ASTRONAUTICAL RESEARCH 1972

PROCEEDINGS OF THE 23RD CONGRESS OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION
VIENNA, 8-15 OCTOBER 1972

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L. G. NAPOLITANO

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ASTRONAUTICAL RESEARCH 1972

PREFACE

Space scientists and engineers belonging to the professional societies associated with the International Astronautical Federation gathered together in Vienna to hold the Federation's 23rd Congress.

A selected number of papers and critical surveys that were presented and debated at this Congress and which span the widely diversified field of astonautics are collected in the present Proceedings, together with a number of summaries of Round Table Discussions and/or Forum Sessions.

As its predecessors in the series, *Astronautical Research 1972* constitutes an indispensable reference for several groups of people: those who are actively engaged in astronautics; those who are interested in following and assessing, year by year, the developments in astronautics, its progress, its new directions in research; and those who are concerned with its many applications.

Space science and technology are bound to play an increasing role in the immediate future, now that greater effort is being devoted to the exploitation of their relevance to other fields of human activity. Problems posed by the scarcity of earth resources and by their inadequate management, pollution problems, problems created by man's indiscriminate and often irresponsible action in vital sectors of the biosphere can be tackled and successfully alleviated, if not solved, by means of the soft and hard advanced technology developed for space systems. Space research is witnessing a widening of its scope and a diversified proliferation of its objectives as more emphasis is being placed on its application to natural and human sciences and to the optimization and control of ecological systems.

Astronautical Research 1972 reflects and emphasizes these new trends by presenting, as a prelude to the Proceedings, the fourth International Astronautical Federation Invited Lecture, 'Impact of Space on World Development' delivered by Dr Guyford Stever, Director of the National Science Foundation of the United States. Dr Stever's concluding remarks set the stage: "Space applications can be used to advance knowledge generally, to support local and regional applications, to stimulate the economy, to improve the environment and to provide further means of international cooperation". These Proceedings provide ample substantiation for such statements and should be perused by those who are either curious or sceptical – or both – about them.

After the summary of the Forum Session, devoted to the theme of the Congress: 'Space for World Development', there follows the main body of the book which consists of four parts.

The first part deals with basic problems and contains papers in the field of astrodynamics and bioastronautics.

The second part deals with the engineering and management aspects of space technology. It contains papers on such classical subjects as structure, materials, and propulsion, as well as papers discussing the technological problems of and the mission objectives for scientifiec spacecraft.

The third part is concerned with the utilization and application of space science and technology. It contains papers dealing with remote sensing and its application to hydrology, with Earth and ocean physics, with navigation and weather satellites, and with materials processing in zero gravity.

The novelty and timeliness of the topics discussed during the I.A.F. Congresses are particularly evident in this section of the Proceedings. Two instances, out of the many available, seem worth mentioning explicitly. The first one is the Round Table Discussion on the results from the mission of the Earth Resource Technology Satellite (ERTS-1) which constituted a 'world première' on an international stage. The second is the paper on the 'Skylab Student Project' describing and commenting the experiments which were devised by students and will be performed during the Skylab mission.

The fourth and last part contains papers from the Third I.A.F. Student Conference. They present, in a significant and interesting perspective, a cross section of the scientific activities of the younger generation and of its assessment of the problems of world development.

In closing, I wish to thank all those who have helped me in editing these Proceedings: the session chairmen for the timely and valuable help in the selection of papers, the language editors Dr P. Contensou and Dr W. F. Hilton for their valid work; the Secretariat in Paris for untiring cooperation and much needed coordinating action; the managing editor of D. Reidel Publishing Company for coping efficiently with the many problems arising from the publication of Proceedings of International Congresses and, last but not least, the authors who have graciously complied with the stringent requirements I have been compelled to impose on the length of their manuscripts.

LUIGI G. NAPOLITANO

Editor-in-chief

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IMPACT OF SPACE ON WORLD DEVELOPMENT

H. GUYFORD STEVER
Director, National Science Foundation

Today, we meet to discuss the impact of space on world development. As a scientist; as the director of an agency of the United States Government, the National Science Foundation; and as a participant in this congress who is concerned about peace on Earth and, therefore, world development, I endorse the theme which brings us together and extend my compliments of those of you who have made this assembly possible. I am grateful that you invited me to join in this worthy task.

