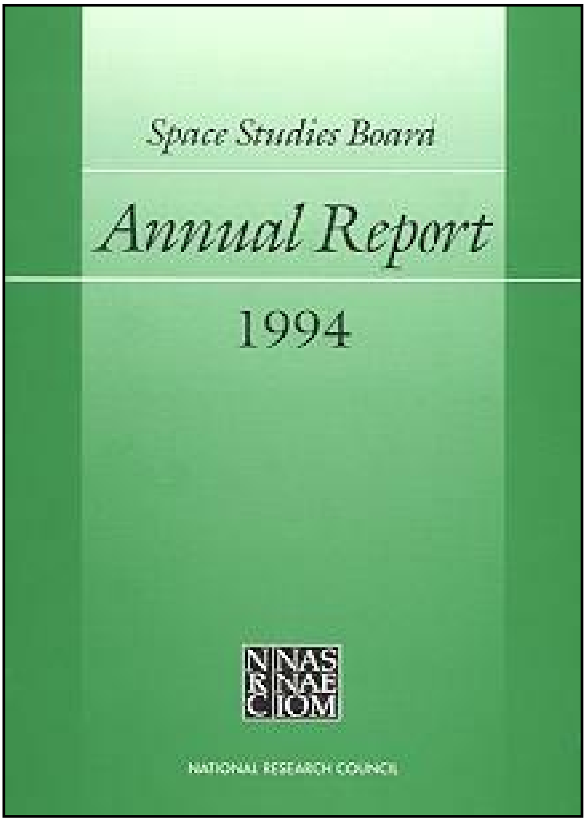
Space Studies Board Annual Report—1994



Space Studies Board
Commission on Physical Sciences,
Mathematics, and Applications

National Research Council

Space Studies Board Annual Report—1994

Notice

The Space Studies Board is a unit of the National Research Council, which serves as an independent advisor to the federal government on scientific and technical questions of national importance. The Research Council, jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, brings the resources of the entire scientific and technical community to bear through its volunteer advisory committees.

Support for the work of the Space Studies Board and its committees and task groups was provided by National Aeronautics and Space Administration contract NASW-4627; National Oceanic and Atmospheric Administration contract 50-DGNE-1-00138; and Naval Research Laboratory purchase order N00173-93-P-6207.

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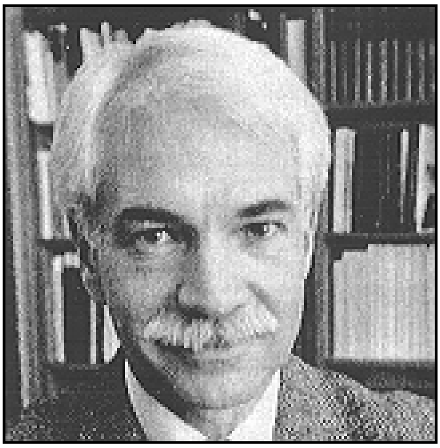
From the Chair



The total expenditure for space research constitutes a significant fraction of the government's investment in research and development. The Space Studies Board is chartered to provide independent advice to NASA and other federal agencies on the conduct of that research. To be effective, the Board, like any financial investment advisor, must give guidance for the short term as well as the long term. Scientific strategies, opportunities studies, and assessments are the Board's traditional instruments for providing long-term guidance. But the rate of change in the space program and throughout government accelerated through 1994 from its already fast pace the year before, placing ever increasing importance on the shorter time scales. The Board and, indeed, the entire National Research Council are attempting to address this urgency in ways that fulfill their charters and that neither compromise the quality of the product nor deliver it too late to be of use.

In times of rapid change, having clearly defined long-term goals and priorities is every bit as important as it is during calmer periods. The Board's Committee on Planetary and Lunar Exploration issued the report *An Integrated Strategy for the Planetary Sciences: 1995-2010*, which serves just that purpose for a major area of space research. It lays out the scientific context and sets priorities by considering scientific importance and the likelihood of significant scientific advance together with the likelihood that the necessary measurements can be carried out in the foreseeable future. This last consideration recognizes both technical and budgetary realities, as it must. The second report of the Board's Committee on Human Exploration, *Scientific Opportunities in the Human Exploration of Space*, gives a broad overview of scientific opportunities offered by programs of human exploration of the Moon and Mars that might be undertaken for primarily nonscientific reasons. While such programs seem to have slipped off the current national agenda, the vision of eventual human exploration beyond low Earth orbit has not. The report stands as a resource for policymakers who rediscover that vision. The Board's Committee on Solar and Space Physics and its federated partner Committee on Solar-Terrestrial Research have addressed the dichotomy between funding and effectiveness in their report *A Space Physics Paradox*. This is a case study of the factors that contribute to the scientific vitality of a discipline, particularly the mix and frequency of large and small space missions. Like any specific case study in history or management, it illuminates issues and makes recommendations that may be equally important in other disciplines. The federated committees performed a study for the NRC's Naval Studies Board entitled *ONR* [Office of Naval Research] *Research Opportunities in Upper Atmospheric Sciences*.

The Board itself relies heavily on its own long-term strategies and opportunities reports when it responds to the increasingly urgent requests from federal agencies for short-term advice. In 1994, as NASA consolidated the space station redesign activities, the Board and its Committees on Space Biology and Medicine and on Microgravity Research issued two short reports dealing with aspects of scientific utilization of the station. These efforts continue a decade-long commitment to helping NASA deal with scientific aspects of this vast program that is driven primarily by complex political, socioeconomic, and diplomatic considerations. A short report by the Committee on Astronomy and Astrophysics provides an assessment of the scientific capability of two infrared astrophysics missions that for budgetary reasons had been considerably reduced in scope by NASA and the scientific community. And the Board issued a short review of its previous recommendations on an x-ray observatory and an interplanetary probe that were being considered for cancellation.

Of course, the Board and its committees spent most of 1994 on studies and reports that will appear in 1995 or even 1996. These cover the full range of space research disciplines and address both short- and long-term concerns. Responding to direction from Congress and NASA, the Board initiated a major activity that transcends specific disciplines, the so-called study on the Future of Space Science. It addresses three exceedingly difficult questions that are central to the conduct of space science: alternatives for the organization of space research, methods for establishing scientific priorities, and technology utilization for space science missions. The activities of three task groups and a steering group, in close interaction with the full Board, were well under way by year's end.

1994 was also a year of major transition for the Board itself. After six years of dedicated service, Louis J. Lanzerotti rose from the chair. Tributes to his leadership were delivered at the 113th meeting in July by Board members and staff, and by the NRC. NASA bestowed its highest honor, the Distinguished Public Service Medal. This award and the naming of minor planet 5504 Lanzerotti are lasting tributes that properly recognize Lou's lasting contributions to space research, contributions that even the extensive cumulative bibliography listed in this report captures only in part. Lou leaves behind a very high standard for me, the Board, and its committees, but he also leaves behind the tools: an admirable ethos, effective practices and procedures, and a superb staff. The entire space research community owes him a debt of gratitude for all he has done.

Great changes are sweeping across NASA and other federal agencies today. The Board is responding to these changes in its many projects, both in the near and long term. Over 35 years, space research has given much to the nation that is practical and ennobling, and we are confident that it will continue to provide excellent value in basic knowledge, technology, and inspiration. The Board looks forward to continuing its work with NASA, NOAA, and the Department of Defense to assure an optimum return on the nation's space research investment in the years ahead.

Claude R. Canizares
Chair
Space Studies Board

April 1995

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Charter and Organization of the Board

The National Academy of Sciences was chartered by the Congress, under the leadership of President Abraham Lincoln, to provide scientific and technical advice to the government of the United States. Over the years, the advisory program of the institution has expanded, leading in the course of time to the establishment of the National Academy of Engineering and the Institute of Medicine, and of the National Research Council (NRC), today's operational arm of the Academies of Sciences and Engineering.

After the launch of Sputnik in 1957, the pace and scope of U.S. space activity were dramatically increased. Congress created the National Aeronautics and Space Administration (NASA) to conduct the nation's ambitious space agenda, and the National Academy of Sciences created the Space Science Board. The original charter of the Board was established in June 1958, three months before final legislation creating NASA was enacted. The Space Science Board has provided external and independent scientific and programmatic advice to NASA on a continuous basis from NASA's inception until the present.

The fundamental charter of the Board today remains that defined by National Academy of Sciences President Detlev W. Bronk in a letter to Lloyd V. Berkner, first chair of the Board, on June 26, 1958:

> We have talked of the main task of the Board in three parts—the immediate program, the long-range program, and the international aspects of both. In all three we shall look to the Board to be the focus of the interests and responsibilities of the Academy-Research Council in space science; to establish necessary relationships with civilian science and with governmental science activities, particularly the proposed new space agency, the National Science Foundation, and the Advanced Research Projects Agency; to represent the Academy-Research Council complex in our international relations in this field on behalf of American science and scientists; to seek ways to stimulate needed research; to promote necessary coordination of scientific effort; and to provide such advice and recommendations to appropriate individuals and agencies with regard to space science as may in the Board's judgment be desirable.
>
> As we have already agreed, the Board is intended to be an advisory, consultative, correlating, evaluating body and not an operating agency in the field of space science. It should avoid responsibility as a Board for the conduct of any programs of space research and for the formulation of budgets relative thereto. Advice to agencies properly responsible for these matters, on the other hand, would be within its purview to provide.

Thus, the Board exists to provide advice to the federal government on space research, and to help coordinate the nation's undertakings in these areas. With the reconstitution of the Board in 1988 and 1989, the Board assumed similar responsibilities with respect to space applications. The Board also addresses scientific aspects of the nation's program of human spaceflight.

THE 1988 REORGANIZATION OF THE BOARD—THE SPACE STUDIES BOARD

In 1988, the Space Science Board undertook a series of retreats to review its structure and charter. These retreats were motivated by the Board's desire to more closely align its structure and activities with evolving government advisory needs and by its assumption of a major portion of the responsibilities of the disestablished NRC Space Applications Board. As a result of these retreats, a number of new task groups and committees were formed, and several existing committees were disbanded and their portfolios distributed to other committees. In addition, since civilian space research now involves federal agencies other than NASA (for example, the National Oceanic and Atmospheric Administration (NOAA), the Departments of Energy and Defense, and the National Science Foundation (NSF)), it was decided to place an increased emphasis on broadening the Board's advisory outreach.

MAJOR FUNCTIONS

The Board's overall advisory charter is implemented through four key functions: discipline oversight, interdisciplinary studies, international activities, and advisory outreach.

Oversight of Space Research Disciplines

The Board has responsibility for strategic planning and oversight in the basic subdisciplines of space research. This responsibility is discharged through a structure of standing discipline committees, and includes preparation of strategic research plans and prioritization of objectives as well as assessment of progress in these disciplines. The standard vehicle for providing long-term research guidance is the research strategy report, which has been used successfully by the Board and its committees over many years. In addition, committees periodically prepare formal assessment reports that examine progress in their disciplines in comparison with published Board advice. From time to time, in response to a sponsor or Board request or to circumstances requiring prompt and focused comment, a committee may prepare and submit a brief report. Agency requests for broader space policy or organizational advice are addressed by suitable ad hoc organizational arrangements and appropriate final documentation. Other special agency requests that require responses synchronized with the federal budget cycle are relayed to standing committees for action or are taken up by ad hoc task groups. All committee reports undergo Board and NRC review and approval prior to publication and are issued formally as reports of the Board.

Individual discipline committees may be called upon by the Board to prepare specialized material for use by either the Board or its interdisciplinary committees or task groups.

Interdisciplinary Studies

Although the emphasis over the years has been on discipline planning and evaluation, the reorganization of the Board recognized a need for cross-cutting technical and policy studies in several important areas. To accomplish these objectives, the Board creates internal committees of the Board and ad hoc task groups. Internal committees, constituted entirely of appointed Board members, are formed for short-duration studies, or lay the planning groundwork for subsequent formation of a regular committee or task group. Task groups resemble standing discipline committees in structure and operation, except that they have predefined lifetimes, typically two to three years, and more narrowly bounded charters.

International Representation and Cooperation

The Board continues to serve as the U.S. National Committee for the International Council of Scientific Unions (ICSU) Committee on Space Research (COSPAR). In this capacity, the Board participates in a broad variety of COSPAR panels and committees.

In the past, COSPAR bylaws have provided that its two vice presidents be from the United States and the U.S.S.R., respectively. The U.S. Vice President of COSPAR has served as a member of the Board, and a member of the Board's staff has served as executive secretary for this office. During 1994, governance of COSPAR evolved to fully democratic election of officers. The Board continues as the U.S. National Committee, but its representation within the COSPAR officer corps is now determined electorally.

As the economic and political integration of Europe evolves, so also does the integration of Europe's space activities. The Board has successfully collaborated with the European space research community on a number of ad hoc joint studies in the past and is now seeking in a measured way to broaden its advisory relationship with this community. The Board has established a regular practice of exchanging observers with the European Space Science Committee (ESSC), an entity of the European Science Foundation. Strengthening contacts with the Russian and Japanese programs is expected to assume higher priority as contacts with European research mature.

Advisory Outreach

The Space Science Board was conceived to provide space research guidance across the federal government. Over the years, the Board's agenda and funding have focused on NASA's space science program. Since the Board's reorganization, however, several influences have acted to expand the breadth of the Board's purview, both within NASA and outside it.

First, the incorporation of scientific objectives into manned flight programs such as the shuttle and space station programs dictate additional interfaces with responsible offices in NASA. The Board is strengthening its links to the Office of Space Access and Technology in NASA through joint activities with the NRC's Aeronautics and Space Engineering Board. Formal contacts may be made with NASA's space operations, international affairs, and commercial offices and programs.

Second, the assumption of the space applications responsibilities from the dissolved NRC Space Applications Board has implied a broadening of the sponsorship base to NOAA, with its responsibilities for operational weather satellites. In response, NOAA became a cosponsor of the Board's Committee on Earth Studies in 1991 and is expected to continue this advisory relationship to the Board in 1995.

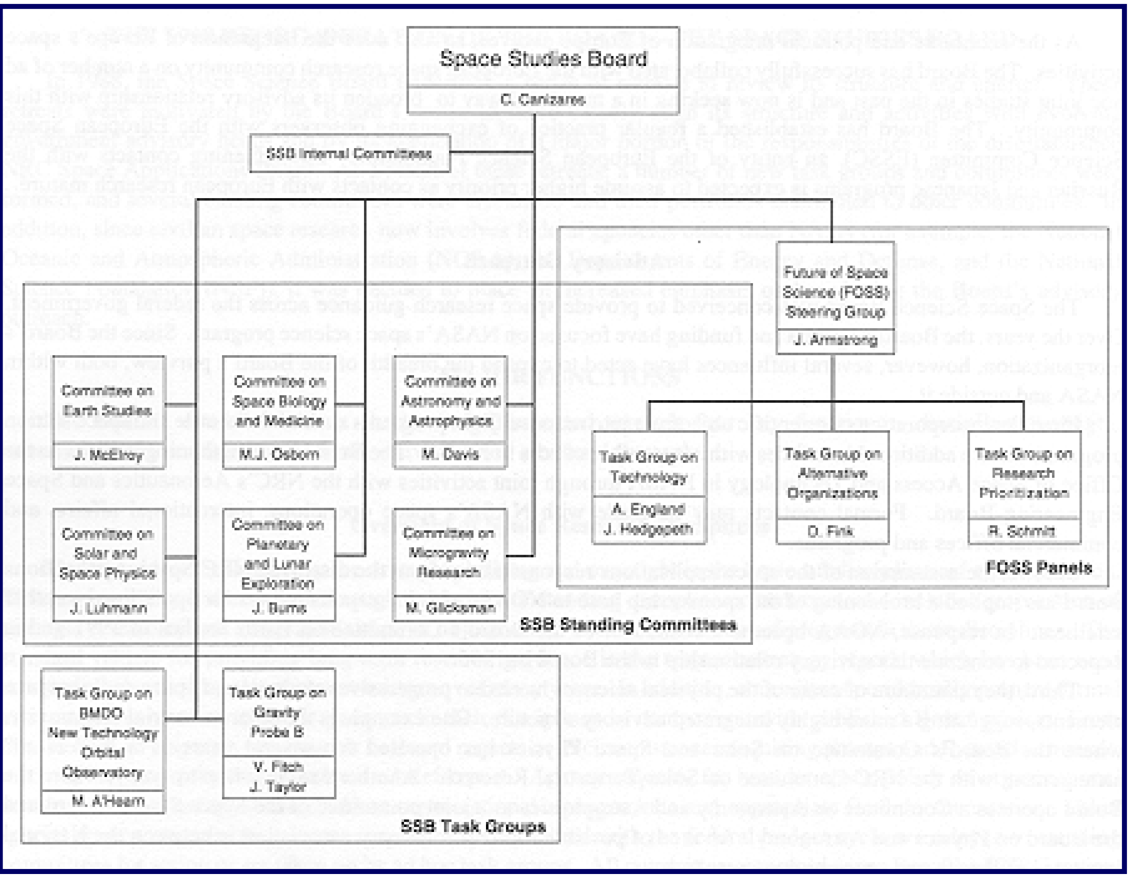
Third, the maturation of some of the physical sciences has led to progressive integration of space and nonspace elements, suggesting a more highly integrated advisory structure. One example is the solar-terrestrial community, where the Board's Committee on Solar and Space Physics has operated for several years in a "federated" arrangement with the NRC Committee on Solar-Terrestrial Research. Another example is astronomy, where the Board operates a Committee on Astronomy and Astrophysics as a joint committee of the Space Studies Board and the Board on Physics and Astronomy. An area of possible future disciplinary association is between the National Institutes of Health and space biology research.

