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ABSTRACT

This report summarizes the findings of one of fourteen panels that studied progress in space science applications and defined user needs potentially capable of being met by space-system applications. The study was requested by the National Aeronautics and Space Administration (NASA) and was conducted by the Space Applications Board. The panels comprised user specialists drawn from federal, state, and local governments and from business and industry. The Technology Panel's activities were focused in general on the earth observation or remote-sensing requirements of all user panels. Among the panel's comments was that every earth observation user-oriented panel described a requirement for frequent repetitive observation either over prolonged periods from sun-synchronous orbits or continuously from geostationary orbit. The Panel also concluded that there is a clear requirement for additional research on the relationship of measurements which can be made from space to basic parameters of interest to users. (MH)

Practical Applications of Space Systems

Supporting Paper 14

Technology

A Panel Report Prepared for the

Space Applications Board

Assembly of Engineering

National Research Council

1974 SUMMER STUDY ON PRACTICAL APPLICATIONS OF SPACE SYSTEMS

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(July 1974)

PRACTICAL APPLICATIONS OF SPACE SYSTEMS

Supporting Paper 14

TECHNOLOGY SUPPORT

The Report of the
PANEL ON TECHNOLOGY SUPPORT
to the
SPACE APPLICATIONS BOARD
of the
ASSEMBLY OF ENGINEERING
NATIONAL RESEARCH COUNCIL

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PREFACE

In November 1973, the National Aeronautics and Space Administration (NASA) asked the National Academy of Engineering* to conduct a summer study of future applications of space systems, with particular emphasis on practical approaches, taking into consideration socioeconomic benefits. NASA asked that the study also consider how these applications would influence or be influenced by the Space Shuttle System, the principal space transportation system of the 1980's. In December 1973, the Academy agreed to perform the study and assigned the task to the Space Applications Board (SAB).

In the summers of 1967 and 1968, the National Academy of Sciences had convened a group of eminent scientists and engineers to determine what research and development was necessary to permit the exploitation of useful applications of earth-oriented satellites. The SAB concluded that since the NAS study, operational weather and communications satellites and the successful first year of use of the experimental Earth Resources Technology Satellite had demonstrated conclusively a technological capability that could form a foundation for expanding the useful applications of space-derived information and services, and that it was now necessary to obtain, from a broad cross-section of potential users, new ideas and needs that might guide the development of space systems for practical applications.

After discussions with NASA and other interested federal agencies, it was agreed that a major aim of the "summer study" should be to involve, and to attempt to understand the needs of, resource managers and other decision-makers who had as yet only considered space systems as experimental rather than as useful elements of major day-to-day operational information and service systems. Under the general direction of the SAB, then, a representative group of users and potential users conducted an intensive two-week study to define user needs that might be met by information or services derived from earth-orbiting satellites. This work was done in July 1974 at Snowmass, Colorado.

For the study, nine user-oriented panels were formed, comprised of present or potential public and private users, including businessmen, state and local government officials, resource managers, and other decision-makers. A number

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*Effective July 1, 1974, the National Academy of Sciences and the National Academy of Engineering reorganized the National Research Council into eight assemblies and commissions. All National Academy of Engineering program units, including the SAB, became the Assembly of Engineering.

of scientists and technologists also participated, functioning essentially as expert consultants. The assignment made to the panels included reviewing progress in space applications since the NAS study of 1968* and defining user needs potentially capable of being met by space-system applications. User specialists, drawn from federal, state, and local governments and from business and industry, were impaneled in the following fields:

Panel 1: Weather and Climate
Panel 2: Uses of Communications
Panel 3: Land Use Planning
Panel 4: Agriculture, Forest, and Range
Panel 5: Inland Water Resources
Panel 6: Extractable Resources
Panel 7: Environmental Quality
Panel 8: Marine and Maritime Uses
Panel 9: Materials Processing in Space

In addition, to study the socioeconomic benefits, the influence of technology, and the interface with space transportation systems, the following panels (termed interactive panels) were convened:

Panel 10: Institutional Arrangements
Panel 11: Costs and Benefits
Panel 12: Space Transportation
Panel 13: Information Services and Information Processing
Panel 14: Technology

As a basis for their deliberations, the latter groups used needs expressed by the user panels. A substantial amount of interaction with the user panels was designed into the study plan and was found to be both desirable and necessary.