We are meeting at a time which is quite significant in man's exploration of outer space. This is the year of ever-increasing cooperative interests in space ventures, including the joint, manned space effort by the Soviet Union and the United States. Thanks to the genius of our early pioneers, many of whom are in this great hall, the results of an era of experimentation now show us clearly the promise which the orderly and determined use of space and space vehicles has to offer. Space science and space technology are already going to work.

The perspective of space gives us new insights and fresh outlooks. In these remarks, I will speak about some of these as a prelude to a discussion of what I refer to as a space ethic. Since ethics have meaning only in the experience of life, I will then examine some past space experiences and prospective space uses in the light of that ethic. World development includes all countries, but our regard for developing countries prompts me to emphasize their special needs.

1. Perspectives of Space

To a scientist, man's leap into space means new data and a way to test theory against reality. To the world-minded, it is access to events everywhere and instantly. But, does space have a meaning which is common to all? I believe that it does. Oddly enough, it is not space itself but the view of earth from space that shows us that Earth is a spaceship. Seeing the earth as a whole for the first time, with its unique colors and complement of resources, and comparing its protective environment with the stark landscape of the Moon was an awesome experience from which man emerged never to be the same again.

Looking at Earth from space, there are no developed or developing countries – just land, sea, and atmosphere. But, looking at space from Earth, it would be unrealistic to overlook or deny the fact that there is a spectrum of space capability and a diversity of national resources for space operations which correlates quite closely with the spectrum of national development.

L. G. Napolitano et al. (eds.), Astronautical Research 1972, 1–11.

As long as the primary emphasis in space was on manned or unmanned exploration or scientific experiment, only those few technologically advanced countries capable of supporting space flight were involved. Now, as the emphasis shifts from exploration to application, and as man is beginning to use space platforms for Earth-oriented applications, the focus of space is broadening. All nations can be involved and can profit – developed as well as developing, those with strong space capabilities as well as countries with none at all. As a result, there is emerging a tension between the concept of earth as a unitary system as seen from space and the earthly realities of men and countries with individual and sometimes conflicting interests. In these circumstances, space becomes an exploitable resource, not just a medium, and the old problems of allocation of a new but scarce commodity face the involved parties. Is space to become tomorrow's tragic commons?

Truly, it may, While there are exceptions, in space and on Earth, man has not usually had a good record when it comes to the allocation of resources. In part, this poor record stems from the concept of allocation – a word I use deliberately because it is so familiar and yet so wrong. It is wrong because allocation divides resources and is contrary to the unitary concept of a a spaceship earth in which the emphasis is on global resources and system management.

2. A Space Ethic

When we shift concepts in this way, the need for an entirely new basis for action arises. To divide a pie, simple rules are enough. Priorities of time, possession, or strength usually govern – whether they are right or wrong. To manage a system, simple rules are not enough. We must know the purposes of the system and, therefore, what we want. If we are to do this, and do it right, we must have an ethic which is grounded in the new perspectives of space – in other words, a space ethic to guide our actions and decisions.

From his earliest beginnings, man has moved from simple to complex modes of cooperation. Such cooperative modes, or symbioses, first involved individuals only, then individuals and society. The next great ethical step forward is the symbiosis of space, Earth, and man. Before we can take such a step, we need to know more about the nature of a space ethic. and what are its implications to man.

It appears to me that a space ethic has some of the following features:

(1) It is holistic in that it emphasizes the organic relation and continuity between the Earth's parts and wholes. Its concern is with the total planetary system, not piecemeal aggregates of unrelated fragments and processes.