With the end of the Cold War, new participants will become involved in areas of space research previously exclusively civilian. In 1993, the Board established partial support for the Committee on Planetary and Lunar Exploration by the Strategic Defense Initiative Organization and performed an initial assessment of the Clementine mission to the Moon and an asteroid. This convergence, which is also taking place in other areas of the federal R&D establishment, is coming about partly because of shared technology interests and partly because of declassification of some defense technologies in response to the changing world geopolitical environment. The Ballistic Missile Defense Organization (BMDO) has considered several space missions of potential scientific interest, including a large-aperture infrared telescope. As a result, the Board continued its sponsorship and advisory relationship with the BMDO by initiating a scientific assessment of this telescope proposal.

In summary, the Board will continue to reach out to nonresearch NASA offices and to other federal agencies, seeking to establish advisory and corresponding sponsorship relationships as appropriate.

ORGANIZATION

The Board conducts its business principally during regularly scheduled meetings of its own membership and of its supporting committees. These include the internal committees of the Board, standing discipline committees, and ad hoc task groups (see chart). During 1995, the Board will also be managing a major policy study entitled "The Future of Space Science"; this project will be executed by a network of ad hoc task groups and an augmented Joint Committee on Technology. The organization of the Board and its panels is illustrated in the figure.



The Space Studies Board

The Space Studies Board is composed of 18 to 24 prominent scientists, engineers, industrialists, and scholars active in space research or science policy, appointed for staggered terms of one to three years. The Board meets three or four times per year to review the activities of its committees and task groups and to be briefed on and discuss major space policy issues. The Board is constituted in such a way as to include as members its committees' chairs; other Board members serve on internal committees of the Board or perform other special functions as designated by the Board Chair. The Board seats, as ex officio members, the chairs of the NRC Aeronautics and Space Engineering Board and of the NRC Naval Studies Board's Space Panel.

In general, the Board develops and documents its views by means of appointed discipline committees or interdisciplinary task groups that conduct studies and submit their findings for Board and NRC approval and dissemination. These committees or task groups may collaborate with other NRC boards or committees in order to leverage existing specialized capabilities within the NRC organization. On occasion, the Board itself deliberates major issues and prepares its own statements and positions. These mechanisms are used to prepare and release advice either in response to a government request or on the Board's own initiative. In addition, the Board comments, based on its publicly established opinions, in testimony to Congress.

Internal Committees of the Board

Internal committees facilitate the conduct of the Board's business, carry out the Board's own advisory projects, and permit the Board to move rapidly to lay the groundwork for new study activities. Internal committees are composed entirely of Board members. Current internal committees include the Executive Committee of the Board (XCOM) and the Committee on International Programs (CIP). The Joint Committee on Technology (JCT) has been temporarily expanded with non-Board members to help carry out a special study, described further below. The Committee on Human Exploration (CHEX), previously a regular standing committee of the Board, has returned to internal committee status pending further maturation of national human spaceflight goals.

Members of internal committees generally serve for one to two years and then are rotated for replacement by other Board members. The functions of the internal committees of the Board are described more fully in the next section.

Discipline Committees

The standing discipline committees form the traditional backbone of the Board and are the means by which the Board conducts its oversight of space research disciplines. Each discipline committee is composed of 10 to 16 specialists, appointed to represent the broad sweep of research areas within the discipline. In addition to developing long-range research strategies and formal program and progress assessments in terms of these strategies, these committees perform analysis tasks in support of interdisciplinary task groups and committees, or in response to other requirements as assigned by the Board. In 1994, there were six discipline committees:

- Committee on Astronomy and Astrophysics (CAA)
- Committee on Earth Studies (CES)
- Committee on Microgravity Research (CMGR)
- Committee on Planetary and Lunar Exploration (COMPLEX)
- Committee on Solar and Space Physics (CSSP)
- Committee on Space Biology and Medicine (CSBM)

Activities of the former Committee on Space Astronomy and Astrophysics were terminated in 1989 when the Astronomy and Astrophysics Survey Committee began its work. The new Committee on Astronomy and Astrophysics (CAA) was established in 1992 and tasked with resuming oversight of NASA's space astronomy program. The CAA is operated jointly with the NRC Board on Physics and Astronomy, for which it performs oversight of ground-based research programs under sponsorship from the NSF.

The CSSP operates in a "federated" arrangement with another NRC committee, the Committee on Solar-Terrestrial Research of the Board on Atmospheric Sciences and Climate. While the two committees retain their separate identities and reporting relationships to their parent boards, they meet and conduct studies jointly, submitting the results to whichever of the respective boards sponsored their activity.

Project on the Future of Space Science

Under various pressures, the nation's civil space research program conducted by NASA for 35 years is undergoing sweeping change. Space science has in many areas successfully completed its initial reconnaissance phase. At the same time, the national imperative to control the deficit has dimmed prospects for future funding growth. In March 1993, a reorganization of NASA eliminated the Office of Space Science and Applications (OSSA), which had theretofore performed agency-wide science mission and program planning. In response to the likelihood of constrained future budgets and the consequent need for careful selection and efficient execution of space science missions, the Senate Subcommittee on VA, HUD, and Independent Agencies provided, under the title "Future of Space Science" (FOSS), that the National Academy of Sciences undertake studies in several germane areas.

Responding to a subsequent request by NASA Administrator Daniel Goldin, the Space Studies Board is undertaking this assessment of the role and position of space science within NASA. This assessment will focus on specific areas identified in the Administrator's request and in the earlier FY94 Senate appropriations report language. These areas are the organization of civil space research programs within the agency, merit-based cross-disciplinary prioritization, including preservation of innovative initiatives, and improvement of technology utilization in science missions.

The adopted approach to carrying out the requested study has been to use the Space Studies Board's in-place advisory structure wherever possible. The Board formed a FOSS Steering Group, two new task groups, and adapted its existing Joint Committee on Technology (JCT) for the project. The chairs of the FOSS steering group and supporting task groups were appointed to the Board. Some current Board members serve as liaison members of the Steering Group and task groups. In addition, the Board's six standing space research discipline committees will also be tasked to support the study.

The following four topics are explicitly specified in the legislative report and the Administrator's request:

- Alternative organizational models for space science,
- Analysis of merit-based prioritization,
- Improvements in technology insertion, and
- Enabling innovative research.

The second and fourth topics are very closely related: a merit-based prioritization scheme must make special provisions for support of unproven research areas if fostering and preserving such research is to be an outcome of the science selection process. Based on analysis of the Senate language and the NASA Administrator's request, the Board has established a four-component study organization:

- Steering Group (FOSS-SG),
- Task Group on Alternative Organizations (FOSS-AO),
- Task Group on Research Prioritization (FOSS-RP), and
- Task Group on Technology (FOSS-T) (JCT).

The distribution of study tasks among these FOSS panels is described in the "Program" section below.

Task Groups

Ad hoc task groups are created by Board action with NRC approval.

Formed during the 1988 reorganization of the Board, the Task Group on Priorities in Space Research has completed its study and been dissolved. Release of its final report is expected in 1995.

In 1993, working through the Committee on Astronomy and Astrophysics, the Board established a Task Group on SIRTF and SOFIA to assess rescopings of these programs. This task group completed its report in 1994 and was disbanded. The committee subsequently established a Panel on Optical and Infrared Astronomy, which examined management issues in ground-based astronomy for the Board on Physics and Astronomy under sponsorship of the NSF. This report was completed and released early in 1995.

In mid-1994, the Space Studies Board formed the Task Group on the BMDO New Technology Orbital Observatory (TGBNTOO) in response to a request by the BMDO. Its report will be completed and issued in mid-1995.

During the final months of 1994, the NRC received a request from NASA Administrator Goldin to perform an assessment of the scientific merit and technical feasibility of the Gravity Probe B (GP-B) mission. Working with the Board on Physics and Astronomy, the Space Studies Board established a Task Group on GP-B to conduct the required study. The final report will be completed in May 1995.

New task groups may be created in 1995 to carry out studies on research and analysis issues, on topics in mission quality assurance and reliability, and on international collaboration in space research.

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2 Activities and Membership

During 1994, the Space Studies Board and its committees and task groups gathered for a total of 31 meetings. Four full-length reports were issued, including a second report on scientific opportunities by the Committee on Human Exploration (CHEX) (Section 3.1) and a first integrated research strategy for solar system exploration by the Committee on Planetary and Lunar Exploration (COMPLEX) (3.3). The remaining two reports (3.2 and 3.4) were prepared by the Committee on Solar and Space Physics (CSSP) working in collaboration with the NRC Committee on Solar-Terrestrial Research; one of these reports, dealing with research opportunities in upper atmospheric sciences, was produced at the request of and under the sponsorship of the Office of Naval Research. Four short reports were released, two on topics in space station science utilization (4.1 and 4.4), one on the scientific value of two restructured infrared astrophysics programs (4.2), and one summarizing previous Board findings regarding the Advanced X-ray Astrophysics Facility and the Cassini Saturn probe (4.3). The Committee on Microgravity Research (CMGR), COMPLEX, and CSSP were heavily engaged in developing or updating research strategies. The Committee on Earth Studies (CES) devoted most of its energy to completion of a sweeping status assessment of fields within its scope, but heard from NOAA/NESDIS officials on several occasions about changes being made in the operational environmental satellite program. The CMGR spent much of its time developing the two space station letter reports it coauthored with the Committee on Space Biology and Medicine (CSBM) and responding to reviews of its research opportunities report. The Committee on Astronomy and Astrophysics' (CAA) Task Group on SIRTF and SOFIA assessed those missions, and the CAA initiated another task group on ground observatory policies under the sponsorship of the NSF. The new steering group of the Board's major project on the Future of Space Science (FOSS) began intensive planning for that study, and initial membership work was done for the high-visibility Task Group on Gravity Probe B. The Defense Department-sponsored Task Group on the BMDO New Technology Orbital Observatory conducted three meetings and began preparation of its final report.

The following sections present highlights of the meetings of the Board and its committees during 1994. Formal reports and letter reports developed and approved during these meetings are represented in this annual report either by their executive summaries (for full-length reports) or by reproduction in full (for short reports).

SPACE STUDIES BOARD

As 1994 began, the post-Cold War evolution of the national policy and budget environment first heralded a year before began to emerge more clearly. With the health care debate simmering in the background and President Clinton's Whitewater problems providing foreground political clutter, the dynamics of deficit control became ever more inexorable, and not least in the civilian space program. The President's FY95 budget proposal for NASA dropped by $251 million from the actual FY94 appropriation, to $14.3 billion in budget authority, while creeping up by a comparable amount in projected outlays. By contrast, the picture for space science was relatively benign for FY95. R&A levels in the budget were disappointing, but the administration was able to continue both the imaging component of the Advanced X-ray Astrophysics Facility (AXAF-I) and Cassini, and to increase the Earth Observing System (EOS) program significantly. The budget even included a new line for Mars Surveyor, a new, small-satellite program oriented toward orbital and landed Mars science that would help recover some of the aspirations lost with Mars Observer. At the same time, NASA concluded some momentous business of 1993 by pronouncing December's Hubble Space Telescope (HST) repair mission a complete success, and closed out the old Space Station Freedom program in favor of a leaner management approach based on a single prime contract with the Boeing company.

The major concerns over the proposed budget were in the out-year projections, where the total space research funding essentially tracked the drop-off in Cassini and AXAF development funding; even forecasted continued growth in EOS did not appear to arrest the overall decline, which thus reflected a real progressive stagnation of research funding rather than a simple rebalancing of the program in favor of the Mission to Planet Earth. Perhaps a more serious threat was that NASA's comparatively favorable FY95 request might not survive the subcommittee allocation process or competition for that allocation with needy social programs within the subcommittee's jurisdiction. And the questionable stability of the space station program, now joined to the destiny of the Russian program, raised an additional uncertainty for the observer trying to imagine what the ultimate outcome of its cancellation might be for space research.

Against this uncertain backdrop, the Space Studies Board began 1994 with a pair of Executive Committee teleconferences. On January 20, the committee conferred on planning for the next meeting of the full Board. A second teleconference was held on February 9 to follow up on the January conversation and to discuss a future study on the goals and rationale for space science. The committee also gave tentative approval for exploration of a new activity, "Horizons in Aerospace Research and Technology," contemplated as a joint activity with the NRC's Aeronautics and Space Engineering Board and directed toward radical innovation in these fields.

The Space Studies Board held its first plenary meeting of the year (its 112th) in Washington, D.C., on February 28 through March 2. Dr. Louis Lanzerotti, chair, introduced Dr. Claude Canizares, director of the MIT Center for Space Research, scheduled to assume the chair of the Board on July 1. A short Board report on the Office of Science and Technology Policy (OSTP) Forum on Science in the National Interest was followed by a panel presentation and discussion on the President's FY95 budget submission. Short presentations on the budget were provided by Dr. Jack Fellows, Office of Management and Budget, Mr. David Moore, Congressional Budget Office, and Messrs. Kevin Kelly and Stephen Kohashi of the staff of NASA's Senate appropriations subcommittee. In the afternoon, NASA Chief Scientist France Cordova gave the agency's perspective on the budget and presented a draft of NASA's new Strategic Plan. Associate Administrators Wesley Huntress, Harry Holloway, and Charles Kennel discussed the status of their programs and implications of the budget. Dr. Herbert Schnopper, deputy chair of the European Space Science Committee, presented plans for reorganizing that committee into a structure closely resembling that of the Board and its committees. NASA Administrator Daniel Goldin later joined the Board for dinner and shared his views in after-dinner remarks; he also challenged the Board with ten broad questions relating to science, particularly space science.

On the meeting's second day, National Oceanic and Atmospheric Administration (NOAA) Administrator D. James Baker briefed the Board on the status and plans of his agency, including such topics as interagency convergence, use of real-time data from non-U.S. satellites, and NASA/NOAA cooperation on EOS. Dr. Baker was accompanied by Deputy Undersecretary Diana Josephson, and National Environmental Satellite Data and Information Service (NESDIS) Director Robert Winokur. Dr. Richard Obermann, of the staff of the House Space Subcommittee, presented a discussion of the legislative and policy environment facing the FY95 budget proposal. The Board viewed a video of the briefing by Dr. Timothy Coffey of the Mars Observer Investigation Board review, and a video of a recent ABC News Day 1 editorial on NASA. Dr. John McElroy, chair of the Committee on Earth Studies, presented a status report on the committee's survey of recommendations and progress in Earth observations. The research strategy being assembled by the Committees on Solar and Space Physics and on Solar-Terrestrial Research was presented for approval; it was decided that an updated draft would be distributed to the Board for a second review and approval by mail ballot.

A briefing on the Clementine mission was presented by Lt. Col. Pedro Rustan of the Ballistic Missile Defense Organization (BMDO) and Dr. Eugene Shoemaker. Following this talk, which included striking images of the Moon returned by the BMDO spacecraft, Dr. Anneila Sargent presented a draft report by the Task Group on the Space Infrared Telescope Facility (SIRTF) and Stratospheric Observatory for Infrared Astronomy (SOFIA). The Board provisionally approved the draft report, with final approval delegated to the Executive Committee pending minor revisions.

The Executive Committee met on March 29 via teleconference to approve the Future of Space Science project and give final concurrence to the report of the Task Group on SIRTF and SOFIA.

During the second quarter of the year, the space research community continued to focus on grappling with the consequences of the Administration's FY95 budget proposal and out-year projections. On March 24, House Committee on Science, Space, and Technology Chair George Brown released the CBO study, Reinventing NASA. The major conclusion of the study was that NASA probably would not be able to successfully maintain its full portfolio of activities on the projected budgets, and the report suggested three representative scenarios in which different elements of today's space program would be eliminated to ensure health for the remaining ones.

