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The Suitability of Various Spacecraft for Future Space Applications Missions

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The Suitability of Various Spacecraft for Future Space Applications Missions

The Task Force of the NASA Space
Applications Advisory Committee of the
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SPACE APPLICATIONS ADVISORY COMMITTEE

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- Mr. Wilbur Pritchard, former Chairman of the SAAC Communications Subcommittee

- Dean Robert Sekerka, Chairman of the SAAC Microgravity Science and Applications Subcommittee

- Dr. L.R. Greenwood, Chairman of the SAAC Remote Sensing Subcommittee

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1.0 INTRODUCTION

The Space Applications Advisory Committee (SAAC) of NASA's Advisory Council was asked by the Associate Administrator for Space Science and Applications to consider the most suitable future means for acomplishing space application missions. To comply with his request SAAC formed a Task Force whose report is contained herein. In their considerations the Task Force looked into the suitability of likely future spacecraft options for supporting various types of application mission payloads. These options encompass a permanent manned space station, the Space Shuttle operating in a sortie mode, unmanned platforms that integrate a wide variety of instruments or other devices, and smaller free fliers that accommodate at most a few functions. The Task Force also recognized that the various elements could be combined to form a larger space infrastructure.

Three mission areas are considered in this report: remote sensing of the earth from space, satellite communications, and materials processing in the space environment. The existence of other applications areas is recognized; however, the three that are considered appear to represent the bulk of the space applications traffic now and for some time to come.

This report summarizes the results obtained by the Task Force. It describes the approach utilized, the findings obtained, their analysis, and the resulting conclusions.

2.0 STUDY APPROACH

Task Force members were chosen by the SAAC Chairman on the basis of their experience and breadth of background pertinent to the subject of the study. This background includes a detailed knowledge on the parts of various members of spacecraft characteristics and capabilities, expertise in space communications, and expertise in space remote sensing applications and data management. In areas where knowledge was limited, information was requested and obtained from three other SAAC Committee members who have considerable background in materials processing or communications.

To further augment this background, fact-finding visits were made by some of the group members to government agencies (NASA, OTA, and ESA) and aerospace companies (Boeing, Fairchild, and Rockwell). Expertise was tapped dealing with a wide gamut of spacecraft configurations and operations, including small, low-cost, automated spacecraft; space servicing of spacecraft; leased spacecraft; Shuttle Orbiter and Spacelab utilization; large space platforms; and Space Station planning.

The group members then exchanged position papers stating each individual's findings and/or observations. These papers were augmented by those requested from the other consulting committee members. Finally, the group leader integrated the contents of the individual papers as modified by discussion among the group members.

3.0 FINDINGS

3.1 SPACECRAFT AND THEIR OPERATION

A. To date, most of the space flights in support of the NASA applications program have utilized small- to moderate-sized unmanned spacecraft except for a one-year period in the early 1970s when Skylab was active. In recent years the Space Shuttle and Spacelab have been used to obtain applications program data during short, sortie-type missions. The results have been good, with valuable applications data and useful information obtained in many areas. Early failures of spacecraft or instruments have significantly affected the progress of programs in a few cases (e.g., Seasat and Landsat 4). The impact has been particularly severe where backup spacecraft have not been available.

B. Spacecraft such as those involved in the Nimbus series of meteorological and environmental satellites and the Seasat program have incorporated a substantial number (the order of six) of different but discipline-related instruments. This grouping technique has proven valuable from the standpoint of synergistic effects and has been cost effective in most cases. The impact of spacecraft failure associated with this grouping of instruments is obviously greater than with simpler spacecraft.

C. Simple, low-cost spacecraft of the Applications Explorer type, usually involving a single instrument, have also proven to be very useful (e.g., HCMM and SAGE). This approach is adaptable to obtaining highly specific applications data or to special purpose missions, for example, those requiring particular orbits.