The major part of the study was accomplished by the panels. The function of the SAB was to review the work of the panels, to evaluate their findings, and to derive from their work an integrated set of major conclusions and recommendations. The Board's findings, which include certain significant recommendations from the panel reports, as well as more general ones arrived at by considering the work of the study as a whole, are contained in a report prepared by the Board.**

It should be emphasized that the study was not designed to make detailed assessments of all of the factors which should be considered in establishing priorities. In some cases, for example, options other than space systems for accomplishing the same objectives may need to be assessed; requirements for

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*National Research Council. *Useful Applications of Earth-Oriented Satellites, Report of the Central Review Committee*. National Academy of Sciences, Washington, D.C., 1969.

**Space Applications Board, National Research Council. *Practical Applications of Space Systems*. National Academy of Sciences, Washington, D.C., 1975.

institutional or organizational support may need to be appraised; multiple uses of systems may need to be evaluated to achieve the most efficient and economic returns. In some cases, analyses of costs and benefits will be needed. In this connection, specific cost-benefit studies were not conducted as a part of the two-week study. Recommendations for certain such analyses, however, appear in the Board's report, together with recommendations designed to provide an improved basis upon which to make cost-benefit assessments.

In sum, the study was designed to provide an opportunity for knowledgeable and experienced users, expert in their fields, to express their needs for information or services which might (or might not) be met by space systems, and to relate the present and potential capabilities of space systems to their needs. The study did not attempt to examine in detail the scientific, technical, or economic bases for the needs expressed by the users.

The SAB was impressed by the quality of the panels' work and has asked that their reports be made available as supporting documents for the Board's report. While the Board is in general accord with the panel reports, it does not necessarily endorse them in every detail.

The conclusions and recommendations of this panel report should be considered within the context of the report prepared by the Space Applications Board. The views presented in the panel report represent the general consensus of the panel. Some individual members of the panel may not agree with every conclusion or recommendation contained in the report.

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ACKNOWLEDGMENT

The Panel wishes to express its sincere appreciation to the following persons who participated in the discussions, provided valuable consultation and contributed significantly to the work of the Panel by providing background information and briefings as needed:

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The Panel could not have completed its work without the assistance of many members of the other panels at the study. While no records were kept which could lead to a proper acknowledgment, almost all members of the study panels were enthusiastic contributors.

CONTENTS

INTRODUCTION

The Panel on Technology* consisted of persons from the private sector knowledgeable in the field of aerospace technology and assembled for the purpose of interacting with all the user-oriented panels to identify key technical issues. It became clear that in the area of remote sensing many user-oriented panels had multiple and overlapping interests related to space-system services.

The panels serving the meteorological and communications communities, Weather and Climate and Uses of Communications,** have been intimately involved in the use of space systems for at least the past decade. Consequently, these two panels easily understood the vast utilities of space applications and the capabilities of the many space-system services available and planned. The Panel on Materials Processing in Space, like the two aforementioned panels, was well-staffed with persons knowledgeable in the space-systems disciplines and required inputs only in the transportation vehicle capabilities area. The Panel on Technology was extremely pleased with the specificity of requirements determined by the other user panels, even though many representatives of these panels were examining the applications of space systems with thoroughness for the first time.

Due to this, the Panel's activities were focused in general on the earth observation or remote-sensing requirements of all user panels. More specifically, presented in this report are considerations relating to (1) the integration of remote-sensor data needs among the many users for a practical system implementation; (2) an evaluation of the NASA program toward such an implementation of an operational system; and (3) the indicated user needs not satisfied without further research and study.

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*At the time of the planning stage of the 1974 Summer Study on Space Applications, the Panel on Technology was designated the "Technology Support Team." The work of this group led to a substantive report, prompting the decision to redesignate the group as a panel of the summer study.

**For further information, see the reports of the individual panels mentioned throughout the report.

INTEGRATION OF EARTH OBSERVATION MISSION REQUIREMENTS

Earth observation needs identified by the user-oriented panels have been accumulated and inter-related to establish space-system commonality. No attempt has been made to design complete space systems which meet specific needs, nor were estimated costs considered. The Panel surveyed all requirements and aggregated those that were similar in desired data, periodicity, and geographic coverage, in order to suggest individual missions which could serve as many users as possible.

REQUIREMENTS

Although the measurement needs of the various users represent a wide variety of parameters, the remote-sensing need can be reduced to common space measurements and orbital coverage patterns. These measurements can be categorized in three segments of the electromagnetic spectrum: visible and/or near infrared, thermal infrared, and microwave.