As usual, the $2.1 billion allocated to the space station program drew both envy and a stout defense. NASA continued to vigorously defend the program, which seemed certain to come under attack again in the Congress. At an April 15 hearing, Administrator Goldin stressed the need for the station as the centerpiece of the U.S. space program and provided a firm cost of $17.9 billion for the project. Negotiations continued with Boeing, the prime contractor, and Russia, now assuming increasing importance as a partner. At a second hearing before the House Subcommittee on Space a few days later, reservations about dependence on the Russians were forcefully expressed by several members, led by ranking minority member James Sensenbrenner. At the same time, full committee Chair Brown attempted to influence the allocation of spending authority within the appropriations committees by threatening to withdraw his support for the station if total NASA funding dropped below $14.3 billion. At the same time, the total House allocation to NASA's appropriating subcommittee came in slightly below the $73.3 billion needed, leaving NASA's outlook uncertain. On May 19, Brown set his limit at $14.15 billion, but left a little flexibility. He also unveiled an authorization bill for FY95 that retained the space station but deleted the Mars Surveyor new start, one of eight yearly planned shuttle flights, and the MSL-1 Spacelab flight. Deletion of the latter was an especially bitter pill, because MSL-1 remanifested some of the science previously planned for the SLS-3 flight just canceled in the course of laying out the U.S.-Russian Shuttle-Mir flight sequence.

A still more serious threat to the NASA budget subsequently emerged in the Senate, where NASA's subcommittee allocation for outlays fell more than $300 million below the House's figure. In a June 7 hearing, appropriations subcommittee Chair Barbara Mikulski suggested that either AXAF or Cassini might need to be cut, in addition to reductions in the space station. This threat was clearly an appeal to the Administration for help in obtaining "additional sources of revenue," as the high-stakes game of chicken continued.

Space science advocates were greatly relieved, then, when the President's space science budget survived the House appropriations subcommittee vote on June 9. Science programs escaped unscathed in the resulting $14.0 billion budget, in which reductions from the Administration proposal were taken in the Human Space Flight and Mission Support accounts. Rep. Brown concluded in a public announcement on June 15 that this funding level, while "substantially below" what was needed, was "adequate to continue the space station program" for another year.

This left Rep. Sensenbrenner to be convinced of the viability of the space station program's collaboration with the Russians. These concerns were resolved to his satisfaction by a letter from President Clinton, received on the evening of June 22, that promised the retention of "in-line autonomous U.S. flight and life support capability during all phases of station assembly." So, on the 23rd, Rep. Sensenbrenner fell into line behind the station, whose prospects were now looking much improved. Also on June 23, Administrator Goldin and Russian Space Agency Director General Juri Koptev signed both an "Interim Agreement for the Conduct of Activities Leading to a Russian Partnership in Permanently Manned Civil Space Station" and a $400 million agreement for Russian space hardware and services. A House amendment, offered by Rep. Richard Zimmer, to kill the station and distribute the liberated resources among space science, the shuttle, advanced launch systems, and aeronautics, began to appear much less threatening. Indeed, the amendment failed by 123 votes when the House appropriations bill went to the floor and was passed on the evening of June 29.

The budget action for U.S. space and space science moved next onto the uncertain terrain of the Senate, where a lower appropriations allocation still threatened the need for hard measures. Actually, space researchers had reason to be grateful: up to this point, the President's FY95 budget for space science, which was generally viewed as adequate and certainly much better than the projections for the out-years, had survived. Indeed, compared to defense research in the universities, which experienced a 50% cut in its House appropriations bill passed in subcommittee at the end of June, civil space research looked good.

There was other good news, too. Placed into lunar orbit on February 19, the Defense Department's Clementine spacecraft successfully completed its mapping mission on May 3 and left for its rendezvous with the minor planet 1620 Geographos. Although the craft subsequently suffered a severe system failure that eliminated this second phase of its science mission, it had succeeded in returning multispectral maps of essentially the entire Moon, the first major advance in lunar exploration since the end of Apollo 20 years before. NASA's strong interest in smaller, faster, and cheaper flight missions guaranteed that this joint NASA-DoD program would be closely studied in times ahead. In a delightful surprise, analysis of downlink image data from the Jupiter-bound Galileo spacecraft revealed that it had observed a tiny moon, later named Dactyl, in orbit around the asteroid Ida. The agency also launched and successfully activated the much-delayed GOES-NEXT (GOES-8) geostationary environmental satellite, significantly upgrading NOAA's ability to detect and track severe mesoscale weather.

Based on an Executive Committee agenda planning teleconference on May 13, the Space Studies Board held its 113th meeting at the Goddard Space Flight Center and at the National Academy of Sciences on June 29-July 1. The sessions at Goddard continued the Board's long-standing tradition of meeting once per year at a NASA field center. Members took advantage of the opportunity to hear presentations on space and Earth science programs by Goddard investigators. The meeting also featured program status briefings by Associate Administrators Huntress, Kennel, and Holloway. Assistant Administrator for Strategic Planning Peggy Finarelli presented the new NASA Strategic Plan, and Chief Scientist Cordova briefed the Board on activities of the new NASA Science Council and on a number of far-reaching strategic science policy questions under current study. A number of moving moments marked the end of Louis Lanzerotti's six years as chair of the Board: the NRC's Commission on Physical Sciences, Mathematics, and Applications gave him an NRC watch, and the National Academy of Sciences presented him with an etched crystal bowl. Later, at dinner, Board staff gave Dr. Lanzerotti a plaque celebrating the naming of minor planet 5504 Lanzerotti, and NASA bestowed on him its highest honor, the Distinguished Public Service Medal. Dr. Claude Canizares assumed the gavel the next morning, beginning a three-year term as the Board's new chair.

The big space science news during the latter part of July was the dramatic collision of the fragments of comet Shoemaker-Levy 9 with Jupiter. The impact, which offered a unique opportunity to study both the dynamics and composition of the comet and the structure of the Jovian atmosphere, was observed by observatories around the world, as well as by Galileo and the HST above it. A significant innovation occasioned by the event was the first worldwide use of the internet to coordinate observing plans and preliminary results almost in real time.

On the budget side, space science had a quiet summer after initial amazement during July at Senator Barbara Mikulski's success in maintaining NASA's appropriation in the Senate bill. Earlier prognoses had been darkened by an outlay deficiency, compared to the House, of $316 million for FY95. In spite of this shortfall, NASA emerged from the Senate Committee on Appropriations with $85 million less than its FY94 total, but $201 million more than the Administration's request, and a whopping $441 million more than the House figure. Both the space station and space science were fully funded, with only relatively minor adjustments made among space science accounts. Just before passage of the bill in the Senate, the space station survived a new Bumpers cancellation amendment, whose 36 votes on August 4 were 4 fewer than it had garnered the year before.

This promise of a satisfactory denouement to the FY95 space science budget cycle had to share the policy spotlight with the release on August 3 of the long-awaited OSTP report Science in the National Interest. Based in part on a high-level symposium held the preceding February, this report promised to articulate the Clinton Administration's policy on science in much the same way that an earlier document had spoken to national goals in technology. The new policy's five goals seemed to address the major areas of concern: it committed the nation to leadership in research and excellence in training both specialists and the general citizenry, and promised to improve the connections between research and national goals and between the major participants in the scientific enterprise. The statement was generally favorably received by the scientific community; for example, in a statement on behalf of the American Institute of Physics, Dr. Roland Schmitt described the document as modernizing national policy "constructively, comprehensively, and sensitively." The only missing element was a mechanism for increasing science's share of the GDP from 2.7 to 3.0% as OSTP recommended. This reservation clouded an otherwise positive reaction by Rep. George Brown and spokespersons from academia and industry the day after the report's release at a hearing on the new policy by the House Subcommittee on Science.

In a footnote, the space research community got a glimpse of the dark side of the new information age. In a series of abrupt events, the Far Ultraviolet Spectroscopic Explorer (FUSE) appeared to be canceled outright and then partly restored. On September 8, email suddenly announced that FUSE had been "canceled," in a "major violation of the peer review process." Another message announced that "the process stinks," and that "we should scream." By the 13th, a calm and carefully reasoned letter was being circulated over NASA Associate Administrator Huntress' signature that budget pressure had ordained the end of the Delta-class Explorers, so that FUSE would be restructured as a MIDEX (mid-class explorer) mission that would retain as much science content as possible. On September 14, FUSE Principal Investigator Warren Moos was soberly, but gamely, presenting his initial planning for restructuring the mission to NASA's internal Space Science Advisory Committee. By the 16th, when an official NASA press release explaining the situation and ongoing planning was circulated on the internet, recognition appeared to be spreading that the highly rated far ultraviolet astronomy objectives addressed by FUSE were not, in fact, being abandoned, but instead were being rescoped for survival, a process already undergone by AXAF and Cassini (not to mention the space station). The network was thereby proved as effective at spreading rumor and alarm as for enhancing valuable scientific cooperation and distributing Shoemaker-Levy 9 images.

During the last days of the fiscal year, the Senate followed suit on the House's approval of the NASA appropriations conference report, leaving the agency about 1% better off than the Administration had proposed and only a comparable amount short of its FY94 budget.

The Space Studies Board did not meet during the third quarter of 1994. Its Executive Committee did, however, assemble on August 1-3 at the NRC Woods Hole study center to complete several action items deferred from the Board's June 29-July 1 meeting at the Goddard Space Flight Center and to work with an initial steering group of the Board's new Future of Space Science (FOSS) project. (The FOSS project will be a set of studies responding to FY94 Senate appropriations report language and a subsequent request by NASA Administrator Goldin. The project, which focuses on science organization, prioritization, and technology utilization, is discussed in a separate section below.) The Executive Committee accepted a new version of the final report of the Task Group on

Priorities in Space Research, chaired by Prof. John Dutton, subject to a few issues in format and presentation. The committee also decided that the third report of the Committee on Human Exploration, dealing with science management issues, should be reconsidered for possible release. The Discovery program report by the Committee on Planetary and Lunar Exploration was approved for submission to external review, and a draft statement of task for an assessment and "lessons-learned" study on the BMDO Clementine mission was also approved. The Executive Committee decided to draw up a possible statement of task on Research and Analysis issues for future consideration.

The Executive Committee met again via teleconference on September 30 to plan activities for the November meeting of the full Board.

On October 12, Magellan fell silent as it slipped into the Venusian atmosphere. This spectacularly successful radar mission, which left only a few percent of the cloud-covered surface of the planet unmapped, also provided an extremely valuable gravity map of Venus during the final phase of its mission. The contrast between the Mars Observer and Magellan poignantly highlighted the stark extremes of failure and success in the exacting realm of interplanetary spacecraft. Late in the year, the astronomical sciences saw a profound example of applying the most modern instrumentation to a classical technique in astronomy. The repaired HST was used to make accurate observations of Cepheid variables in the galaxy M100. The resulting measurement of the distance to this galaxy, 56 million light-years, implies that the universe is only about half as old as previously estimated and raises numerous questions in cosmology and stellar evolution.

The Board's last meeting of 1994 was on November 7-9 at the Beckman Center, in Irvine, California. Chair Claude Canizares welcomed new members Drs. Martin Glicksman (Rensselaer Polytechnic Institute), Marcia Rieke (University of Arizona), Janet Luhmann (University of California at Berkeley), Mary Jane Osborn (University of Connecticut), and John Donegan (USN, retired) to the Board. Dr. Canizares also reported that the Board would be setting up a panel to perform a science reassessment of the Gravity Probe B mission, at the request of NASA Administrator Goldin. The top priority for this meeting, the Board's 114th, was planning and approval for committee activities, since many Board committees were completing major projects and were in a position to start new ones. Because a number of NASA science office strategic plans were either in circulation or nearing finalization, however, the Board took advantage of videoconferencing capabilities to discuss these efforts and plans with agency science officials. Conversations on program status and planning were held with NASA Chief Scientist Cordova, Associate Administrator Kennel and Dr. Robert Harriss of the Office of Mission to Planet Earth, and Associate Administrators Huntress and Holloway. A videoconference briefing was also presented by Mr. Robert Winokur and Mr. John Hussey of NOAA/NESDIS on the status of the new Integrated Program Office for the polar-orbiting operational environmental satellites.

After these important program updates, the Board reviewed the activities of its committees. Committee on Astronomy and Astrophysics representative Jeremiah Ostriker described preliminary findings of that committee's study on optical and infrared astronomy from ground-based observatories. The committee is funded jointly by NASA and NSF, and this study was intended to provide guidance to NSF on managing the conflicting budget demands of major new observatories under development and routine operations and maintenance of its existing inventory of ground observatories. The Board heard about planning for the Future of Space Science project from Chair John Armstrong. Key members of the steering group of the project conferred on these plans via videoconference over lunch on the first day of the meeting.

During the second day, Board Director Marc Allen informed the Board that the final report of the Task Group on Priorities in Space Research would shortly be sent out for review. This report, which describes the mixed success of the prioritization methodology developed by that task group, should be released by mid-year. Committee on Earth Studies Chair John McElroy reviewed the status of the committee's large survey report, which was just about to enter institutional review; Dr. McElroy obtained the Board's approval for the committee's next project, a two-part assessment of synthetic aperture radar applications in the context of U.S. and foreign systems, both those flying and those in planning. Committee on Microgravity Research Chair Martin Glicksman reported that his committee's research opportunities report had been returned to the NRC's Report Review Committee for final sign-off, with release expected in January 1995. There was general discussion of new tasks for that committee. Dr. Mary Jane Osborn, new chair of the Committee on Space Biology and Medicine, described the meeting of her committee in October, held concurrently with the American Society for Gravitational and Space Biology; several topics for a study had been discussed, but it was decided that further clarification of agency interests was needed before a final topic could be selected. New Committee on Solar and Space Physics Chair Janet Luhmann reported that her committee's research strategy was out for institutional review; Board approval was obtained for two new studies, one a research briefing on space weather and the other an assessment of solar and space physics aspects of the new Office of Space Science strategic plan. Committee on Planetary and Lunar Exploration Chair Joseph Burns told the Board about the status of three reports: the integrated strategy was in final edit; the assessment of the role of small planetary missions in planetary science was in review; and the study on lessons learned from the Clementine mission was in progress. The Board approved the committee's plans for a new study comparing current NASA Mars mission planning to recommendations in the new integrated strategy. Board staff member David Smith reported that the Task Group on the BMDO New Technology Orbital Observatory would hold its last meeting in December, with a final report to be submitted to the Board in mid-year.

On the last day of the meeting, the Board discussed several new Board-level projects, including one on international collaborations in space science, a second on the role of Research and Analysis (R&A) and Mission Operations and Data Analysis (MO&DA) programs, and a third on mission cost and quality. The latter would be conducted jointly with the Aeronautics and Space Engineering Board. Chair Canizares requested members' comments on the international task and said that he would work on a draft study proposal for the mission cost and quality activity. He concluded the meeting by welcoming suggestions by members for new Board appointments.

On the whole, space research had a good year in 1994; numerous discoveries resulted from the repaired HST, and Ulysses continued its successful out-of-the-ecliptic mission. The Cassini and AXAF development programs remained on track. And granting certain new risks from the incorporation of a major new international partner, the space station seemed somewhat stabilized under a more realistic management structure.

At the same time, space research faced a new world as 1995 began. With the end of 40 years of Democratic control in the House of Representatives and a corresponding turnover of leadership in the Senate, NASA and NOAA would be dealing with new committee chairs and members, and indeed even new committees. Rep. Bob Walker, the new head of the new House Committee on Science replacing Rep. Brown's Committee on Science, Space, and Technology, revealed the outlines of the future in a briefing on December 14. Rep. Walker indicated strong support for the space station and university research. He stated an intention to continue Rep. Brown's war against earmarking, as well as an interest in pursuing the creation of a cabinet-level Department of Science. In a divergence from previous policy, Rep. Walker questioned whether aspects of the Mission to Planet Earth and related programs might not be more political than scientific, and also expressed the preference for a stronger emphasis on basic science at NSF in place of the current trend toward applied science.

The overall science funding picture remained unclear. Various tax-cut proposals were in the air, as well as the Republican "Contract with America" and President Clinton's "middle-class bill of rights." The final outcome of many of these proposals could dramatically affect not only funding levels for individual programs in the discretionary portions of the budget, but even the existence of some performing entities themselves. One example of the latter was the suggested elimination of the U.S. Geological Survey. While Rep. Walker has said that he favors inflationary increases for the space agency, the effects of political turmoil as the Congress reinvents itself over the next few months appeared unfathomable.