(2) It expands ethical concerns which typically have only involved man to man, or man to society relationships. Copernicus taught us that the Earth was not the center or our solar system. Our voyage in space tells us that man is not the center of our ethical system. Indeed, in a holistic system there is no center, and man shares the system with other environmental creatures and objects which warrant and have become the subject of serious ethical concern. To illustrate the change in our thinking,

in a recent case before the United States Supreme Court, Justice Douglas advocated that "valleys, estuaries, beaches, ridges, groves of trees, swampland, or even air" be permitted to be parties in litigation. He justified this on the ground that, and I quote:

> The river, for example, is the living symbol of all the life it sustains or nourishes – fish, aquatic insects, water ouzels, otter, deer, elk, bear, and all other animals, including man, who are dependent on it or enjoy it for its sight, its sound, or its life. The river, as plaintiff, speaks for the ecological unit of life that is part of it.

(3) A space ethic deals with the processes of natural systems. The space ethic stresses action which preserves natural regulatory systems. It avoids action which taxes the capacity of any kind of natural system, especially when there is a danger of irreversible damage or waste of nonrenewable resources. Fortunately, from our new positions in space, we are able to engage in environmental monitoring on an adequate scale for the first time. The Earthwatch Program, approved in June 1972 at the U. N. Conference on the Human Environment in Stockholm, is a welcome step in the direction of monitoring hazardous conditions in the environment. I am sure that satellites will play an ever-increasing role in the effort to maintain the natural systems on which we all depend.

It is not enough to describe an ethic, we must also think about its viability in the emerging space world. For those of us who have 'lived' space for so many years, its implications for world development seem as endless as space itself. Let us, however, bring space down to Earth by noting that satellites are likely to change our values and social priorities in the future as much as the automobile did in the past. When autos were first put into use, we had no idea that they would affect where we live; that they would change the air we breathe, the work we do, and, in many cases, what we want. Space may not change all that – in fact, I hope it doesn't – but man's values and desires will surely be transformed.

It may be too early to tell how far and fast our values will evolve, but we ought to think of space applications more as social evolution than as technical innovation. Not only can we expect changes in social institutions and the kinds of decisions we will make, but perhaps our personality may change as it did when we got behind the wheel of a fast, powerful auto.

Space applications also enlarge and, at the same time, contract the perceived boundaries of the human community. When we see ourselves as part of a single, planetary system, the notions of city, state or national boundaries seem at best only conveniences and at worst anachronistic. Regardless of man made boundaries, exposure to other cultures and personalities – mainly through the medium of electronic satellite communication – is tending to move us toward becoming a 'global village'.

People now take rapid communication for granted, forgetting that television is only about a third of a century old, radio use on a large scale is barely a half century old, and telephones not yet a full century. In these comparatively few years, we have witnessed a homogenization of world culture as well as the weakening of local institutions. Even the way we use our senses and react to things begins to be more and more of a kind. We seem to be in a process of 'implosion' as we recreate on a global scale, through space technology, the ancient and feudal way of communicating by one person telling another. At the same time, the explosion of social forces is no longer dissipated and absorbed into distant territories, but reverberates from all part of the globe.

Obviously, with major changes in values and social institutions, together with the way people decide matters and relate to one another, the future will be much different than the past. The need for a space ethic that can shape and remold the future is heightened. As different decisions are made, new uses for old data will be conceived and new data developed. New options will open up, and old ones will no longer be feasible. To structure such a dynamic world is the crucial problem of our era, and its timely solution is by no means assured.

I have been speaking of extensive changes that might take place as a result of our space activities. But the need for and the needs of international cooperation tend to continue in the same direction and can be increased by space activities. Consider, for example, the International Telecommunication Union. The ITU, formed in 1865, has often been criticized for limiting its activities to regulating policy among national telecommunications administrations. And yet, it has lasted longer than most other international organizations. The reasons which explain this past durability for ITU, and which will be operative in space activities of the future, include:

- Acceptance of the need to insulate some scientific and technological activities from the unpredictable turns of international politics;
- The desire to maintain benefits derived from cooperation; and
- The expansion of the range of available national opportunities.