Visible and Near Infrared Measurements

The needs explored by the Panels on Land Use Planning; Agriculture, Forest, and Range; Inland Water Resources; Extractable Resources; and the coastal zone portion of the needs explored by the Marine and Maritime Uses Panel can be satisfied to a large extent by spatial resolution of 10 to 30 meters in approximately 6 spectral bands. There are some special requirements for resolution of less than 10 meters. Temporal and dimensional coverage can be satisfied by sun-synchronous, low-altitude orbits which satisfy weekly and seasonal demands.

The user needs investigated by the Panel on Weather and Climate are largely satisfied by existing and planned instruments which are characterized by low spatial resolution and highly accurate radiometric measurements in selective spectral bands. Orbital requirements include both daily coverage of the globe (polar and sun-synchronous orbits) and continuous observations (geostationary orbit).

The needs considered by the Panel on Environmental Quality span both the atmospheric and earth surface measurements closely associated with those considered by the Panels on Weather and Climate, Land Use Planning, and Inland Water Resources. Orbit needs also vary from continuous to seasonal coverage.

The Panel on Marine and Maritime Uses described special needs for high spectral discrimination for water color measurements in various ocean and inland water regions.

Thermal Infrared Measurements

The thermal infrared measurements are required by all user-oriented panels concerned with land, water, and atmosphere. The land and water measurements are usually derived temperature measurements, whereas the atmospheric observations are generally aimed at highly accurate irradiance measurement in selected absorption bands. Two distinct specifications will satisfy all user needs: (1) atmospheric measurements are needed from both polar and stationary orbits, and (2) the land and water measurements can be obtained almost entirely by polar orbits. Continuous to seasonal coverage is required within the above noted specifications.

Microwave Radiometry

Various panels expressed need for microwave radiometry. The Panel on Marine and Maritime Uses had additional requirements for active microwave measurement of wave dynamics. The most stringent requirement imposed by the users was that of obtaining a high resolution, all weather, twenty-four hour a day capability. Additionally, some users had requirements for surface, jungle canopy, and jungle surface penetrations. The practicality of meeting these specific requirements will involve more detailed study.

IMPLEMENTATION

A review of the remote-sensing needs outlined in the previous sections, together with the coverage requirements, indicates that natural groupings can be established in the measurement of data and in the orbital coverage. In the measurement of data there are two classifications; atmospheric (characterized by low spatial resolution and accurate radiometric measurement in selected absorption bands), and surface (characterized by high spatial resolution, 10 to 30 meters, and cartographic and photometric accuracy in multiple spectral bands in the atmospheric windows). Orbital coverage can also be divided into two classifications: sun-synchronous and geostationary.

Table I lists the user needs according to the above stipulative categories. Presented are some simplistic logical groupings of missions which result in minima of two and four common space systems that could be implemented to satisfy the technical data requirements for a large portion of the users. A minimum of four could be achieved if the shortest periodicity and the most stringent spectral and spatial resolutions of all candidate users of a single spacecraft are incorporated. A minimum of two is achieved only if atmospheric and surface imaging is combined in a single spacecraft. Many spacecraft are needed if a mix of requirements relating to spectral resolution, spatial resolution, and data-taking rates is imposed on the space system.

Data Subscriber	Sun Synchronous		Geosynchronous	
	Atmospheric	Surface	Atmospheric	Surface
Weather and Climate	✓		✓	
Land Use		✓		
Agriculture	0	✓	0	
Inland Water	✓	✓	✓	✓
Extractive Industries	0	✓	0	
Environmental	✓	✓	✓	✓
Marine and Maritime	0	✓	0	✓

Key: ✓ = primary requirement
0 = subsidiary interest of data subscriber for weather and climate data

TABLE I PROPOSED MODEL FOR INTEGRATED EARTH OBSERVATIONS MISSIONS

The needs of a particular user are then satisfied by subscription to the data from the appropriate satellite at the periodicity and spectral bands of his requirement, as shown in Table I.

Separation of atmospheric monitoring from surface imaging, at least at low altitude -- as in the present surface imaging of the Earth Resources Technology Satellites (ERTS, now renamed LANDSAT) and the atmospheric monitoring of the NIMBUS and improved TIROS Operational Satellites (ITOS) programs -- would seem to be the most practical approach considering the observation period requirements and the mature state of the meteorological operational program.

The number of like spacecraft required in sun-synchronous orbit will be determined by the highest periodicity requirement and/or the number of sun angles selected as a compromise of preferences of various users.