Membership of the Space Studies Board

Claude R. Canizares,§ Massachusetts Institute of Technology (chair)
Louis J. Lanzerotti,* AT&T Bell Laboratories (former chair; U.S. representative to COSPAR)
John A. Armstrong, IBM Corporation (retired)
Joseph A. Burns, Cornell University
John J. Donegan, U.S. Navy (retired)
Anthony W. England, University of Michigan
James P. Ferris,* Rensselaer Polytechnic Institute
Daniel J. Fink, D.J. Fink Associates, Inc.
Herbert Friedman,* Naval Research Laboratory
Martin E. Glicksman, Rensselaer Polytechnic Institute

Harold J. Guy,§ University of California at San Diego
Noel W. Hinners,§ Martin Marietta Astronautics
Robert A. Laudise, AT&T Bell Laboratories
Richard S. Lindzen, Massachusetts Institute of Technology
Janet G. Luhmann, University of California at Berkeley

John H. McElroy, University of Texas at Arlington
William J. Merrell, Jr.,* Texas A&M University
Norman F. Ness,* University of Delaware
Marcia Neugebauer, Jet Propulsion Laboratory
Mary Jane Osborn, University of Connecticut
Simon Ostrach, Case Western Reserve University
Jeremiah P. Ostriker,§ Princeton University
Carlé M. Pieters,§ Brown University
Judith Pipher, University of Rochester
Marcia J. Rieke, University of Arizona
Roland W. Schmitt, Rensselaer Polytechnic Institute (retired)
William A. Sirignano,* University of California at Irvine
John W. Townsend, Jr.,* NASA (retired)
Fred W. Turek,* Northwestern University
Arthur B.C. Walker, Jr., Stanford University

François Becker, École Nationale Supérieure de Physique (liaison from the European Space Science Committee)
Marvin A. Geller, State University of New York at Stony Brook (ex officio, chair of the Committee on Solar-Terrestrial Research)
Jack L. Kerrebrock, Massachusetts Institute of Technology (ex officio, chair of the Aeronautics and Space Engineering Board)
Vincent Vitto, Massachusetts Institute of Technology (ex officio, chair of the Naval Studies Board Space Panel)

Marc S. Allen, Director
Richard C. Hart, Deputy Director
Betty C. Guyot, Administrative Officer
Anne K. Simmons, Administrative Assistant

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§member of the Executive Committee
*term expired during 1994

COMMITTEE ON INTERNATIONAL PROGRAMS

The Committee on Space Research (COSPAR) of the International Council of Scientific Unions held a plenary meeting on July 10-22 in Hamburg, Germany. During the plenary meeting, COSPAR conducted its first completely open election of new officers, for the period 1994-1998. Dr. Louis Lanzerotti, former chair of the Space Studies Board and currently the U.S. National

Representative succeeding Dr. Herbert Friedman, was elected a vice president. In May, National Academy of Sciences President Bruce Alberts issued a letter of invitation to COSPAR to hold its 2002 meeting in the United States as the second World Space Congress.

On September 19-20, Board Chair Claude Canizares and Director Marc Allen attended a meeting of the European Space Science Committee (ESSC) in Paris, France. The meeting featured discussions on a number of topics, including plans of the ESSC to strengthen its ties to both COSPAR and to the European Union, the prospects of Earth observation becoming a European Space Agency (ESA) mandatory program, the ESA PRODEX program (by which countries with small space programs can take advantage of ESA's expertise in acquisition and system engineering), and ESA's manned space flight and microgravity office. Dr. Roger Bonnet, ESA director of space science, reviewed mission plans and status for the committee. Dr. Canizares briefed the members on Board status and activities and answered questions about OSTP's Forum on Science in the National Interest. The possibility of a collaborative Board-ESSC study on successes and failures in U.S.-ESA space science cooperation was discussed with the ESSC, and again later at a private meeting with Dr. Bonnet. The Board's Committee on International Programs will be reconstituted to lead the Board effort on this study.

JOINT COMMITTEE ON TECHNOLOGY FOR SPACE SCIENCE AND APPLICATIONS

The Joint Committee on Technology for Space Science and Applications, an activity conducted jointly by the Space Studies Board and the NRC's Aeronautics and Space Engineering Board, was restructured during 1994 as the Task Group on Technology of the Future of Space Science project. This project and the activities of its task groups are described below.

COMMITTEE ON ASTRONOMY AND ASTROPHYSICS

At the Committee on Astronomy and Astrophysics (CAA) first meeting of 1994, on April 21-22 in Washington, D.C., Dr. Hugh Van Horn, director of NSF's Division of Astronomical Sciences, discussed changes he had made in the astronomy programÑfor example, increasing funding for the planetary science program. NASA Chief Scientist France Cordova spoke of NASA's strategic plan, the budget pressure the agency faces, and NASA's participation in the National Science and Technology Council. Dr. Wayne Van Citters gave a status report on the Gemini Telescope Project, NSF's major optical astronomy project for the decade, stating that the international agreements were in place and contracts would be let in 1994. Committee member Richard McCray, who chairs the Panel on Ground-Based Optical and Infrared Astronomy (OIR Panel), gave a progress report on the panel's first meeting at the headquarters of the National Optical Astronomy Observatories in Tucson, Arizona, in February 1994. The OIR Panel was formed in response to a request from Dr. Van Horn for a strategic review of U.S. nighttime optical and infrared astronomy, both public and private, in a period of flat budgets and construction and operation of the Gemini telescopes.

The committee heard a report on NASA's "Strategic Priorities in Astrophysics" from NASA Astrophysics Director Daniel Weedman. He discussed the issue of comparative technical readiness for the Space Telescope Imaging Spectrometer and the Near-Infrared Camera, the Space Infrared Telescope Facility (SIRTF), and the Stratospheric Observatory for Infrared Astronomy (SOFIA). He described the 1997 Hubble Space Telescope (HST) reboost mission and 1999 refurbishment mission, the former mandated by the solar activity cycle. When asked about the cost of operations, he said he could not see a way to reduce the spending on HST other than canceling instruments. Dr. Guenter Riegler presented information on Mission Operations and Data Analysis (MO&DA) budgets and on the merging of the astronomical theory programs.

Committee Chair Marc Davis described the briefing for NASA Administrator Daniel Goldin about the report of the committee's Task Group on SIRTF and SOFIA, which was presented by task group and committee member Anneila Sargent. Prof. Sargent stressed to Mr. Goldin that the task group's deliberations had been predicated on the recommendations of the 1991 Astronomy and Astrophysics Survey Committee report, *The Decade of Discovery in Astronomy and Astrophysics* (NAP 1991). The section entitled "The Decade of the Infrared" of this report described how the unique complementarity in the infrared capabilities of SIRTF, SOFIA, and the Gemini telescopes would be utilized. Prof. Davis also recounted a conversation with Rep. George Brown about the pressures on the NASA science budget. The committee heard progress reports on three Board on Physics and Astronomy activities: the Cosmology Panel, the Neutrino Astrophysics Panel, and the Committee on Cosmic-Ray Physics, which had completed an interim report.

The committee met for the second of its two meetings of 1994 on September 29-30 at the Beckman Center in Irvine, California. The committee spent a large part of the meeting reviewing the draft report of the OIR Panel, due to the NSF Division of Astronomical Sciences at the end of 1994. OIR panel member J. Anthony Tyson reported on his study of engineering and technical support staff at the National Optical Astronomy Observatories headquarters.

Committee Chair Davis described the status of the research briefing being prepared by the Panel on Cosmology, which he also chaired, and of two other astronomy-related studies being performed by other panels of the Board on Physics and Astronomy, one on cosmic-ray physics and the other on neutrino astrophysics. Prof. Roger Ulrich of Caltech presented an invited talk on astroseismology. The field is relatively new and was not included in the 1991 astronomy survey report, but there is interest in proposing a new NASA mission in this area. Member Jonathan Grindlay suggested that a long-duration balloon flight would be a good candidate, especially now that the Northern Hemisphere has been opened up for circumpolar flights due to improved geopolitical conditions. NASA spends about $10 million per year on balloon programs. The committee decided to investigate whether NASA would be interested in a research briefing on balloon-borne astronomy.

Committee member Arthur Davidsen reported on NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) mission. FUSE mission costs were originally projected at roughly $250 million, but the mission was being rescoped to $100 million. Originally, it was to have been launched on a Delta rocket, but was now planned for a 1998 launch on a "med-lite" vehicle.

Dr. Robert Dickman, of the NSF's Division of Astronomical Sciences, described the Millimeter-Wave Array (MMA) project. The MMA was the top-ranked radio astronomy project in the 1991 astronomy and astrophysics survey report. The committee also discussed the role of smaller university radio telescopes in an era of large arrays and the possibility of combining university telescopes into arrays.

Prof. Thomas Phillips, Caltech, briefed the committee on the Submillimeter Intermediate Mission (SMIM), an orbital 3-meter millimeter-wave telescope. SMIM shares heritage with the Large Deployable Reflector, which was a recommendation of the 1982 astronomy survey (the Field report), and with ESA's Far-Infrared Space Telescope (FIRST) mission. Prof. Phillips said that NASA has supported the technical development well, but in order to continue, the project must have a U.S. commitment for the international partners by 1996. Concern was expressed that the United States might experience problems with an international agreement, as it did with the International Gamma-Ray Laboratory (INTEGRAL). The committee discussed exploring the general issue of international cooperation on astronomy projects.

CAA Membership

Marc Davis, University of California at Berkeley (chair)
Leo Blitz, University of Maryland
Arthur F. Davidsen, Johns Hopkins University
Sandra M. Faber,* University of California at Santa Cruz
Holland C. Ford, Space Telescope Science Institute
Jonathan E. Grindlay, Harvard-Smithsonian Center for Astrophysics
Doyal A. Harper, Yerkes Observatory
John P. Huchra, Harvard-Smithsonian Center for Astrophysics
Kenneth I. Kellermann, National Radio Astronomy Observatory
Richard A. McCray, University of Colorado at Boulder
Jeremiah P. Ostriker, Princeton University
Bernard Sadoulet, University of California at Berkeley
Anneila I. Sargent,* California Institute of Technology

Robert L. Riemer, Executive Secretary
Anne K. Simmons, Administrative Assistant

*term ended during 1994

COMMITTEE ON EARTH STUDIES

The Committee on Earth Studies (CES) met in Washington, D.C., on February 3-4. Dr. Charles Kennel, recently appointed associate administrator for the Mission to Planet Earth (MTPE), provided an overview of the status of MTPE programs. Among key strategic issues facing MTPE were (1) how to keep science from being a surrogate for the policy debate; (2) how NASA can better communicate the MTPE program and its "relevance" to issues viewed as important by the public, industry, science community, educators, Congress, and the Administration; (3) OSTP's desire for expansion of NASA's involvement in the U.S. Global Change Research Program through MTPE to address issues of assessments, mitigation, and adaptation; (4) MTPE's ability to respond in an environment of constrained funding, shifting priorities, and multiyear program execution; (5) the most efficient implementation approach for a technology development program that supports MTPE and how it should be related to the Space Technology Strategic Enterprise; (6) NASA's pursuit of convergence of operational and research systems and the transfer of operations to other agencies; (7) reconciliation of constrained federal funding with agencies' sometimes competing priorities; and (8) meeting high expectations associated with past successes, such as the identification of ozone depletion. Dr. Kennel described MTPE program strengths and weaknesses and the local, state, national, and international groups that are MTPE customers.

Immediate issues facing MTPE in 1994 were (1) the future of Landsat; (2) continuation of Earth Observing System (EOS) science instrumentation and spacecraft development; (3) response to the NRC report on the EOS Data and Information System (EOSDIS—reprinted in the appendix below); and (4) the continued health of basic science and R&A in an environment of severe budget pressures. (When the budget was later released, it showed a request for NASA's MTPE for FY95 of $1.238 billion, $214 million over the amount for FY94.)

Dr. Ghassem Asrar, EOS program scientist, briefed the committee on the EOS program's status. First launch (the Tropical Rainfall Measurement Mission) is scheduled for August 1997. The MTPE office was addressing concerns raised by the EOS Payload Advisory Panel in a report issued following its October 1993 meeting. Mr. Dixon Butler, director of NASA's MTPE Operations, Data, and Information Systems Division, provided the committee an update on EOSDIS. A key development since the committee's last briefing on EOSDIS in September 1993 was the January 1994 release of the NRC report reviewing the program (see Appendix). Butler indicated that the agency is working to implement the report's recommendations. Several other influences also acted to shape EOS data policyÑincluding statements by former OSTP Director D. Allan Bromley, OMB Circular A-130, and Committee on Earth Observation Satellites (CEOS) principles concerning all earth observation satellite programs.

Mr. Robert Winokur, recently appointed assistant administrator for NOAA/NESDIS, and Mr. John Hussey, acting deputy assistant administrator for NOAA/NESDIS, summarized the current status and plans for NOAA's satellite programs. With GOES-7 remaining operational GOES-I was scheduled for launch in April 1994. NOAA-11 and -12 were operational, with NOAA-9 and -10 on standby. NOAA-13 had been launched the previous August, but had suffered a power system failure two weeks later. The Failure Review Board investigation concluded that the failure occurred in the battery charge controller unit. EUMETSAT will assume AM mission responsibility with the launch of METOP-1 in 2000, but PM mission responsibility remains with the United States. Plans were still evolving for convergence of NOAA's Polar-Orbiting Environmental Satellite (POES) system, the DoD Defense Meteorological Satellite Program (DMSP), and EOS-PM.

It was reported that EOSAT had temporarily suspended Tracking and Data Relay Satellite System (TDRSS) acquisitions to rest the Landsat-4 Ku-band communications subsystem, which is now in a standby mode. Landsat-6 had been launched the previous October, but did not achieve orbit. An ad hoc working group led by OSTP, with participation from NOAA, NASA, DoD, and OMB, was reviewing options and developing a strategy for U.S. land remote sensing in light of the Landsat-6 failure. In early January, DoD indicated it would no longer support Landsat as part of the Landsat-7 Program Management Team. OSTP asked NOAA and NASA to develop a set of implementation options that would ensure Landsat data continuity.

Mr. William Townsend, of NASA MTPE, briefed the committee on the status of the NOAA-NASA-DoD convergence study. The purpose of the study was "to identify realistic opportunities for additional cost savings through further integration of all or parts of the DoD and NOAA operational polar-orbiting environmental satellite programs and capitalizing on NASA EOS-PM technologies." The tri-agency study had begun in July 1993, and had been submitted to OSTP for review; an implementation plan was to be submitted to Congress by April 1994.

The Committee on Earth Studies met a second time in Washington, D.C., on April 7 and 8. The meeting was devoted entirely to completing its new discipline-wide survey report. Contributions for individual chapters and appendixes were integrated by committee Chair John McElroy. By the end of the meeting, final review and writing assignments were made and a schedule for completing the report in time for Board review was developed. Because of its length, the report was to be sent to the Board in early May, allowing eight weeks for review.

In other committee business, Dr. McElroy asked members to provide to Board staff the names of candidates to replace retiring members and chair. Nine committee members are scheduled to rotate off the committee in June 1994.

These members were originally scheduled to rotate off the committee in December 1993, but their terms were extended in order to complete work on the report.

The summer meeting of the Committee on Earth Studies was convened at the NAS Georgetown facility on July 6-7. Much of the first day was devoted to finalizing responses to Board comments on the survey report. The report had been approved by the Board at its June-July 1994 meeting subject to the resolution of a few remaining issues to the satisfaction of the Board's Executive Committee.

The committee received an extensive briefing from Dr. Kennel and colleagues on the current status of EOS, EOSDIS, plans for the convergence of polar-orbiting environmental satellites, and Landsat. Dr. Kennel also discussed his draft request for a study of spaceborne synthetic aperture radar. In addition, there was an extensive presentation on the use of Doppler-lidar systems to measure atmospheric velocity fields.

The second day of the meeting was devoted to two main topics. The first was a briefing from Mr. Winokur on convergence, Landsat, commercial remote-sensing satellites, and the possible role of small satellites in applications, such as sea-surface altimetry. The second topic was the proposed study of synthetic aperture radar. The committee decided that it would devote its next meeting to a workshop on space-based synthetic aperture radar. Given the specialized nature of this topic, there was discussion about possible augmentation of the committee with experts on these systems and their applications.

The fall meeting of the committee, originally planned for November 14 and 15, was postponed until mid-January 1995 in order to organize a workshop on synthetic aperture radar.