D. The spacecraft "bus" concept has been incorporated to varying degrees in a number of designs (Agena, Nimbus, Block 5, AEM, and MMS). The utility of this approach has been hampered in part by the unwillingness of design-investigator teams to compromise optimum designs. In some cases such spacecraft have been more capable and therefore more expensive than needed by the investigator team. Nevertheless, past experience indicates that this approach should prove economically attractive, and a number of organizations are continuing to pursue the bus concept in both the USA and Europe.

E. Only one type of spacecraft, MMS, has been designed and flown with provisions for in-orbit servicing, repair, and updating. One successful repair mission involving this spacecraft type has been accomplished. The Space Telescope will also have repair capability. Studies conducted by NASA-Goddard Space Flight Center and by the Fairchild Space Company have shown that this approach to the extension of useful life is both economically and programmatically attractive.

F. Until the recent shuttle/spacecraft flights, there had been no significant United States involvement with manned space experimentation for nearly a decade (since the Skylab program terminated in early 1974). Skylab experience indicates that such human involvement would be useful in servicing and repair and in other kinds of endeavors contributing to space applications missions. Such uses of people in space have not been adequately studied or well documented. An added factor involves the rapid advance in robotic systems and artificial intelligence technology, which has the potential for altering and enhancing man-machine relationships in space.

G. Considerable improvement can and should be made in the accommodation of space applications experiments on the Space Shuttle from the standpoint of accessibility and cost effectiveness as well as in the use of available human resources. The Shuttle Orbiter and Spacelab operations during sortie missions should be as close as possible to those envisioned for the Space Station in order to obtain early related experience. These activities should include human involvement in servicing, repair, adjustment, and modification of spaceborne equipment.

H. If a space station is placed in orbit, it can increase the effectiveness of many elements of the applications program; however, because of the high cost of accommodating people in the environment of space, the manned space station program is not to be justified on purely economic grounds, but on additional considerations beyond the scope of this report.

I. Because the initial manned elements of the space station will operate in a low-inclination orbit, while remote sensing from space for global information gathering requires near-polar orbits, this segment of the space applications program will have to depend (at least initially) upon unmanned space platforms supported by Space Shuttle sortie operations, possibly using an Extended Duration Orbiter. These polar platforms may benefit from the use of hardware elements that have commonality with the manned space station. Certain areas of remote sensing as well as associated technology development and screening experiments can be conducted in the Space Station in a low-inclination orbit.

J. In the future, support of earth observations and other new applications areas will involve an increased emphasis on geosynchronous orbit operations. Therefore, reducing costs of operations to and in geosynchronous orbit will become increasingly important.

K. In the longer term, certain types of applications missions may involve very large and flimsy space structures in geosynchronous orbit. These structures would probably have to be assembled in space (in a near-zero g environment). Direct human involvement in such assembly and checkout operations will likely be a necessity.

3.2 PROGRAMMATIC FACTORS AFFECTING SPACECRAFT DECISIONS

A. Over the past half dozen years, only two dedicated NASA space applications missions have been approved for development. This number does not include Space Shuttle sortie missions in low-inclination orbits. This situation is in sharp contrast to that of the preceding decade when, on the average, about two such dedicated missions were approved each year. One of the reasons for this change is that current missions have become more complex and costly.

B. NASA has been unsuccessful in attempts to establish, in conjunction with other agencies, a major space flight program in support of oceanography (such as a Seasat follow-on), in spite of the important accomplishments of the first

Seasat prior to its failure and in spite of strong support from many segments of the oceanographic community.[1]

C. The operational responsibility for atmospheric and land remote sensing has been vested in NOAA. In the case of land remote sensing, NOAA has requested° proposals from industry for implementation of a commercially sponsored operational satellite system.

D. NOAA has launched and continues to launch a number of polar orbiting and geosynchronous meteorological satellites in order to assure continuity of data pertinent to its operational functions. NASA has obtained agreements with NOAA to fly certain instruments "piggyback" on these satellites, but only on a "space available" basis.

NASA has great difficulty in gaining approval of the space flight proposals in satellite communications in spite of well defined, widely acknowledged benefits to the user community and to the communications industry in general. Although one such project, the Advanced Communications Technology Satellite (ACTS), has been recently approved, it is the first one in the last 15 years.