These continuing imperatives of protecting the search for and use of knowledge, maximizing their benefits and the number of participants, will, however, take place in a new context of world development. At first, we viewed development of emerging countries as a problem of capital investment. When it became clear that effective capital investment depended on managerial skill, we turned to technicians and experts of various kinds to administer capital productively. Then, it seemed that they could not function unless they were part of an institutional framework manned by a well-trained local citizenry. This too had its problems, and for the past decade there has been gradual but steady decline in the percent of gross national product committed by donor countries to less developed countries. In part, this decline may also be due to the increasing awareness on the part of so called developed countries that they too are underdeveloped in many respects. This sensitivity is especially true for those aspects of society included in the phrase 'quality of life', such as the physical envorinment, culture, art, and the like.

Whatever the reason may be for current developmental problems, it seems clear that we are standing at a new threshold, in which the *aims* of world development are more important than how we do it. Later in these remarks, I will try to show how the space ethic can help us identify the proper aims of development and cope with change caused by space activities. In so doing, it can provide a basis for assessing the negative and positive aspects of production and access to goods. It can provide a rationale for solidarity among men within regions and throughout the world. Finally, it bounds the proper use of developmental technology by protecting natural regulatory systems.

3. Space Experience and Its Lessons

All of this sounds rather abstract and difficult to apply. What are the pertinent lessons of our experience in space? What are the policy guidelines which will help us in our increasing effort to use space for world development? In this context, the significant space activities relate to scientific research, meteorological services, communication, navigation, and Earth resources.

I admit to a certain personal bias in placing scientific research at the head of my list of space activities which are significant for world development. But this attitude is based on positive evidence that scientific research is indispensable for long-term progress in world development and other activities as well. Research provides a liveliness and a flow of ideas far out of proportion to its cost. It is a highly reactive ingredient, without which developmental progress would begin to lose its momentum. While our research potential usually outruns our pocketbook, I think it fair to say that the funding levels and the criteria of choice in selecting experiments in space do show a continuing and encouraging support for scientific research. What is equally important is the maintenance of the ambiance of space research. By this I mean open programs, sharing of information, and access to experiments.

Substantial progress has been and is being made in this direction. The broader question is: can the openness, sharing, and broad participation so characteristic of the scientific enterprise be extended into operational areas, as a model for the space ethic? To a considerable extent, we have done so in regard to meteorological services. When experimental evidence made it clear that meteorology was at a turning point because satellites could measure atmospheric conditions over the entire surface of the Earth at frequent intervals, a single coherent world service was established – the World Weather Watch. Members of the World Meteorological Organization receive or can expect to receive, through the World Weather Watch, such benefits as extended weather forecasts, storm warnings, and environmental information related to pollution. We now enjoy worldwide availability of automatic picture transmissions which may be received by comparatively simple equipment in any country over which the satellite is passing. With such equipment, it is possible to secure photocopies of the surrounding areas within a distance of about 2000 kilometers, and I understand that about 100 countries are now using this transmission. One can hardly find a better illustration of open sharing with wide operational participation.

It is important to note that a widespread network to collect meteorological data existed before the advent of the satellite. More than 8000 land stations were in operation, and more than 5000 merchant ships reported weather observations when at sea. Using a global telecommunications system, these data were exchanged rapidly and continuously.

I cite the preexistence of an operational meteorological network because of its effect on how the new space satellite capability was put into use. Initially, meteorological satellites were an experimental problem in space science and technology. As the satellite systems became operational, the problem became one of data collection and handling. Fortunately, a framework for coping with the problems already existed and could be extended readily through customary arrangements.

Even with this advantage, it is clear that data management is becoming a critical issue. In the words of D. A. Davies, secretary-general of the World Meteorological Organization:

> The price for using (satellite meteorological) data to maximum advantage will inevitably increase; even the most highly developed countries will be forced (as they are at present) to establish priorities for data acquisition and use. For countries and organizations which remain completely in the data-user class the cost of receiving and processing the data to meet their particular needs will rise sharply. A possible result is that most users will be forced by economic necessity to accept the fruits of increased space activity in the form that the provider is able to supply them with little or no modifications or adaptation.