CES Membership

John H. McElroy, University of Texas at Arlington (chair)
William Bonner, University of Colorado
George Born, University of Colorado
Janet W. Campbell,* University of New Hampshire
Dudley Chelton, Jr., Oregon State University
John Evans, COMSAT Laboratories
Elaine Hansen, University of Colorado at Boulder
Roy L. Jenne, University of Colorado
Kenneth Jezek,* Ohio State University
Edward T. Kanemasu, University of Georgia
Richard Kott,* Center for Geographic Analysis, Assessment, and Applications

Conway Leovy,* University of Washington
John MacDonald,* MacDonald-Dettwiler Associates
Pamela Mack, Clemson University
Stanley Morain, University of New Mexico

Clark Wilson, University of Texas at Austin

Richard C. Hart, Executive Secretary
Joyce M. Purcell, former Executive Secretary
Carmela J. Chamberlain, Administrative Assistant

*term expired during 1994

COMMITTEE ON HUMAN EXPLORATION

The membership of the Committee on Human Exploration expired at the end of 1993. Its second report, Scientific Opportunities in the Human Exploration of Space (National Academy Press, Washington, D.C.), was released in early 1994 and a third study, on science management within human flight programs, was circulated to the Board for review. Revision of this final report continued in response to the evolution of NASA's long-term planning.

COMMITTEE ON MICROGRAVITY RESEARCH

The Committee on Microgravity Research (CMGR) met on January 19-21 at the Beckman Center to review the status of NASA's microgravity program, discuss NASA's commercial programs, and plan future activities. NASA's Dr. Roger Crouch briefed the committee on the status of the NASA Microgravity Science and Applications Division, including highlights of 1993, the FY94 budget, planned Mir flights, and recent NASA Research Announcement activities. A video teleconference with Dr. Richard Ott concerning NASA's commercial programs was canceled due to severe weather conditions in Washington, D.C. The majority of the meeting was devoted to discussing possible future tasks, including (1) assessment of the quality and quantity of science in the microgravity science program; (2) assessment of NASA's commercial programs in microgravity and biotechnology; (3) the possible role of institutes (in the sense of the Lunar and Planetary Institute or the Space Telescope Science Institute) in microgravity science; and (4) assessment of international science programs in microgravity.

The committee held its second meeting in Washington, D.C., on April 28-29 in joint session with the Board's Committee on Space Biology and Medicine to review the scientific capabilities of the redesigned International Space Station Alpha (ISSA).

The committee heard presentations by the following: Mr. Wilbur Trafton, deputy associate administrator for Space Station, on an overview of ISSA and its program management plan; Captain William Shepherd, deputy program manager for Space Station at the Johnson Space Center, on the details of the ISSA design; Dr. Harry Holloway, associate administrator of the Office of Life and Microgravity Sciences and Applications, on changes since the committee's February 1994 letter related to the status of Spacelab and space station research management; Dr. Joan Vernikos and Mr. Robert Rhome, directors of the Life and Biomedical Sciences and Applications Division and of the Microgravity Science and Applications Division, respectively, on plans for life and microgravity sciences research on the ISSA; and Dr. Arnauld Nicogossian, deputy associate administrator of the Office of Life and Microgravity Sciences and Applications, on the Shuttle/Mir program.

Most of the remaining meeting time was devoted to drafting a second letter to NASA on the space station; this second letter focused on science utilization aspects of the ISSA design.

The committee held a third meeting at the Beckman Center on June 1-3 to revise the second ISSA letter and to finalize the strategy report by responding to comments of the NRC's institutional review. Dr. Hannes Walter, of the European Space Agency (ESA), briefed the committee on the status and activities in ESA microgravity research, including the ESA organization, the difference between ESA "mandatory" and "optional" programs, the 1994 budget and objectives of the ESA microgravity program, ESA's research facilities, activities of ESA's Microgravity Advisory Committee, the status of the Columbus program, and international cooperative activities.

Dr. Roger Crouch of NASA briefed the committee on recent activities in the U.S. microgravity program, including recent agreements and meetings with U.S. research agencies and foreign spaceflight agencies, NASA research solicitations, grants, and schedules, NASA microgravity mission status for 1994-95, the program phasing schedule leading to ISSA availability, the collaborative Mir Phase 1 program, and details of NASA's life sciences and microgravity budget. The remainder of the meeting was spent in revising the ISSA letter and in reviewing the strategy report.

At its final meeting, the Committee on Microgravity was convened by its new chair, Dr. Martin Glicksman, at the Beckman Center on September 23-24 to complete revisions to the committee's "strategy" report. (One of the changes approved at the meeting was a title change from "Strategy" to "Opportunities.") After a brief discussion of the agenda, the meeting was turned over to the former chair, Dr. William Sirignano. The committee broke up into section revision groups, which revised their own sections. On the second day of the meeting, further changes were recommended to bring the sections into agreement with each other, to address issues raised by the NRC's Report Review Committee and parent commission, and to correct problems noted by committee members during their review of the material prior to the meeting. While most major issues were resolved to the committee's satisfaction at this meeting, several discipline-specific questions remained. Individual members agreed to resolve them, with some revisions to the discipline sections of the report left as writing assignments. The report was resubmitted to institutional review later in the fall for delivery to the sponsor in early 1995.

CMGR Membership

Martin E. Glicksman, Rensselaer Polytechnic Institute (chair)
William A. Sirignano,* University of California at Irvine (former chair)
Robert A. Altenkirch, Mississippi State University
Rosalia N. Andrews, University of Alabama at Birmingham
Robert J. Bayuzick, Vanderbilt University
Howard M. Einspahr, Bristol Myers Squibb Company
L. Gary Leal, University of California at Santa Barbara
Ronald E. Loehman, Sandia National Laboratories
Alexander McPherson,* University of California at Riverside
Simon Ostrach,* Case Western Reserve University
Morton B. Panish, AT&T Bell Laboratories (retired)
Ronald F. Probstein, Massachusetts Institute of Technology
John D. Reppy, Cornell University
Warren C. Strahle, Georgia Institute of Technology (deceased)
Julian Szekely, Massachusetts Institute of Technology
Julia R. Weertman,* Northwestern University
Forman A. Williams, University of California at San Diego

Sandra J. Graham, Executive Secretary
Victoria Friedensen, Administrative Assistant

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*term expired during 1994

COMMITTEE ON PLANETARY AND LUNAR EXPLORATION

The Committee on Planetary and Lunar Exploration (COMPLEX) met at NASA Ames Research Center on February 23-25 to revise its report, *An Integrated Strategy for the Planetary Sciences: 1995-2010*, in response to NRC review. In addition, the committee continued to work on its study on the ability of small planetary (Discovery) missions to achieve priority objectives in planetary science. The committee heard briefings on NASA's recent "Roles and Missions" study and its potential impact on space science at Ames, and held a videoconference with Associate Administrator for Space Science Wesley Huntress on NASA's proposed FY95 budget and the proposed Mars Surveyor program. The committee heard a series of presentations by the principal investigators (PIs) of representative candidate Discovery missions. The goal was not to assess the scientific potential or programmatic risk associated with any particular mission, but rather to focus on management issues. Each of the proposals presented exhibited a different managerial relationship between the PI team, its industrial partner, and the associated NASA center. The day ended with a public presentation in Ames' space science auditorium by committee Chair Joseph Burns on current committee activities.

The final day of the meeting began with briefings on the status of the SOFIA and SIRTF projects. In discussing these two missions, the committee received a report on the previous week's meeting of the Board's Task Group on SIRTF and SOFIA from the committee's representative, Dr. Alan Tokunaga. The remainder of the day was devoted to further discussions of the Discovery program. The most important issue raised was continued uncertainty in the management of the Discovery program and, in particular, the amount of oversight NASA would exert over individual PI teams. The committee drafted an informal letter to the chair of the Board on its concerns in this area. The meeting ended with a tour of the NASA Kuiper Airborne Observatory.

The committee met again at the Beckman Center in Irvine, California, on May 31-June 3 to finish drafting the report, The Role of Small Missions in Planetary and Lunar Exploration. The meeting alternated between discussions, writing, and relevant presentations. Committee member Michael Carr and JPL's Charles Elachi briefed the committee on plans for future Mars missions, including Mars Surveyor, and on issues relating to international cooperation in Mars research. The committee dispersed into small groups to draft sections of the report on small missions, and later reconvened for an update report by member Maria Zuber on the Clementine mission. Later, member Barry Mauk gave a report on a recent Applied Physics Laboratory conference on small satellites. On the third day, committee member Fran Bagenal briefed the committee on activities and future plans of NASA's Outer Planets Science Working Group. The final presentation of the week came from member Alan Tokunaga, who had represented the committee on the Board's Task Group on SIRTF and SOFIA. By the end of the meeting, a completed draft of the body of the small missions report had been compiled from the sections prepared by the individual writing groups.

During the course of the meeting, members took time out from writing to discuss future study plans. Prime among these was a study of the lessons learned from Clementine, a topic arising out of Dr. Zuber's presentation and related work on the small missions report. A charge was drafted for discussion and approval at the Board's June-July meeting. Other suggested studies included an assessment of the Planetary Data System, instrumentation for planetary astronomy, the declining role of postdoctoral fellows in planetary science, and an assessment of the proposed Pluto Fast Flyby. Decisions about future plans were deferred until the October 10-12 meeting planned for Washington, D.C.

The committee met at the National Academy of Sciences in Washington, D.C., on October 10-12, to begin work on a study of the lessons learned from the Clementine mission. Most of the meeting was devoted to briefings on Clementine's scientific achievements and how they rated relative to the most important priorities in lunar science and to operational aspects of the mission. To this end, the committee heard from members of Clementine's science, engineering, and operations teams. The committee was also briefed on Ballistic

Missile Defense Organization plans for a Clementine follow-on, and also on NASA's plans for Lewis and Clark, a pair of low-cost, Earth-sensing satellites currently under development using a streamlined, Clementine-like management approach. By the end of the meeting, members had compiled an initial draft of text on Clementine's scientific achievements and detailed notes on the mission's implementation, budget, management, technology utilization, operations, and data processing. Work on this project was to continue at the committee's upcoming February meeting.

Much of the remainder of the meeting was devoted to briefings on the activities of the Board's task group on a proposed Ballistic Missile Defense Organization (BMDO) 4-meter telescope and on the status of the planetary astronomy programs at NASA and NSF. Time was also spent discussing suitable candidates for committee membership (including candidates for chair) and future study plans. Ideas discussed included an assessment of the Planetary Data System, instrumentation for planetary astronomy, the declining role of postdoctoral fellows in planetary science, and an assessment of NASA's Mars exploration plans. While no final decision was made, there was more interest in undertaking a Mars study than any of the other topics.

COMPLEX Membership

Joseph Burns, Cornell University (chair)
James R. Arnold, University of California at San Diego
Fran Bagenal, University of Colorado at Boulder
Geoffrey A. Briggs, NASA Ames Research Center
Michael H. Carr, U.S. Geological Survey
Philip R. Christensen, Arizona State University
James L. Elliot, Massachusetts Institute of Technology
John F. Kerridge,* University of California at San Diego
Barry H. Mauk, Johns Hopkins University
William McKinnon, Washington University
Norman R. Pace,* Indiana University
Darrell F. Strobel, Johns Hopkins University
Alan T. Tokunaga, University of Hawaii
George W. Wetherill, Carnegie Institute of Washington
Roger Yelle, University of Arizona
Maria Zuber, Johns Hopkins University

David H. Smith, Executive Secretary
Altoria Ross, Administrative Assistant

*term expired during 1994

COMMITTEE ON SPACE BIOLOGY AND MEDICINE

The Committee on Space Biology and Medicine (CSBM) met in Washington, D.C., on April 27-28. The primary purpose of the meeting was to draft a joint letter with the Committee on Microgravity Research on the research capabilities of the redesigned International Space Station Alpha (ISSA). A secondary purpose of the meeting was to discuss committee membership issues and future tasks for the committee.

Mr. David Moore of the Congressional Budget Office (CBO) discussed various options for changing the way NASA does business, as presented in the CBO March 1994 study, Reinventing NASA. Dr. Richard Obermann, of the House Space Subcommittee, discussed his views on critical issues facing NASA and what actions Congress might take on the agency's 1995 budget proposal.

Mr. Wilbur Trafton, deputy associate administrator for Space Station, and Captain William Shepherd, of JSC's Space Station Office, briefed the committee on the station's current design, the schedule for its assembly, and accommodations for research. Mr. Trafton reported that communication both within the station office and between that office and the rest of NASA had improved dramatically: "things that once took months now take minutes." Partially in response to a joint Committee on Space Biology and Medicine/Committee on Microgravity Research letter sent to NASA Administrator Daniel Goldin in February, the station's research manager is now collocated in the program office. Mr. Trafton reviewed highlights of the ISSA program over the past nine months, including the selection of a prime contractor (Boeing) and a major design review in March 1994. Goals for 1994 include closing out Space Station Freedom program contracts, clarification and refining of relationships with international partners, and the complete incorporation of Russia as a full partner on the Station.

Dr. Arnauld Nicogossian, deputy associate administrator for NASA's Office of Life and Microgravity Sciences and Applications (OLMSA), discussed current planning for the Shuttle-Mir program as a three-phase program. Phase I would include U.S. experiments, and crew and shuttle flights to Mir. Phase II would be a joint build-up of Mir, and Phase III would be completion and operation of the International Space Station with Russia, Canada, Europe, and Japan. Plans were for a U.S. crew member to fly on Mir from March to June 1995, and there would be a total of 24 months of U.S. crew stay-time on Mir. He noted that the only canceled Spacelab flight during Phase I was SLS-3 and stated that science scheduled for that flight was being transferred to other carriers. There was also the prospect of added Bion capability to fly life sciences experiments. A primary objective of the early Shuttle/Mir program would be to characterize Mir's environment in terms of acceleration, and vibroacoustic, radiation, atmospheric and water quality conditions as a context for understanding experiment results.

Dr. Harry Holloway, associate administrator for OLMSA, summarized developments in the ISSA program since transmittal of the committee's joint letter of February 25, 1994. A significant change was the creation of the position of chief scientist of orbital research, to work jointly with OLMSA and the Space Station Office. In addition, a research manager office (from OLMSA Headquarters) had been created and "matrixed" to the Space Station Office at JSC. Memoranda of understanding between OLMSA and the Space Station Program Office were under negotiation concerning roles and responsibilities in science integration, management, and development. OLMSA would design, build, and manage science facilities for the ISSA.

Dr. Joan Vernikos, director of NASA's Life and Biomedical Sciences and Applications Division, discussed issues associated with the space station and the Shuttle-Mir program, including Russian participation as research subjects, funding for and location of the centrifuge facility on the station, and accommodations for precursor research formerly scheduled for now-canceled Spacelab flights. Dr. Vernikos and Mr. Robert Rhome, director of the Microgravity Sciences and Applications Division, discussed their respective divisions' research plans for the station. Dr. Vernikos addressed (1) how priorities would be set, (2) the relationship of priorities to the committee's research strategy, (3) the strategy for selection and scheduling of research, and (4) the role of Russia and other international partners on the station. Mr. Rhome outlined the research announcement plan for the station and detailed his division's long-term research plan for ISSA.

The committee held its October 21-22 meeting in San Francisco, concurrent with the 10th Annual Meeting of the American Society for Gravitational and Space Biology (October 19-22) and a results symposium on the SLS-2 mission (October 23). Committee members were encouraged to attend as many of the ASGSB and SLS-2 sessions as possible and later reported that the direct exposure to the work of so many low-gravity investigators was very useful. The committee met in an open session on Friday, October 21, to listen to a number of presentations from NASA life sciences representatives. Dr. Vernikos presented an overview of the current structure and planning of life sciences work at NASA. Deputy Director Frank Sulzman briefed the committee on the division's new peer review process, which was implemented during the summer of 1994 to evaluate both intramural and extramural proposals. The committee expressed concern that this type of peer review process, which the committee had strongly urged NASA to adopt, might be dismantled due to changes in procurement requirements. A representative of the NASA Ames Research Center life sciences program, Dr. Charles Wade, made a presentation on work at the Center. The new chief of life sciences at Ames, Dr. Emily Morey-Holton, was also on hand to answer questions. In the discussion that followed the presentations, Dr. Vernikos outlined some of the problems with which her division was dealing and suggested areas in which the committee might provide useful guidance.

When the committee met in executive session the following day, it agreed on minor changes necessary to update its task statement. Each committee member then had an opportunity to propose potential new projects for the committee and these were discussed at length. A project plan was developed, and the committee agreed on the general wording of the plan before the meeting was adjourned.