E. Although the reduction in the level of activity in NASA space applications missions may be caused, in part, by a general reduction of support within and outside NASA, in the remote sensing area, mission costs appear to be an overriding factor. Current programs in earth observations have space elements costing roughly a third of a billion dollars and the overall ground support doubles that figure. This problem is compounded by the addition of new disciplines and new user groups to the program.

F. Problems have been encountered with the ground handling and reduction of data even in cases where spacecraft have performed well. These problems involve the timing of data availability, integration of data bases, and the like. This area has not been given sufficient funding and programmatic priority. Support during the early stages of a program is a particular problem. The advent of substantial onboard processing may alleviate this problem to some degree.

G. A considerable effort is being made by commercial/industrial firms to undertake space endeavors that go well beyond their historic involvement with government contracts for the design, development, and production of spacecraft. These endeavors include commercial sponsorship in such areas as spacecraft, space operations, and space research facilities. NASA could take greater advantage of these commercial initiatives for their potential economic and programmatic gains.

H. Most materials processing experiments at near zero g, other than those using short duration rocket or aircraft flights, have been conducted to date on manned missions. The high power, the large volume, and the retrieval

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[1]The Navy has recently begun the Navy Remote Ocean Sensing System (NROSS) for which NASA will provide an advanced scatterometer (NSCATT) instrument.

capabilities associated with manned missions make such missions attractive for use in materials experimentation. The hiatus that occurred in the manned program has resulted in few flight opportunities and even when materials processing experiments have been conducted, the involvement of the astronauts has been minimal.

I. Much of the NASA materials program is scientific in nature, reflecting the state of the art in most of the disciplines being investigated. A few efforts with commercial potential are also being pursued and appear promising. The NASA effort in this area ($20M annually) is very modest in comparison to the effort in most other applications discipline areas.

J. In the last half dozen years, more commercial communications satellites have been launched than the total of all other launches in the civil area.

K. Future NASA space activities are expected to involve multifaceted operations going well beyond the past unmanned applications missions. This new approach, involving such factors as servicing and repair requires a much broader and deeper systems engineering effort than has occurred in the past.

4.0 ANALYSES OF FINDINGS

4.1 REMOTE SENSING

Unless NASA provides greater internal support, obtains greater external support, and/or reduces costs of its remote sensing programs, only limited experimental space program data can be expected in the future just as has, in fact, occurred in the recent past. This situation is aggravated further by the need to place a greater funding emphasis on the ground data handling and processing part of the remote sensing system.

4.1.1 Near-Term Solutions

Several approaches to solving this dilemma appear promising, some of which NASA has already initiated. NASA is using the Space Shuttle for the initial evaluation of sensors. These efforts should be increased by providing greater accessibility and flexibility. Unmanned spacecraft for the sole purpose of instrumentation or sensor evaluation should be relegated largely to low-budget missions of the Explorer class. In the past, this approach has produced very satisfactory results for both NASA and the investigators. Another approach is to fly sensors as ancillary payloads on a host spacecraft. We note that NASA is doing this in conjunction with the NOAA polar Metsat program. Missions flown by various defense agencies may also hold promise for "piggyback" payloads. Grouping a large number of instruments on a large complex spacecraft purely for sensor evaluation purposes should be carefully evaluated, especially where there is no possibility for servicing, repairing, or updating.

NASA should also stimulate and support commercial initiatives such as those involving leasing or other types of joint endeavor arrangements. This support may serve a dual purpose in helping to initiate and sustain commercial initiatives in the operational remote sensing area.