Two lessons emerge from this experience. First, we must distinguish between the problems which are typical of the scientific as compared to the operational phases of space activities. Problems in the scientific phase may tax our intellectual capacities but they do not normally involve the scale or level of activity dealt with operationally. The sharing of scientific knowledge is not usually severely limited by funding, but the cost of data sharing may limit what is shared, how often, and by whom. Even with the best of intentions, we have to accommodate to the real world where sharing and participation take on different meanings as circumstances change.

The second lesson relates to the virtues of precedent. Existing institutions and customary services which preceded satellites have generally offered the best means to take advantage of the new capabilities they provide. Expertise, contacts, treaty and other legal agreements are powerful incentives to work within traditional arrangements. This is particularly true for meteorological observations, where the satellites improved the quantity and quality of data available rather than creating entirely new possibilities, as in the case of remote sensing of Earth resources.

It is clear that putting space to work in world development is far more complicated than only using it for scientific study. That is not to say that openness, sharing, and wide participation are not desirable. As scientists, we believe they are essential, but there is a lot more to the problem.

The development of the INTELSAT global telecommunications system provides important lessons. Under INTELSAT, international satellite communications, after passing from the experimental into the commercial phases, followed commercial arrangements that are very little different from those used for international radio and cable communications. What made INTELSAT different was the possibility of any country having direct communications access to any other country through a satellite. This was in sharp contrast to presatellite international commercial communications, in which the bulk of the countries in the world could only communicate with each other by going through carriers controlled by just a few countries.

INTELSAT is also different because international communications are an entirely quantitative thing. Rates can be estimated, charged, and adjusted; capital investment can be computed, and return on profit estimated. Consequently, it becomes possible to have a commercial enterprise devoted to optimizing communications services at the lowest cost. Of course, there are a lot of national and political interests involved, but month by month, year by year, the operation of INTELSAT is a business enterprise.

Given the important new precept of direct, country to country communication on a global basis, the impact on existing methods of communications, and the commercial 'utility' character of the enterprise, it was clear that a new type of organization or consortium was needed to capitalize and regulate this new international capability. This was no easy task. Even negotiation methods needed to be changed. In the past, telecommunications entities had been able to negotiate directly with their counterparts in international communications. Now in the space age, governments have national interests in outer space, and political factors have to be taken into account. As a result, negotiations have to be conducted on a multi-national basis, and at a governmental level. Despite these difficulties, interim arrangements were established in 1964 and new, definitive arrangements agreed to in May 1971. It is not my purpose to analyze this agreement except to note that through a process of compromise the essential business character of INTELSAT has been maintained while creating a broader international quality to the management of the system.

Global communications satellites have had more impact on world development than any other space activity. Are there any lessons for us out of this experience to date that will help us in the broader application of the space ethic? As in the case of meteorological satellites, a significant distinction exists between scientific and technological experimentation and the administration and management of satellite operations. Operationally, we see repeated the general practice of retaining customary arrangements.

On the other hand, important new ideas were introduced regarding organization and economics. Given the capabilities existing in the world in the early 1960's, the United States could have created its own global communications system. The United States could have just built it, flown it, and sold the services at rates it determined. It would have been a U.S. system, and such profits as it made would have all come to the United States. As you know, it did not do so. Nor did it seek to establish some international agency to control operations. Having voted for the United Nations resolution of December 1961 that communications should be available to the nations of the world as soon as practicable on a global and nondiscriminatory basis, the United States felt that the most effective mechanism would be some form of commercial, international, public utility. Notwithstanding the many difficulties of reconciling national interests and adjusting to different viewpoints, the wisdom of choosing a multi-national, quasi-governmental organizational alternative is demonstrated by the later course of events which are familiar to this audience.

Experience in testing or operating new satellite systems is not the only way we learn how to apply a space ethic to world development. Policy commitments hammered out through intensive negotiation at the United Nations, and formally accepted by the governments of the world, also represent important guidelines. Let me cite a few:

- space should be used for the benefit of all peoples, irrespective of their degree of economic or scientific development
- space is not subject to national appropriation
- space shall be free for exploration, use, and scientific investigation
- space activities shall be conducted in accordance with international law

4. Space Ethics and Remote Sensing of Earth Resources

I have, to this point in my remarks, described a space ethic, factors affecting its viability, and some experiential and policy guidelines which might be useful in its application. Now we must see how all this might work in practice. As a test case, I have selected remote sensing of the Earth's resources by satellite because it is most relevant to the theme of this Congress.