CSBM Membership

Mary Jane Osborn, University of Connecticut (chair)
Fred W. Turek,* Northwestern University (former chair)
Robert E. Cleland, University of Washington
Mary F. Dallman, University of California at San Francisco
Francis (Drew) Gaffney, Vanderbilt University
Marc D. Grynpas, Samuel Lunenfeld Research Institute
James R. Lackner, Brandeis University
Robert W. Mann, Massachusetts Institute of Technology
Clinton T. Rubin,* State University of New York at Stony Brook
Fred D. Sack, Ohio State University
Warren K. Sinclair,* National Council on Radiation Protection and Measurements
Fred H. Wilt,* University of California at Berkeley

Sandra J. Graham, Executive Secretary
Joyce M. Purcell, former Executive Secretary
Victoria Friedensen, Administrative Assistant

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*term expired during 1994

COMMITTEE ON SOLAR AND SPACE PHYSICS

The Committee on Solar and Space Physics (CSSP) and the Committee on Solar-Terrestrial Research (CSTR) met jointly in Washington, D.C., on February 16-18 to continue work on their strategy report and to review the budget status of their sponsoring agencies. The CSTR is a committee of the NRC's Board on Atmospheric Sciences and Climate. The committees received presentations on FY95 budgets from NSF (Atmospheric Sciences Division), NASA, and NOAA. Dr. Timothy Killeen presented the status and scientific background for the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) mission. The committees discussed and revised sections of the strategy report. The report had been mailed earlier to members of the Board for review during its February-March meeting, and so revisions made at the joint committee meeting were later given to the Board as an update package.

The committees, which always meet in a federated configuration, considered a number of possible future activities to be undertaken after completion of the strategy report. These included preparing input for the NRC's Board on Atmospheric Sciences and Climate research strategy study (the committees would prepare a section of the report on middle and upper atmospheric science) and studying impacts of space weather, including effects on the electric power industry, communications satellites, and other space and ground systems. The committees decided to prepare a special report in response to a request to the NRC's Naval Studies Board on opportunities in upper atmospheric physics. This would be undertaken at a meeting in April. A special session on the Solar-Terrestrial Energy Program (STEP) was held in order to review the activities of the U.S. coordination office.

The committees met together at the Beckman Center on April 12-16 to continue work on their strategy report and to prepare a report sponsored by the U.S. Navy on research opportunities in upper atmospheric sciences. The committees spent April 12-13 working on a report for the Office of Naval Research, beginning with a videoconference on April 12 with Navy officials and NRC staff in Washington, D.C., to receive final instructions for the effort. The committees spent the rest of April 12 and 13 preparing the report on research opportunities in upper atmospheric sciences, which was reviewed by the Naval Studies Board. The remainder of the meeting, April 14-16, was spent working on the NASA research strategy report.

The federated committees met again at the Beckman Center on June 15-17 in order to continue work on the strategy report and discuss several new activities. CSTR Chair Marvin Geller reported on the recent Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) meeting in Sendai, Japan; CSTR is the U.S. National Committee for SCOSTEP. ICSU has recommended that SCOSTEP merge with either COSPAR or the International Association of Geomagnetism and Aeronomy (IAGA), but the federated committees felt that SCOSTEP should remain independent because of its role in managing international programs such as the Solar-Terrestrial Energy Program (STEP). Chair Geller prepared a letter to the president of SCOSTEP expressing this view on behalf of CSTR.

The committees discussed and revised sections of the space physics strategy report, which had been approved by the Space Studies Board in late February with several suggested revisions. A number of illustrations that would improve the document were identified. Once these illustrations were received at the Board office and needed revisions made, the report proceeded to NRC report review.

Also discussed were a number of potential future activities to be undertaken after the strategy report, including preparing input for a strategy study by the NRC's Board on Atmospheric Sciences and Climate. The federated committees would contribute a section of the report on middle and upper atmospheric sciences. The committees discussed the format of the study and a schedule for completing it, identified a number of topics that should be included, and made assignments for producing material on each. Impacts of space weather were further discussed. It was learned that several federal agencies were interested in this subject to varying degrees: NOAA and NSF seemed most interested, DOD uncertain, and NASA less interested. NASA Space Physics Division Director George Withbroe noted that potential customers' needs were not well expressed and that there was in fact not a wide perception of the existence of a problem. What was needed was a robust science study that would clearly explain the issues and demonstrate concrete examples of the effects of space weather on the terrestrial environment. He noted that such a study by the Academy would be useful.

Dr. Withbroe then briefed the committees on the status of NASA activities. He reported on ongoing and planned programs and noted that the environment within NASA was looking favorable for starting the solar-terrestrial probes; a new concept (a programmatic packaging of the solar probe and the Pluto flyby) called "Fire & Ice," a joint program with the Russians, was gaining momentum; the Explorer program would be shared 50/50 between NASA's astrophysics and space physics divisions; NASA was considering possible extended missions for Ulysses and the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) (although there would be a major budget problem in 1998); and TIMED needed to be downsized in order to reduce its cost below the $100M ceiling.

The committees met in Washington, D.C., on October 26-28 for their annual fall meeting. Much of the meeting was devoted to briefings from both agency representatives and user/providers on "space weather" activities and needs, and on plans for establishing a "National Space Weather Service." As described by Dr. Richard Behnke (NSF) and Col. Tom Tascione (DOD/USAF), such a national space weather service would be a multiagency cooperative effort to which NOAA, NSF, DOD, and NASA would contribute according to their interests. The effort was still in an organizational stage, but might eventually give rise to a coherent, applications-oriented branch of space physics research. In response to the current interest and activities relating to space weather, the joint committees considered (and a proposal was ultimately forwarded to the Board for approval for) the production of a briefing document on the scientific foundations for a national space weather program. This report would be based on the space weather aspects of the committee's report, A Science Strategy for Space Physics, in NRC review. In addition, the committee received a verbal request from NASA's Space Physics Division Chief George Withbroe for assistance in identifying future space science mission opportunities, and a proposal to do this was later forwarded to the Board for approval. The committees were also briefed by Dr. Larry Paxton (Applied Physics Laboratory) on the opportunities for space physics experiments using the MSX (Midcourse Space Experiment) spacecraft, soon to be launched by the Ballistic Missile Defense Organization (BMDO). Additional presentations were given by Dr. Mark Schoeberl (NASA Goddard Space Flight Center) on the Upper Atmosphere Research Satellite's contribution to solar and space physics and by Dr. Juan Roederer (University of Alaska) on work in the former Soviet Union on reported biological effects of solar variability.

CSSP Membership

Janet G. Luhmann, University of California at Berkeley (chair)
Marcia Neugebauer,* Jet Propulsion Laboratory (former chair)
Spiro K. Antiochos, Naval Research Laboratory

Janet U. Kozyra, University of Michigan
Donald G. Mitchell, Johns Hopkins University
Jonathan F. Ormes,* NASA Goddard Space Flight Center
George W. Parks,* University of Washington
Douglas M. Rabin,* National Optical Astronomy Observatories

Arthur D. Richmond, National Center for Atmospheric Research High Altitude Observatory
Harlan E. Spence, Boston University
Michelle F. Thomsen, Los Alamos National Laboratory
Roger K. Ulrich, University of California at Los Angeles
Ronald D. Zwickl,* National Oceanic and Atmospheric Administration

David H. Smith, Executive Secretary
Altoria Ross, Administrative Assistant

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*term expired during 1994

PROJECT ON THE FUTURE OF SPACE SCIENCE

The Future of Space Science (FOSS) project is a cluster of studies responding to FY94 Senate appropriations report language and a subsequent request by NASA Administrator Daniel Goldin. The Senate report language stated the following:

> *The future of space science*—The Committee has included $1,000,000 for the National Academy of Sciences to undertake a comprehensive and independent review of the role and position of space science within NASA. It will come as no surprise that the Committee did not support or recommend the dismantling of the Office of Space Science and Applications. The contributions made by that office in strategic planning, cross disciplinary priority setting, and management controls were among the best that the Federal Government has ever undertaken in any of its many scientific components. Given the administration's desire to reinvent Government, the Committee believes the time has come to seriously consider the creation of an institute for space science that would serve as an umbrella organization within NASA to coordinate and oversee all space science activities, not just those in physics, astronomy, and planetary exploration. Such an institute could function just as the National Institutes of Health now does within the Department of Health and Human Services. The Committee recognizes that there are certain tradeoffs in the creation of any new entity. The Academy should look at mechanisms for priority setting across disciplines on the basis of scientific merit, better means to include advanced technology in science missions, and ways to permit less developed scientific disciplines to have a means of proving their value, despite skepticism about them in the more established scientific fields.

Additional guidance was provided in the FY95 legislative report:

> *The future of space science*—The Committee is concerned that no new space

science missions are now planned to be launched by NASA after 1997 at this time. In addition, it is deeply troubled by reports that a so-called wedge of funding in the 1996 budget for any new science flight projects may require one-half of the funds to come from existing science budgets. Neither condition is acceptable, and the Committee will expect whatever pool of funds to be used for future new starts to come outside of the existing base of space science funds. The Committee expects the National Academy of Sciences to factor this funding and mission vacuum into its assessment for the need for a national institute for space science.

FOSS Steering Group

At an initial FOSS Steering Group (FOSS-SG) meeting on August 1-3 at Woods Hole, the group discussed the organization of the study as well as membership for its own expansion and for several supporting task groups. Statements of task for all elements of the study were approved, as well as a master schedule for the activity. The next activity of the steering group was set for early January 1995.

FOSS-SG Membership

John A. Armstrong, IBM Corporation (retired) (chair)
Anthony W. England, University of Michigan
Daniel J. Fink, D.J. Fink Associates, Inc.
Ursula W. Goodenough, Washington University
John M. Hedgepeth, Digisim, Inc.
Jeanne E. Pemberton, University of Arizona
William Press, Harvard-Smithsonian Center for Astrophysics
P. Buford Price, University of California at Berkeley
Roland W. Schmitt, Rensselaer Polytechnic Institute (retired)
Guyford Stever (retired)
James Wyngaarden, National Institutes of Health (retired)

Marc S. Allen, Executive Secretary
Carmela J. Chamberlain, Administrative Assistant

FOSS Task Group on Alternative Organizations

The FOSS Task Group on Alternative Organizations (FOSS-AO) met in Washington, D.C., on December 8-9. After a discussion by Chair Daniel Fink on the history and background of the study and the overall structure of the FOSS effort, members heard a series of orientation briefings. NASA Chief Scientist France Cordova described the present NASA organizational structure with emphasis on the science organizations, strategic planning, the role of the chief scientist, and NASA's relations with other federal agencies engaged in scientific programs. Subsequently, task group member Thomas Malone described the background, organization, infrastructure, and procedures of the National Institutes of Health (NIH). Each of the 24 institutes comprising NIH develops its own budget submission and has a significant advocacy community.

The group next met with Mr. Kevin Kelly, outgoing clerk of the Senate Subcommittee on Veterans Affairs, Housing and Urban Development, and Independent Agencies (VA-HUD-IA), who explained that the appropriations subcommittee's request for the FOSS study stemmed from the breakup of NASA's Office of Space Science and Applications (OSSA) into the three present science offices, and from concern that no senior science official at NASA was fully empowered to coordinate and establish priorities among these three science programs. Anticipating great competition among the science programs in FY96, including a planned Mission to Planet Earth program increase within a roughly constant (at best) total science budget, Mr. Kelly stated the possibility that the Congress would be forced to set science priorities itself. He insisted that scientists should set science priorities, and not politicians or general managers. He was also concerned with an apparent loss in planning continuity—a reference to former Associate Administrator Lennard Fisk's strategic and program planning approach that relied heavily on research community advisory committees in a consensus "Woods Hole process." He felt that at present the position of NASA's chief scientist, a staff position without a budget or line authority, has no institutional authority, independence, or control over field center activities.

At the end of the first day, the task group hosted a panel session of the three key science associate administrators: Dr. Wesley Huntress (Office of Space Science), Dr. Harry Holloway (Office of Life and Microgravity Sciences and Applications), and Dr. Charles Kennel (Office of Mission to Planet Earth). These officials discussed their respective organizations, how each developed strategic plans, and how they interacted with each other to evolve an overall NASA strategic science plan.

This was followed by members' discussion of a number of issues, including how to structure their final report and with whom they needed to talk at future meetings. It was suggested that the report would need an "environmental" section that would describe external forces on the agency. Some other themes that also emerged for consideration were: space science budgets are decreasing; the infrastructure is too large; the balance among universities, NASA, industry, other government agencies is not obviously optimum; "faster-better-cheaper" is driving change, with effects on the role of technology, risk, and infrastructure; the rationale for space science is changing; science is not always driving priorities (e.g., the proposed Pluto Fast Flyby is linked to technology motivation); and international cooperation (especially with Russia) is based on political considerations. The group concluded by setting a meeting schedule to complete its work.

FOSS-AO Membership

Daniel J. Fink, D.J. Fink Associates, Inc. (chair)
Martin Blume, Brookhaven National Laboratory
John F. Cassidy, United Technologies Research Center
Robert S. Cooper, Atlantic Aerospace Electronics Corporation

Gerald P. Dinneen, National Academy of Engineering
Harold B. Finger, General Electric Company (retired)
Hanna H. Gray, University of Chicago
Noel Hinners, Martin Marietta Astronautics Company
Thomas E. Malone, Association of American Medical Colleges (retired)
Norine E. Noonan, Florida Institute of Technology
James R. Thompson, Jr., Orbital Sciences Corporation
Arthur B.C. Walker, Jr., Stanford University
Sidney C. Wolff, National Optical Astronomy Observatories

Richard C. Hart, Executive Secretary
Nathaniel B. Cohen, Consultant
Carmela J. Chamberlain, Administrative Assistant

FOSS Task Group on Research Prioritization

The FOSS Task Group on Research Prioritization (FOSS-RP) held its first meeting on November 28-30 in Washington, D.C. After committee orientation, task group Chair Roland Schmitt welcomed Mr. Kevin Kelly, outgoing clerk of NASA's Senate appropriations subcommittee. Mr. Kelly explained the origin of the congressional request for the study and expressed Sen. Barbara Mikulski's desire that the conclusions of the report be clear and definitive, particularly with respect to institutional issues and ways of identifying programs for support.

Subsequently, the task group heard from a series of federal officials about priority setting at their agencies. Ms. Diana Josephson, Deputy Undersecretary of Commerce for Oceans and Atmospheres, briefed the task group on the NOAA Strategic Plan. She explained that the process of establishing priorities was part of the annual budget cycle. The first strategic plan was developed in ten weeks, employing a number of program teams aimed at building a consensus. Next, Ms. Judy Sunley, NSF Assistant to the Director for Science Policy and Planning, briefed the task group on NSF's strategic planning process, which was begun in January 1994 and involved three groups: a committee on strategic program planning (made up of the seven assistant directors and two office heads), a working group to outline and develop some of the details of the plan, and a task force of the National Science Board to follow the development of the plan. The essence of the approach was for the high-level leaders to establish priorities through a consensus process. The last speaker on agency planning processes was NASA Chief Scientist France Cordova. Dr. Cordova explained that the Board science strategies (and other NRC reports) served as the basis for NASA science planning. Science division implementation plans were developed with the help of internal advisory committees and were then integrated into science office strategic plans (in the case of the OSS, with the help of the Space Science Advisory Committee). The office strategic plans were incorporated into NASA's overall strategic plan. The conceptual framework for the NASA Strategic Plan was based on a number of "enterprises" (Mission to Planet Earth, aeronautics, human exploration and development of space, scientific research, and space technology), functions (transportation, space communications, human resources, and physical resources), and their interactions together and with primary customers, decision makers, and resource providers. Dr. Cordova stated a belief that the external scientific community could be helpful in setting priorities among different disciplines and in determining the proper balance between science and infrastructure. While science should be the most important criteria for setting priorities, there are some constraints such as the health of particular communities and infrastructure needs, for example.

Mr. Joseph Alexander, currently Environmental Protection Agency Deputy Assistant Administrator for Research and Development, but previously NASA Assistant Associate Administrator for Space Science and Applications, described how strategic planning was done within the former Office of Space Science and Applications (OSSA). He explained that there were three steps in the process: (1) individual disciplinary scientific goals and priorities were set by NRC committees; (2) internal NASA committees (the NASA Advisory Council and its subcommittees) then addressed operational and programmatic aspects to develop a priority list from criteria that included scientific merit as well as other measures such as technical feasibility and societal benefits; and (3) science managers at NASA Headquarters balanced these factors and responded to budget opportunities in structuring the final program.

Since several task group members had been involved in other NRC studies that addressed priorities, Chair Schmitt asked each member to comment on past experiences. A discussion arose about a possible approach of fixed allocations for different scientific disciplines in an analogy to an investment strategy where a portfolio is structured with consideration to characteristics such as risk versus reward, asset allocation, and diversification. The meeting ended with scheduling the date for the task group's final meeting, and with a teleconference with Board Chair Claude Canizares. Dr. Canizares thanked the members for serving and invited any questions. He also noted that the Board's disciplinary committees have been asked to provide input from their communities to the FOSS study.