4.1.2 Longer-Term Solutions

The foregoing statements are not meant to imply that integration of a number of mission-compatible sensors on a single platform is not worthwhile. In fact this approach is unquestionably the longer-term way to go in the earth sensing program using such spacecraft as a multi-mission bus (e.g. the Multimission Spacecraft, MMS) or a larger space platform. Because of differences in size, capability, and cost, the two types of spacecraft have some dissimilarities, but they also have many similar features. These two types of space systems provide common facilities support both in space and on the ground, affording significant potential cost advantages. Because of the high unit cost the impact of any early failure is great; early wear-out and obsolescence are also concerns. These concerns dictate that such future spacecraft should be repairable, serviceable, and amenable to updating, preferably on orbit. The interests of the investigative teams in these types of facilities should rest more with the scientific or applications phenomena and problems being addressed and their relationship to the data obtained than with the details and performance of individual instruments.

Differences do exist between the intermediate-sized spacecraft bus (e.g. MMS) and the larger space platform. These differeces are associated with the perceived size and payload capability. The bus concept is intended to include more than one spacecraft, with a lower initial capital investment, in support of a program that is more evolutionary in character. A problem exists when the spacing of individual starts is such that a reasonable continuity of production is not possible. This situation has been typical of recent bus experience and many of the cost and program advantages have been lost. However, even in the present environment, the bus concept is valuable because it is a necessary intermediary to a larger space platform which involves a longer lead time and represents a large capital investment in a very long-lived space observatory.

Nevertheless, the larger space platform appears to support the longer-term program needs of the remote sensing community in a cost-effective way. The idea of obtaining simultaneous earth data from a wide variety of disparate sensors all registered to a common reference and tied to a common data base is a good one and argues for proceeding in this direction. Indeed, critical information needs associated with global habitability and the related areas of atmospheric, ocean, and arctic conditions are best supported by this type of system. If the platform approach is taken as the next step in earth observations data acquisition, its development needs to be started prior to that of the manned Space Station to minimize the data gap previously mentioned. Even current instrument developments appear to be optimally aligned with the platform approach. For example, great flexibility can now be built into a multispectral instrument, enabling real time selection of spectral bands, IFOV spatial resolution, pointing, data rate, and the like. Further studies appear to be needed to establish optimum platform sizing.

Several words of caution are in order in connection with this approach. Development and space tests of the instruments in advance of their installation on the platform are highly desirable to assure that they will do the job commensurate with the overall costs. The platform must not be allowed to become such a complicated undertaking that it largely consumes available funds, has an undesirably long development time, and crowds out the instrument activities that make it worthwhile. Additionally, there is fear that the process of integration with the platform could, in view of current Space Shuttle experience, reach such a cost and complexity level as to close the door to involvement of small, low-budget, experimental activities typical of those at the university level. Accommodation of low-budget activities with short development times may be critical to the total success of the platform concept. Furthermore, early proof of low integration costs for payloads on the platform is of high priority. Perhaps Shuttle sortie missions can be designed to demonstrate this capability. All in all, the space platform, although representing a large initial capital investment should have a low life-cycle cost in relation to what it can accomplish in data acquisition. The high benefit cost ratio occurs as a result of its long life and the common facilities support that it can provide to the various sensor systems installed on the platform. This is predicated on the ability to provide servicing, repairs, and updating on a timely, practical, and cost-effective basis. The size and number of such platforms is yet to be determined.

4.1.3 Use of People in Space in Support of Remote Sensing

The manned space station includes many of the intrinsic capabilities just discussed for the large space platform and has the advantage of direct human involvement, but a number of significant differences merit discussion. The manned elements of the initial space station are to be placed in a low-inclination orbit from which it can provide support to missions going to planetary and geosynchronous distances as well as to certain astronomy missions. Obviously, under these conditions the space station cannot provide earth observational coverage at the higher latitudes, whereas a large space platform in polar orbit can provide complete global coverage, which is a dominant user need in most programs. If the observations are intended to involve solely the tropical or subtropical regions or deserts, the space station orbit is satisfactory. In fact, more frequent coverage would be obtained, and under varying lighting conditions, as compared with the polar orbiting platform.

In any event, the space station should prove to be very useful in the area of technology development and in the screening of instruments to fly later on the space platform. The human involvement in such activities would be beneficial in terms of evaluation, adjustment, and management. The high overhead cost associated with human presence is recognized, but there are many reasons for a Space Station and the applications program should be able to take advantage of the human presence without an undue burden from this overhead. Other human presence factors, such as disturbance or contamination, would have to be evaluated in specific cases to determine the utility of the space station for uses where such factors are critical.

