the technology, the organizations, and the operational systems which make space flight possible. Nations providing the capabilities for manned space flight or participating in manned space flight should take into account the essentially human and spiritual response to the human adventure in space. Flight opportunities should be provided to people, such as writers and artists, who can better transmit those adventures to the multitudes who cannot personally participate.

f) Efforts should be undertaken to maximize the economic and social benefits available from the exploitation of space by the use of manned missions or unmanned missions as are best suited to the specific tasks to be accomplished.

g) Analysis of space missions should be extended beyond the planned end of useful life of the satellite, to include the ultimate fate of the space debris. Ideally, no debris should be left in near-earth space, but in any case the amount of debris should be minimized in order not to prejudice the future use of space by others. A possible criterion might be to ensure that the debris from a century of anticipated space operations should not shorten the expected operational life of additional satellites by 0.1%. One must balance the costs of controlling debris against the cost of damage if debris is not controlled.

h) In cases in which centralized organizations are used to increase efficiency of *building* and *operating* systems of satellites, special means and care are needed to ensure that new technology is introduced whenever it can reduce the overall cost of providing a given level of service. Alternatively, care must be taken to avoid introduction of technology which can unwarrantedly increase costs to consumers who cannot control the total system.

i) The availability of global communications should be accompanied by means for improvement of local communications, with a view to allowing individuals and groups to maintain cultural diversity and to retain and enhance a sense of community.

Conclusions

Increasing human capabilities in space could bring forth an era where distance stands abolished and all humans on the planet truly begin to feel and function like members of one global family. The very same space awareness could make us live hereafter in greater harmony with our beautiful and fragile home in the solar system and to monitor, use and care for its resources for the common good of us all.

We could share the richness of our cultures, the increasing fund of our knowledge and understanding, the new techniques of bettering the conditions of life, and the delights of our intellectual and spiritual adventures — all this again because we could all have a voice and might be able to talk to whomsoever we want.

Such a world has now become possible. How much more desirable it would be to use our magnificent tools of space technology and operation to work toward this goal rather than to slide toward the unthinkable possibility that much, if not the whole, of the human race may be wiped out from the surface of this planet, perhaps within the lifetime of our children.