FOSS-RP Membership

Roland W. Schmitt, Rensselaer Polytechnic Institute (retired) (chair)
William F. Brinkman, AT&T Bell Laboratories
Larry W. Esposito, University of Colorado at Boulder
Robert A. Frosch, Harvard University
David J. McComas, Los Alamos National Laboratory
Christopher F. McKee, University of California at Berkeley
Morton B. Panish, AT&T Bell Laboratories (retired)

Carlé M. Pieters, Brown University
Rudi Schmid, University of California at San Francisco
Eugene B. Skolnikoff, Massachusetts Institute of Technology

Richard C. Hart, Executive Secretary
Carmela J. Chamberlain, Administrative Assistant

FOSS Task Group on Technology

The FOSS Task Group on Technology (FOSS-T; formerly the Joint Committee on Technology), operated jointly with the NRC's Aeronautics and Space Engineering Board, met on August 23-24 in Washington, D.C. Ms. Mary Kicza, assistant associate administrator (Technology) for the Office of Space Science (OSS), delivered a detailed presentation on that office's April 1994 Integrated Technology Strategy. The committee members were very interested, and it was decided that the plan and its implementation would be a major focus of the next meeting, scheduled for November 14-16. The two other NASA science offices, the Office of Life and Microgravity Sciences and Applications and the Office of Mission to Planet Earth, briefly discussed their planning in advanced technology development.

Dr. Giulio Varsi of OSS described the Discovery Technology Program and the Discovery Technology Fair planned for August 25 in Crystal City, Virginia. The program was designed to promote the development of less expensive spacecraft for space science missions.

NASA Chief Engineer Wayne Littles also met with the committee. He stated that his role is compatible with the first general recommendation of the NRC report Improving NASA's Technology for Space Science (National Academy Press 1993): "The NASA Administrator . . . should act to establish a coordinating position with the clear responsibility to ensure cooperation between technology development efforts within different parts of NASA . . . " (p. 3). Mr. Littles believed that the impetus for using new or advanced technology in missions should be to reduce their cost and to enable things that would not otherwise be affordable. NASA Chief Scientist Cordova was scheduled to attend but was unable to be present.

The task group met again in Washington, D.C., on November 14-16 to receive comprehensive briefings from each of the NASA offices involved with technology for space science and to discuss future plans. The committee heard briefings from the following individuals and organizations: Chief Scientist Cordova, Ms. Mary Kicza of the Office of Space Science, Mr. Michael Kaplan of the Astrophysics Division, Dr. Miriam Forman of the Space Physics Division, Mr. Giulio Varsi of the Solar System Exploration Division, Messrs. Granville Paules and Mike Luther of the Mission to Planet Earth, Mr. Sam Venneri of the Office of Space Access and Technology, Dr. Bert Hansen of the Office of Life and

Microgravity Sciences and Applications, Mr. Gary Martin of the Microgravity Sciences and Applications Division, and Dr. Guy Fogleman of the Life and Biomedical Sciences and Applications Division. The meeting was attended also by an invited technical advisor to the committee, Dr. Henry Plotkin, recently retired from NASA Goddard Space Flight Center. The members agreed to prepare write-ups on the NASA briefings and related discussions. During an executive session, the committee reviewed the overall schedule for the FOSS study and agreed to develop a committee report to be delivered to the FOSS Steering Group in July 1995. A tentative calendar of 1995 meetings to meet this schedule was set.

FOSS-T Membership

Anthony W. England, University of Michigan (co-chair)
John M. Hedgepeth, Digisim, Inc. (co-chair)
Joseph P. Allen, Space Industries International, Inc.
Robert P. Caren, Lockheed Corporate Headquarters
John J. Donegan, U.S. Navy (retired)
James W. Head III, Brown University
John M. Logsdon, George Washington University
Simon Ostrach, Case Western Reserve University
Judith Pipher, University of Rochester
Alfred Schock, Orbital Sciences Corporation

Noel E. Eldridge, Executive Secretary
Carmela J. Chamberlain, Administrative Assistant

TASK GROUP ON PRIORITIES IN SPACE RESEARCH

Revision of the final report of the Task Group on Priorities in Space Research (TGPSR) continued during 1994. After a series of discussions during 1993 when it was determined by the Board that the instrument developed by the task group would not be adopted for operational use, it was decided to recast the final report simply as a summary of the instrument's two trial applications, but without recommendations. This rewritten version of the report was submitted for NRC review in late 1994 and is expected to be released in 1995.

TGPSR Membership*

John A. Dutton, Pennsylvania State University (chair)
William P. Bishop, Desert Research Institute
Lawson Crowe, University of Colorado at Boulder
Peter Dews, Harvard Medical School
Angelo Guastaferro, Lockheed Missiles and Space Company, Inc.

Molly K. Macauley, Resources for the Future
Thomas A. Potemra, Johns Hopkins University
Arthur B.C. Walker, Jr., Stanford University

Marc S. Allen, Executive Secretary
Joyce M. Purcell, former Executive Secretary
Carmela J. Chamberlain, Administrative Assistant

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*task group disbanded during 1993

TASK GROUP ON SIRTF AND SOFIA

The Task Group on SIRTF and SOFIA (TGSS) met at NASA Ames Research Center on February 17-18. In connection with plans to redesign and/or rescope the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA), NASA had requested that the NRC assess the potential impact of proposed changes to these programs on their abilities to achieve their respective scientific goals. The Committee for Astronomy and Astrophysics (CAA), operated jointly by the Space Studies Board and the Board on Physics and Astronomy, established the task group to carry out this review.

The task group's charge was to determine whether the rescoped missions remained responsive to the principal infrared astronomy scientific objectives identified in the NRC report The Decade of Discovery in Astronomy and Astrophysics (National Academy Press 1991), in previous recommendations of the Space Studies Board's Committee on Space Astronomy and Astrophysics, and in earlier astronomy and astrophysics survey committee reports. At the meeting, the task group heard a series of presentations by Drs. Michael Werner, Edwin Erickson, George Rieke, David Hollenbach, Theodore Dunham, and Lawrence Simmons. A draft report was prepared and submitted to the Space Studies Board for approval at its February-March meeting. This report was approved and issued in final form in April.

TGSS Membership*

Doyal A. Harper, Yerkes Observatory (chair)
Anneila I. Sargent, California Institute of Technology (vice-chair)
Frederick Gillett, National Optical Astronomy Observatories
Daniel McCammon, University of Wisconsin

Philip D. Nicholson, Cornell University
Alan Tokunaga, University of Hawaii
Charles Townes, University of California at Berkeley

James Houck, Cornell University, liaison from the NASA Astrophysics Mission Operations Working Group

Robert L. Riemer, Executive Secretary
Anne K. Simmons, Administrative Assistant

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*task group disbanded during 1994

TASK GROUP ON THE BMDO NEW TECHNOLOGY ORBITAL OBSERVATORY

The Task Group on the Ballistic Missile Defense Organization (BMDO) New Technology Orbital Observatory (TGBNTOO) met three times during the final quarter of 1994. Its first meeting was held at Itek Optical Systems in Lexington, Massachusetts, on October 6-7, to begin work assessing the astronomical potential of BMDO's proposed 4-meter space telescope. In addition to presentations on the project from Lockheed and Itek officials, the task group toured Itek's facilities for the production and testing of large optics. The committee viewed the 4-meter Adaptive Large Optics Technologies (ALOT) telescope in Itek's large, thermal vacuum chamber and saw elements of the 11-meter Large Optical Segment (LOS) project being figured and tested. During the course of the meeting, the committee composed a list of questions about the optical and spacecraft components of the proposed telescope. In addition, members were assigned individual tasks to be completed in time for the next meeting at Lockheed. These tasks included assessments of minimum requirements for a Kuiper belt survey; minimum requirements for an occultation project; an optical layout for instruments with fewer surfaces and components; a parametric study of the optics error budget; minimum requirements for a 2-micron survey; comments on optical design issues; and information on reliability and lifetime of closed-cycle coolers.

The task group's second meeting took place at the Lockheed Missiles and Space Company in Sunnyvale, California, on November 17-18 (and November 19 at the committee hotel) to continue its assessment of the astronomical potential of BMDO's proposed 4-meter space telescope. In addition to presentations (many in response to questions submitted by the committee following the October meeting at Itek), the committee toured Lockheed facilities relevant to a possible 4-meter telescope flight project. These facilities included the DELTA thermal vacuum chamber, a large acoustic test chamber, the assembly line for MILSTAR, Mir, and Space Station solar arrays, and the F-Sat/Iridium assembly area. On the final morning of the meeting the committee drafted a detailed outline of portions of the report and distributed new writing assignments.

The task group held its final in Washington, D.C., on December 19-20 to complete its assessment of the proposed 4-meter space telescope. Members learned of Dr. Holland Ford's resignation from formal membership and welcomed Dr. Roger Angel to full membership on the task group. There was a brief discussion of Col. Gary Payton's letter of October 24 stating BMDO's termination of all support for space experiments within the Directed Energy Program. The task group statement of task was subsequently slightly revised to reflect this. The remainder of the meeting was devoted to discussions, drafting of sections of the report, and formulating final conclusions. The task group's near-term goal was to circulate a new draft, incorporating material written during or soon after the meeting in order to expedite Board and NRC review.

TGBNTOO Membership

Michael F. A'Hearn, University of Maryland (chair)
Roger Angel, University of Arizona
Anita Cochran, University of Texas at Austin
James L. Elliot, Massachusetts Institute of Technology
Christ Ftaclas, Hughes Danbury Optical
Garth D. Illingworth, University of California at Santa Cruz

Holland C. Ford, Johns Hopkins University, liaison from Space Telescope Science Institute

David H. Smith, Executive Secretary
Altoria Ross, Administrative Assistant

TASK GROUP ON GRAVITY PROBE B

Gravity Probe B (GP-B) is a complex experimental program in gravitational physics that has been under development for more than 30 years. This flight experiment is intended to measure, for the first time, the Lense-Thirring effect, one of the predictions of Einstein's theory of relativity; it will also measure geodetic precession with unprecedented accuracy. With additional program costs projected at $340 million, this is now the third costliest NASA space science mission after AXAF and Cassini. During the past several years, a number of prominent scientists have questioned the scientific value of the program, while others have strongly defended it. Because of the tight constraints on present and near-term future NASA budgets, the NRC has been asked to perform a critical review of the scientific merit and prospects for success of the GP-B mission. The scope of the study will encompass three issues:

- Scientific importance—including a current assessment of the value of the project in the context of recent progress in gravitational physics and relevant technology;

- Technical feasibility—the technical approach will be evaluated for likelihood of success, both in terms of achievement of flight mission objectives but also in terms of scientific conclusiveness of the various possible outcomes for the measurements to be made; and

- Competitive value—if possible, GP-B science will be assessed qualitatively against objectives and accomplishments of one or more projects of similar cost (e.g., the Cosmic Background Explorer—COBE).

In order for the results of the study to be ready in time to affect the FY96 NASA budget request, they are to be presented to the NASA Administrator by June 1, 1995. Meetings of the task group (TGGPB) are planned for January, February, and March 1995.

TGGPB Membership

Val L. Fitch, Princeton University (co-chair)
Joseph H. Taylor, Jr., Princeton University (co-chair)
Eric B. Adelberger, University of Washington
Gerard W. Elverum, Jr., TRW Space and Technology Group (retired)
David G. Hoag, Draper Laboratories (retired)
Francis E. Low, Massachusetts Institute of Technology
John C. Mather, NASA Goddard Space Flight Center
Richard E. Packard, University of California at Berkeley
Robert C. Richardson, Cornell University
Stuart L. Shapiro, Cornell University
Mark W. Strovink, University of California at Berkeley
Clifford M. Will, Washington University

Ronald D. Taylor, Executive Secretary
Susan G. Campbell, Administrative Assistant

Last update 8/25/00 at 4:19 pm

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3
Summaries of Major Reports

[Executive summary text is not provided below;
instead, links are provided to the online reports.]

3.1 Scientific Opportunities in the Human Exploration of Space

A Report of the Committee on Human Exploration

3.2 A Space Physics Paradox

A Report of the Committee on Solar-Terrestrial Research and
the Committee on Solar and Space Physics

3.3 An Integrated Strategy for the Planetary Sciences: 1995-2010

A Report of the Committee on Planetary and Lunar Exploration

3.4 ONR [Office of Naval Research] Research Opportunities in Upper Atmospheric Sciences

A Report of the Committee on Solar-Terrestrial Research,
Committee on Solar and Space Physics,
and the Naval Studies Board

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4
Short Reports

During 1994, the Space Studies Board and its committees and task groups issued four short reports, which this section presents in full in chronological order of release. Two of them, reprinted in Sections 4.1 and 4.4, provide guidance on the Space Station and Shuttle-Mir programs developed jointly by the Board's Committee on Microgravity Research and Committee on Space Biology and Medicine. Section 4.2 presents an assessment of two prospective programs in space infrared astronomy, the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA). In July 1994, the Board reiterated previous advice regarding the Advanced X-ray Astrophysics Facility (AXAF) and the Cassini Saturn-Titan mission; this short report is presented in Section 4.3.

[Short report text is not provided below;
instead, links are provided to the online short reports.]

4.1 On Life and Microgravity Sciences and the Space Station Program

The Space Studies Board's Committee on Space Biology and Medicine and the Committee on Microgravity Research jointly sent the following letter to NASA Administrator Daniel S. Goldin on February 25, 1994.

4.2 On the Space Infrared Telescope Facility and the Stratospheric Observatory for Infrared Astronomy

The Space Studies Board sent the following letter and short report to Wesley T. Huntress, Jr., NASA Associate Administrator for Space Science, on April 21, 1994.

4.3 On the Advanced X-ray Astrophysics Facility and Cassini Saturn Probe

On July 5, 1994, the Space Studies Board sent the following letter to Presidential Science Advisor John Gibbons.

4.4 On the Utilization of the Space Station

On July 26, 1994, the Space Studies Board, Committee on Space Biology and Medicine, and Committee on Microgravity Research sent the following short report to NASA Administrator Daniel S. Goldin.

Menu

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http://www.nap.edu/catalog/12187.html

On Life and Microgravity Sciences and the Space Station Program

On February 25, 1994, Space Studies Board Chair Louis Lanzerotti, Committee on Space Biology and Medicine Chair Fred Turek, and Committee on Microgravity Research Chair William Sirignano sent the following letter to NASA Administrator Daniel Goldin.

Following their joint meeting last November 4 with you, Bryan O'Connor, and Harry C. Holloway concerning planning for the space station, the Space Studies Board's Committee on Space Biology and Medicine (CSBM) and Committee on Microgravity Research (CMGR) wrote a summary of their reactions to the discussion and plans along with associated recommendations.[1] Important decisions concerning selection and management of space station science are currently being made and will continue to be made over the next several months. It is the objective of the Board and its committees to contribute positively to these ongoing discussions and decisions as they are occurring rather than after the fact in order to help assure the scientific underpinnings of the station during this formative stage. In brief, the Board and the CSBM and CMGR have concluded the following:

1. Research in space biology and medicine and in microgravity conducted under the space station program should be selected and managed using proven techniques employed by the Office of Space Science and Applications (OSSA) in the past, for example, with the Spacelab program, which should serve as a model for space station research planning. The responsibility for these activities should reside with the Office of Life and Microgravity Sciences and Applications (OLMSA), not with the Space Station Program Office. Placing responsibility for selecting and managing space station science outside of the OLMSA could have a number of detrimental effects (see pages 2-3 below).

2. Termination or restructuring of the long-planned Spacelab program could result in the loss of much high-quality science and essential data that should be used in planning the design of the space station for research utilization (see page 4 below).

Rapid political and economic developments around the world are combining with severe budgetary pressures to create turbulence in the U.S. civil space program, including the space station program. Clearly, issues related to building and operating the space station will continue to be discussed and debated within NASA, with the Congress, and with our international partners before final resolution is obtained. The research community that will use the space station has a responsibility to the American public to provide advice on how to ensure optimal scientific return from the orbital laboratory. The Board and its committees recognize that only a snapshot of space station planning is

currently available and that the information provided on November 4 does not reflect final decisions. The intent is to offer constructive suggestions about critical research management issues and the precursor research programs.