Earth-orbiting satellites give us the potential ability to secure repetitive, synoptic coverage of energy emanating, at various wavelengths, from the Earth's surface. Collection and study of these energy emanations will allow us to identify objects and secure a variety of information which has economic, social, cultural, and ecological value.

Obviously, if successful, such a satellite system would be able to perform a wide variety of tasks. Not all of these tasks, however, are equally well understood. For example, the problems of environmental monitoring are not as familiar to us as those of mapping or cultural and resource data collection. Also, we don't know the optimum configuration for an Earth resources survey, the best sensors to use, the most efficient way to process data, and the economics of such surveys.

Clearly, we are in an experimental phase and, as you know, the Earth Resources Technology Satellite called ERTS-A has recently been launched. As was the case in other satellite programs, a substantial fundamental research effort is part of the total package, and many countries in different stages of development are participating. Representatives from 40 countries and 16 international organizations attended a U.S.-sponsored International Workshop in the Earth Resources Survey System. Canada is active with ERTS data acquisition and data processing facilities, and in preparation for a remote sensing system, Brazil and Mexico have entered into cooperative agreements with the United States. Under these agreements, remote sensing aircraft programs are helping to pave the way for use of spacecraft data by development of necessary skills and ground truth data. India, too, has undertaken a similar domestic aircraft program.

I am mentioning these details in order to highlight the fact that the program has proceeded on an open, unrestricted basis with full sharing of available information and wide participation. At the same time, it is proceeding deliberately, and we hope prudently, so that developing countries can make their own decision, in the light of their special circumstances, as to the proper degree and timing of any commitments of money and manpower.

Anticipating that earth resource satellites should be capable of yielding valuable data, President Nixon has promised to make the data of its future programs available to all "as this program proceeds and fulfills its promise." Assuming a validation of the experimental phase, what are some of the attributes of an earth resources satellite system that are relevant to an ultimate operational system?

Of first importance, we must recognize that an Earth resources satellite system represents a new capability for providing different and additional kinds of information not hitherto available. But it will not be 'selfsufficient'. For maximum effectiveness, it must be supplemented by aircraft and some ground observation. In such circumstances, a new ingredient is added – national sovereignty. No government has yet contested the proposition that satellites can overfly countries without interference. But nobody denies that the required supplemental aircraft ground observations will be subject to national control.

A desire to maintain national control of earth resource data is not an archaic attitude which has no place in the space age. The provision of meteorological data or communication links are services which can't be prejudicial to a country, because they don't have to accept them. Countries can decide for themselves if the benefits of a service are worth the cost. In the case of remote sensing of Earth resources, countries may see the capability as being prejudicial but don't have the same opportunity to prevent its application in their territory. Accordingly, there will be a strong interest in having quite explicit, binding international agreements which govern the use of this capability.

Another significant consideration that bears on operational characteristics of remote sensing of earth resources is the variety of taks to be performed. Unlike the relatively simple objectives of meteorological or communications satellites, an Earth resource satellite will have many purposes to be served, representing a broad range of interests in both kind and intensity. For example, there will be resource surveying tasks to do over areas of the globe that are not subject to national sovereignty – such as the oceans and polar regions. There will be resource surveying to be done which by its content has an international, scientific, or economic interest over and above the interest of individual countries. Then, of course, there will be tasks which arise directly from the national interests of individual countries. Certainly, individual and industrial purposes are also to be served. Given the range and complexity of tasks, it is evident that no simple operational scheme is going to suffice.

Taking these considerations into account, as well as the fact that there is still much to do in the experimental phase, it takes a brave if not a foolhardy individual to try to be precise about the nature of operational Earth resource satellite systems. Being one but not the other, I emphasize that I speak only as a private individual with a long-term interest in space affairs. With that qualification, I will now offer some thoughts on how the space ethic can influence the application of Earth resources