Instrumentation for gathering oceanographic weather-related phenomena (e.g., ocean temperature) may be incorporated in a low orbit meteorological satellite system.

A number of considerations such as complexity of a spacecraft or practical institutional arrangements may dictate design of a dedicated spacecraft that could lead to a decision to group services in a different way. The Panel on Technology does not intend to specify a program in detail but rather to suggest

practical groupings. The Panel believes that such an implementation is practical and that a program should be planned to lead to some minimal operational system at the earliest possible date, as well as the inclusion of a sufficient data processing and dissemination system.

NASA PROGRAM ADEQUACY

The technical objectives of the NASA programs and plans in the space segment seem well directed toward the above mission requirements at a practical level. However, in view of the potential payoff over the next ten years, we think that there is a serious need for an accelerated pace of implementation of research and development on both systems and instruments. There appears to be a gap of several years between the NASA schedule and the user desires which could be closed by budget increases. If such increases are not possible within NASA resources then there is an apparent need for funding participation by user agencies.

The second serious concern is that except for the meteorology program, there is no visible provision for a transition to operational systems beyond experimental flights of NASA. Operational continuity is essential for all users if they are to invest in and profit from the benefits of space applications. The dominant problem in the development of useful applications of remotely sensed data is not in the space segment itself, but in the area of data processing and dissemination. Even today, every user cites the problem of inaccessibility of processed data. Yet all requirements point to higher resolution, more spectral bands, more frequent repetition, and quicker access. A useful resource observation system hinges on a satisfactory solution of the data processing problem.

Finally, the shuttle launch capability must proceed at the Western Test Range in order that the maximum benefits from the shuttle can be realized in the applications program.

REQUIREMENTS FOR ADDITIONAL STUDY AND RESEARCH

There is a clear need for additional research to establish the relationship between basic parameters of interest to the user and what is possible to measure from space. In several cases (such as agriculture) specification of sensor spectral band requirements is inhibited by lack of knowledge of optimum discriminants in multispectral data.

Many parameters, such as subsurface water conditions, may be better monitored by ground data platforms. Several panels have indicated need for satellite data collection and relay from *in situ* instruments. Applicability of this technique appears to deserve more study by all users.

In a similar vein, recognition should be given to concurrent service or technology developments by other agencies when considering new requirements. Particular attention is invited to the Global Positioning System (NAVSTAR) under advanced development by the Department of Defense, a system which ultimately might serve most navigation needs.

User-oriented panels have identified several problems with potential for solutions using space systems, but for which that potential is at best uncertain, and which require further study. These problems include:

1. Geologic mapping (10 to 20 meters) through jungle cover.
2. All-weather mapping of iceberg fields to distinguish icebergs as small as 10 meters wide.
3. High-resolution (30 meters) thermal mapping of earth surface to detect geologic substructure.
4. Urban land-use monitoring with multispectral resolution of 1 to 10 meters.
5. Fathometry to a depth of 30 meters for shoal mapping.
6. Detection of bioluminescence.

SUMMARY AND CONCLUSIONS

An assessment by the Panel on Technology of the information provided by the other panels involved in the 1974 Summer Study on Space Applications warrants the following comments:

Every earth observation user-oriented panel described a requirement for frequent repetitive observation either over prolonged periods from sun-synchronous orbits or continuously from geostationary orbit.

The application of Spacelab short-period (sortie) missions either to operational applications missions or to research and development needs further definition.

Most user-oriented panels seek multispectral imaging throughout the visual and the far infrared (thermal) bands and resolutions of at least 30 meters in the visual or near infrared bands. Several panels also have requirements for microwave imaging radiometry.

Several panels expressed a variety of desires for high-resolution radar imaging, but neither the commonality of characteristics nor the practicality of meeting these needs is yet clear.

There is a clear requirement for additional research on the relationship of measurements which can be made from space to basic parameters of interest to users, and for continued development of sensing instruments based on this research.

The bulk of the user requirements for operational earth observations can be integrated into a few space systems.

The Panel on Technology detects no serious deficiencies in the NASA plans for technical objectives related to the above mission requirements, but does feel that there is serious need for an accelerated pace of implementation of research and development on both systems and instruments.

Except in the area of meteorology, there is no provision for operational systems extending beyond the NASA research and development flights.

The dominant development problem for useful application of remotely sensed data is not the space segment, but the data-processing and dissemination segment.

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