4.2 COMMUNICATIONS

Over the past decade more civil communications satellites have been launched than the total of all other types; the great majority of these were commercial endeavors. Because this trend is likely to continue, the future character of communications satellites may be determined mostly by decisions made in industry. The expected STS/Centaur launch capability of 10,000-14,000 lbs., directly to geosynchronous orbit, is much greater than any communications satellite currently in service. Industrial companies in the business of building and operating such commercial satellites justifiably take the evolutionary low-risk approach, and it is not clear that any plan exists to build spacecraft that would require even full STS/Centaur capability. In order to lead the way to new opportunities, NASA on at least two occasions has proposed flight programs to demonstrate advanced communications technology or systems. These proposals, although broadly supported by the overall space communications community, have encountered strong opposition by specific industrial elements based on competitive concerns.

A futuristic area of space platform development involves the placing of very large structures in geosynchronous orbit. These structures could take the form of very large parabolic antennae, large mirrors or lenses, or very large arrays. Their first uses are expected to be in communications (such as mobile systems), but eventually they would involve applications in earth observations, transmissions of electric power to and from orbit, and ultimately the generation of large amounts of solar power in space. Such lightweight, flimsy spacecraft structures will not be readily deployed in geosynchronous orbit as a single unit. Assembly, adjustment, and checkout of the units in low earth orbit is a possibility particularly if precise optical-type surfaces are required, and provided it is feasible to spiral such structures out to geosynchronous orbit under very low-g conditions. A space station would be highly useful in performing such operations once it becomes operational. NASA should initiate a technology development program in support of this area to provide for space evaluations of these possibilities.

In the nearer term, consideration should be given to servicing and equipment replacement of geosynchronous satellites at the module level. At least one study has been made that shows economic advantages may exist. Operations of this nature would be accomplished in a robotic mode, but may be supported by a space station operating in low earth orbit.

4.3 MATERIALS PROCESSING

Only a limited amount of U.S. experimentation with microgravity in the space environment has been possible. The first orbital experiments took place in the early 1970s on Apollo and Skylab. After a hiatus of nearly a decade, a few experiments have been conducted on the middeck of the Space Shuttle and within the last year, further experimentation has taken place during the first Spacelab flight under European sponsorship. All of these experiments have to some degree shown promise of providing new insights into materials and processes (both orbital and terrestrial) as well as applications within certain industries as a result of experimentation in the near weightless environment. In spite of this potential, the level of support given this program area is exceedingly low compared to other applications areas.

Only limited insights have been obtained about the kind of laboratory most suited to this work. The involvement of astronauts has been largely one of a switch thrower or in the conduct of very rudimentary experiments, such as with liquids floating in the cabin. This present state of knowledge, therefore, dictates that one must still extrapolate from experience obtained in earth-based laboratories.

The feeling of researchers in this field is that the space material laboratories should be like their ground-based counterparts to the degree practical. First, the laboratory should enable intimate human professional involvement in the setup and conduct of the experiments and rapid examination and testing of specimens onboard. The apparatus should be amenable to adjustment and reconfiguration based upon results of immediately prior tests. Sizeable volume (thousands of cubic feet) and power (tens of kilowatts) will be required to support a wide variety of general and special-purpose equipment which must be readily installed or removed as required. Special consideration to safety and environmental control will be necessary.

A dedicated module attached to a Space Station appears well suited to the nature of this research. It would draw upon other elements of the station for support, for power, habitation, heat rejection, general supplies, and the like. For experiments requiring extremely low levels of gravity, a co-orbiting platform could be employed as an adjunct to the attached module. Means for periodic visits by experimenters to this platform from the Space Station should be provided.

Prior to the advent of the Space Station, materials processing experiments should continue aboard the Space Shuttle and Spacelab and efforts should be made to improve the accessibility to these craft for conducting this kind of research in as flexible a fashion as possible. In addition, other interim platforms or modules may be utilized for materials experiments. They would be of the type which remain in orbit and would be visited by experimenters or payload specialists periodically, using the Shuttle in a sortie mode. Some such devices might afford sigificant stay times for human involvement.

If and when actual production of materials in space takes place, such activities would appear quite amenable to automation. Human intervention would appear necessary even in these cases for purposes of adjustment, reconfiguration, servicing, and repair.

5.0 CONCLUSIONS

A. NASA should review its space platform utilization strategy in the applications area and state how such strategies enhance the applications of other entities such as NOAA and industry. By so doing, NASA could gain and provide more support for its applications programs.

B. A well-balanced and aggressive applications program would utilize most of the spacecraft types and operating modes presently being considered, but with certain changes in emphasis. The unmanned, non-serviceable free-flyer will be relegated in most cases to simple, small, low-cost spacecraft. The multiple-instrument spacecraft will be upgraded to platforms affording servicing, repair, updating, and growth.

C. Use of the Shuttle for checking out performance of sensors prior to their installation on automated platforms appears to be a cost-effective way to assure that the right kind of data will be obtained.

D. Future investigator activity will emphasize data integration, analysis, and application rather than the technology of instruments, data systems, or spacecraft. The investigators will have to accept some compromises in data acquisition and system performance to obtain the advantages of the integrated space platform.

E. Even though larger and more completely integrated platforms are contemplated, the applications program should consider the use of smaller platforms in advance of the Space Station. These could include platforms developed under commercial or other auspices and made available through joint endeavors, leasing, international agreements, and the like. On-orbit servicing is a most important feature.

F. Development of the polar orbit platform, currently an element of the Space Station program, should precede those elements of the space station intended for use in low-inclination orbit. The polar orbit platform is critical to the understanding of global habitability trends, ocean conditions, and other serious environmental questions. It can also provide important Space Station logistics experience, using the shuttle sortie mode.

G. Planning of Space Shuttle and Spacelab on-orbit operations must consider strongly how to obtain the maximum experience in a Space Station operational mode so that the Space Station program can move out effectively once the station capability is established in orbit.

H. The materials processing program can be adequately accommodated on Shuttle, Spacelab, and ultimately the Space Station, provided considerable improvement occurs in integration costs, accessibility, and operational flexibility. Where low g-level disturbances are a problem, separate platforms servicing the Space Shuttle or Space Station will be utilized. The materials processing program does need expanded support in terms of general funding, as well as facilities for accomplishing tests on board these craft.

I. The materials processing laboratory of the Space Station should be a dedicated module which facilitates the onboard involvement of materials scientists and engineers. The design of this module should strive to obtain the general characteristics and flexibility of a ground-based materials laboratory.

J. Long range planning should include a program defining goals and technology for very large structures to be assembled in low-earth orbit and spiraled out to geosynchronous orbit in support of mobile communications and other applications. In the nearer term, the possibilities for servicing and replacing equipment aboard geosynchronous satellites should be evaluated.

K. The Space Station with its associated human space involvement shows real promise for supporting the applications program in the areas of space servicing, assembly, technology development, and generally in other activities where it is impractical or unrealistic to program precisely that activity in advance. The Space Station will provide outstanding capabilities in operation support areas such as servicing assembly and evaluation.

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15. Supplementary Notes

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16. Abstract

The Space Applications Advisory Committee (SAAC) of NASA's Advisory Council was asked by the Associate Administrator for Space Science and Applications to consider the most suitable future means for accomplishing space application missions. To comply with this request, SAAC formed a Task Force whose report is contained in this document. In their considerations, the Task Force looked into the suitability of likely future spacecraft options for supporting various types of application mission payloads. These options encompass a permanent manned space station, the Space Shuttle operating in a sortie mode, unmanned platforms that integrate a wide variety of instruments or other devices, and smaller free fliers that accommodate at most a few functions. The Task Force also recognized that the various elements could be combined to form a larger space infrastructure.

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