As you know, based on its charter and expertise, the Board has provided continuing advice on basic science and research aspects of the human spaceflight program. Several times since 1983, the Board has provided advice on the space station.[2-4] Although the Board's 1991 and 1992 statements acknowledged that the space station would serve national goals other than science, such as education and stimulating the U.S. technology base, both statements emphasized the need to appropriately design and equip the station for effective research by the life and microgravity sciences, the two principal disciplines the space station is intended to serve. The presidential directive to redesign the space station and plans to integrate the station with the Russian space station program prompted the Board to ask its CMGR and CSBM for a new review of the space station program that would focus on research management and the station's technical capability to support a research program. At the November 4 meeting, the CMGR and CSBM looked at planning for research management for the space station program and at precursor research during the period leading up to the station's availability. The two committees expect to consider the station's capabilities for enabling scientific research at a later date when its design is better defined. The role of OLMSA in managing the space station research program, and some recommendations regarding pre-station use of the space shuttle for preparatory research and cooperative research opportunities on Russian facilities, are discussed below.

Planning and Management to Enable Scientific Research

Planning and operating a space station as an international research facility will clearly present special challenges. Among the complex issues are how research opportunities will be advertised, how experiments will be reviewed for selection, how data will be archived and made available, how research time will be allotted, and how research management responsibilities will be allocated among international partners. It is imperative that a rigorous process of open solicitation, peer review, and continued input from the scientific community be developed and followed by NASA for the space station program.[5]

Getting the best research results from the space station will require maximizing the quality of each individual phase of the research process, as well as integrating the phases smoothly into a coherent whole, beginning with early

planning stages and continuing through hardware design and development to flight operations and data analysis. An optimal program must also include vitally important contributions from underlying theoretical and supporting ground-based research programs. All of these components must be fitted together in a balanced and cost-effective way that includes flight opportunities as only one element, albeit a central one, of an integrated orbital research program.

The Board and its committees are concerned about whether a scenario in which the Space Station Program Office manages this complex process would give the best results. The Advisory Committee on the Redesign of the Space Station (the Vest Committee) recommended that the space station management organization include a Research Manager line position, with corresponding influence on development of the space station system and operations.[6] It is the committees' understanding that the purpose of this recommendation was to encourage a management structure in which the science utilization function plays more than an advisory staff role. During the November meeting, the committees' impression was that the space station program managers interpreted the Research Manager's role in broader terms, to include essentially all aspects of the orbital research program-definition of the science program, selection of investigations and experimenters, and development and operation of the flight hardware.

Specific concerns of the committees about possible detrimental effects on an integrated research program from structuring science management along flight hardware development lines include the potential for the following:

- Lack of attention to the supporting ground-based and theoretical research programs and poor integration of these programs into the flight program;

- Lack of familiarity with the science community and the process of scientific investigation versus the engineering and system development process;

- Weakened recognition that the research community does not divide cleanly, if at all, along flight experiment facility lines (e.g., there are not separate science communities for a centrifuge, cell culture system, human physiology equipment, and so on);

- Inadequate resources devoted to, or distraction of management attention from, use of the space station for scientific research. Research utilization must function in the context of the very real demands of developing a uniquely complex, human-rated, highly visible, and international space station system under tight budget pressure;

- Lack of focus on the needed evolution of instrumentation over the lifetime of the space station system; and

- Lack of emphasis on data analysis, storage, accessibility, and dissemination.

The Integrated Product Team concept described to the committees, wherein individual flight-facility-oriented development teams are managed in turn by OLMSA, the Space Station Program Office, and then again by OLMSA, would not appear to vitiate these concerns.

NASA's OLMSA has two divisions devoted entirely to developing and operating major scientific programs conforming to the best recognized standards of science management, used effectively in the past by the former OSSA. Founded on the principles of open solicitation and intimate involvement of the most able researchers in their areas, these standards have demonstrated success in generating scientific advances from federal investment. The Board and the CSBM and CMGR recommend that NASA utilize these standards and its existing science offices structure to effectively manage use of the space station for scientific research.

The CMGR's and CSBM's specific recommendations are the following:

1. The space station system Research Manager should be directly responsible to the science offices responsible for flying space station payloads. NASA should adopt for the space station program the approach used successfully in planning and managing the research for the Spacelab program, which provides for both a flight director and a mission manager. The space station mission (research) manager should be responsible for the payloads and associated risks, including analysis and integration, establishment of milestones, and crew training. That person should be responsible to the science offices, whereas the flight director, who is responsible for the spacecraft, launch and landing, mission operations, and so on, should be responsible to the Office of Space Flight.

2. OLMSA should be responsible for defining the life and microgravity sciences research to be performed aboard the space station. To ensure a broad and balanced research program, including theoretical and ground-based components, OLMSA should actively involve the microgravity and life sciences research communities.

3. Once it has defined the science program, OLMSA should manage and conduct open solicitation and peer-reviewed selection of all experiments to be flown, including those for both operational and fundamental science studies, in concert with its international collaborators.

4. OLMSA should provide mechanisms by which the international scientific community can have direct and continued input into the design, development, and operation of the space station and its scientific hardware.

Spacelab Utilization
and Cooperative Research Opportunities on Mir

In order to make the most effective use of the space station, it is essential to have a complete and current body of scientific data and experience relevant to the design of experiments that will fly. The Board, the CMGR, and the CSBM are concerned about the possible termination of the long-planned Spacelab program as NASA proceeds with the emerging Shuttle-Mir program. Spacelab accounts for virtually all of the life and microgravity science experiments published in the shuttle era. Spacelab should continue, not just as a visible U.S. commitment both to the U.S. scientific community and to ESA, but also because Spacelab science results will be critical for defining space station science.

Cooperating with the Russians on Mir may provide political, technological, and, possibly, scientific advantages (i.e., long-duration on-orbit experience). However, the extremely successful space life sciences and international microgravity missions that have flown on Spacelab indicate that Spacelab can provide more high-quality science than can Mir, at least in the near term. (Mir presently lacks some essential scientific capabilities: no freezer or storage facilities, no in-flight analytical capability, no sample return capability, no on-board computing capability, and no down-link video[7]) For example, Spacelab's greater capability may be particularly evident in the case of SLS-4, Neurolab. This mission, planned in active cooperation between NASA and the National Institutes of Health (NIH), represents a new direction for space life sciences that has been strongly encouraged by both the research community and the Congress. With responses to the Neurolab Announcement of Opportunity now in hand, continued support for this mission is essential to strengthen cooperation between NIH and NASA. Cancellation of the mission or substitution of middeck experiments for a dedicated Spacelab mission would have serious consequences for meeting this objective and for the continued participation of the mainstream life sciences community that NASA seeks to attract.

The availability of a suitably equipped Spacelab on planned crew exchange missions would greatly enhance the science yield of the Mir missions. Repeated flights of similarly configured missions should be cost-efficient and maintain life and microgravity science research capabilities while the new international station is being developed.

Because plans for cooperative space science research efforts between the United States and the Russians have not yet been fully defined, the Board and its committees cannot explicitly address their potential effects on U.S. life and microgravity sciences research. However, it is realistic to infer significant impacts on the currently planned program. The Board and its committees strongly encourage NASA to thoroughly analyze, document, and discuss with the affected research community the current and potential research capability of Mir. Spacelab must be available for certain experiments. Research opportunities provided by the Shuttle-Mir flights should be carefully planned and should be used to maximum scientific advantage. Research opportunities with the Bion/Cosmos program should also be exploited. Data obtained from Shuttle-Mir flights and the Bion/Cosmos program, along with data from Spacelab, will help in planning for effective use of the space station for scientific research.

In summary, the Board, the CMGR, and the CSBM strongly recommend that until the space station becomes operational, Spacelab continue to be used for scientific research in order to (1) maintain a forefront research program that is capable of contributing to design of a space station that can be used productively for life and microgravity sciences research; (2) maximize use of existing experiments, hardware, and technologies; (3) develop and test new hardware and technologies for their use on the space station; (4) facilitate interactions within the broader research community; and (5) provide an in-flight test facility to characterize and evaluate samples and subjects during flight and prior to reentry after long-duration missions.

As discussions and planning for the space station program evolve, the Board and its committees expect to continue to provide advice on maximizing the scientific return from the space station program and on the role of Spacelab in this regard. We look forward to continuing this dialogue as the space station program continues to evolve.

NOTES

[1]Presentations by Daniel S. Goldin, NASA Administrator, Bryan O'Connor, Acting Space Station Program Director, Harry C. Holloway, Associate Administrator of the Office of Life and Microgravity Sciences and Applications, Joan Vernikos, Director, Division of Biomedical Sciences and Applications, and Robert Rhome, Director of the Microgravity Science and Applications Division, to a joint committee meeting of the Space Studies Board's Committee on Space Biology and Medicine and Committee on Microgravity Research, November 4, 1993.

[2]Space Science Board Assessment of the Scientific Value of a Space Station and letter to NASA Administrator James Beggs, September 9, 1983; Space Studies Board Position on Proposed Redesign of Space Station Freedom Program, March 14, 1991; and Space Studies Board Assessment of the Space Station Freedom Program, March 30, 1992. Space Studies Board letter to Joseph Alexander, Assistant Associate Administrator for the Office of Space Science and Applications, NASA Headquarters, December 12, 1990.

[3]Space Studies Board testimony to the U.S. Senate Subcommittee on VA, HUD, and Independent Agencies, Committee on Appropriations, May 1, 1987, and Space Studies Board testimony to the U.S. Senate Committee on Science, Space, and Technology, May 10, 1990. Space Studies Board testimony to U.S. House of Representatives Task Force on Defense, Foreign Policy, and Space, Committee on the Budget, April 28, 1992.

[4]Space Studies Board, *A Strategy for Space Biology and Medical Science for the 1980s and 1990s*, National Academy Press, Washington, D.C., 1987; *Assessment of Programs in Space Biology and Medicine 1991*, 1991; *Toward a*

Microgravity Research Strategy, 1992; and *A Strategy for Microgravity Research for the 1990s*, in preparation.

[5]Committee on Space Biology and Medicine letter to Harry C. Holloway, Associate Administrator, Office of Life and Microgravity Sciences and Applications, NASA Headquarters, April 26, 1993.

[6]*Final Report to the President, Advisory Committee on the Redesign of the Space Station*, June 10, 1993, The President's Advisory Committee on the Redesign of the Space Station.

[7]Vladimir Titov, Soviet Cosmonaut, Long-duration Experience on Mir, presentation to the Committee on Space Biology and Medicine, February 14, 1990; Marcia Smith, Congressional Research Service, The Soviet Manned Space Program-Overview, presentation to the Committee on Space Biology and Medicine, May 13, 1991; Samuel Keller, NASA Headquarters, U.S./USSR Cooperative Activities-Status, May 14, 1991; Frank Sulzman, NASA Headquarters, Description of Soviet Space Station Mir: Size, Resources, Utilization Issues, May 14, 1991; Richard Obermann, U.S. House of Representatives, Committee on Science, Space, and Technology, Feasibility of U.S./USSR Mir for Cooperative Life Sciences Research, discussion with Committee on Space Biology and Medicine, February 13, 1992; Frank Sulzman, NASA Headquarters, Research Potential and Issues Associated with U.S. Use of Mir-Options, Advantages, and Disadvantages, presentation to the Committee on Space Biology and Medicine, May 14, 1992; Frank Sulzman, NASA Headquarters Update-U.S./USSR Cooperation, Status of Facilities, presentation to the Committee on Space Biology and Medicine, September 29, 1992; Joseph Alexander, NASA Headquarters, Potential U.S./USSR Cooperative Life Sciences Research Using Shuttle-Mir, January 27, 1993; Joan Vernikos, NASA Headquarters, Update on Planning for Shuttle-Mir Missions, April 29, 1993; and Joan Vernikos, NASA Headquarters, Optimizing the Scientific Benefits of the U.S./Russian Shuttle-Mir Program, November 5, 1993.

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On the Space Infrared Telescope Facility and the Stratospheric Observatory for Infrared Astronomy

On April 21, 1994, Space Studies Board Chair Louis Lanzerotti sent the following letter to Dr. Wesley Huntress, associate administrator for NASA's Office of Space Science.

In your letter to Prof. Marc Davis, Chair of the Committee on Astronomy and Astrophysics (CAA), dated November 9, 1993, you requested that the National Research Council (NRC) conduct an assessment of scientific capability of the rescoped Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA) in the light of previous NRC recommendations for space and airborne astronomy. The CAA, a joint committee of the Space Studies Board and the Board on Physics and Astronomy, established a Task Group on SIRTF and SOFIA to perform this study. I am pleased to enclose the Task Group's report.

Please contact me if you have any questions about the report.

REPORT OF THE TASK GROUP ON THE SPACE INFRARED TELESCOPE FACILITY AND THE STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY

I. INTRODUCTION

In the 1991 National Research Council report, *The Decade of Discovery in Astronomy and Astrophysics*, the Astronomy and Astrophysics Survey Committee characterized the 1990s as "the Decade of the Infrared." The Bahcall report (after the Committee Chair, John Bahcall) expected that the ongoing revolution in the technology for detecting infrared and submillimeter radiation would lead to major advances in our understanding of fundamental astronomical problems ranging from solar system studies to cosmology. To this end, the report (pp. 75-80) strongly recommended three new infrared equipment initiatives:

- The Space Infrared Telescope Facility (SIRTF)-a 0.9-m-diameter, liquid-helium-cooled telescope with unprecedented sensitivity for imaging and moderate-resolution spectroscopy between 2 and 700 μm, to be launched by a Titan IV-Centaur into a high Earth orbit (altitude 100,000 km);

- An 8-m-diameter telescope, optimized for low-background, diffraction-limited operation between 2 and 10 μm and equipped with adaptive optics, to be built on Mauna Kea, Hawaii; and

- The Stratospheric Observatory for Infrared Astronomy (SOFIA)-a 2.5-m-diameter telescope mounted in a Boeing 747 aircraft and optimized for diffraction-limited imaging and high-resolution spectroscopy from 30 μm to submillimeter wavelengths.

SIRTF and the 8-m ground-based telescope were the highest-priority large, new initiatives in, respectively, the space- and ground-based categories. SOFIA was one of the highest-rated moderate initiatives. The report stressed that the combination of these three instruments provided enormous potential for discovery in the large and relatively unexplored wavelength band between 1 and 1000 μm-an especially relevant spectral region for studies of cosmology, galaxy evolution, star-forming regions, and planetary systems.

Since the report's release in 1991, NASA's ability to undertake new missions, particularly large missions, has become increasingly constrained. The constraints have arisen not only from budget restrictions, but also from concerns about the risks associated with large, complex missions. NASA planners are now rescoping proposed initiatives to comply with new guidelines for the development of scientific missions. NASA's Associate Administrator for Space Science, Wesley T. Huntress, Jr., has requested that the Committee for Astronomy and Astrophysics (CAA)[1] assess the effects of proposed changes to the SIRTF and SOFIA programs on their respective abilities to achieve the scientific goals that justified their high rankings in the Bahcall report.

In response, the CAA established a task group with CAA members Doyal Harper (University of Chicago) as chair and Anneila Sargent (California Institute of Technology) as vice chair to review the current status of SIRTF and SOFIA. Members of the Task Group on SIRTF and SOFIA (TGSS) are listed in Appendix A [not provided]. Their charge was to "determine whether the rescoped Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA) missions remain responsive to the principal scientific objectives identified in the report The Decade of Discovery in Astronomy and Astrophysics (the Bahcall report) for infrared astronomy and [to] previous recommendations of the Space Studies Board's Committee on Space Astronomy and Astrophysics and earlier astronomy and astrophysics survey committee reports." The charge specified further that "[t]he TGSS's determination will be based on an evaluation of technical information about rescopings of these two major NASA programs."

The TGSS met at NASA's Ames Research Center on February 17 and 18, 1994, and heard presentations from representatives of both SIRTF and SOFIA. Project Scientists Michael Werner (JPL, SIRTF) and Edwin Erickson (NASA-Ames, SOFIA) described the status of their respective missions, including the scientific and technical rationale behind the redesign of the mission elements and expected costs. The scientific aims of SIRTF and SOFIA were amplified by science team members George Rieke (University of Arizona) and David Hollenbach (NASA-Ames), respectively; SOFIA Deputy Project Scientist Edward Dunham (NASA-Ames) addressed the particular capabilities of SOFIA for planetary science, while the Project Manager for SIRTF, Lawrence Simmons (JPL), elaborated on the details of its extensive technical redesign. The TGSS's assessment of the current state of the missions is based on these presentations.

The TGSS concludes that, despite reductions in scientific scope that have resulted from NASA's current cost ceiling for new science missions, SIRTF remains unparalleled in its potential for addressing the major questions of modern astrophysics highlighted in Chapter 2 of the Bahcall report. The TGSS is unanimous in its opinion that SIRTF still merits the high-priority ranking it received in the Bahcall report. The task group also concludes that the SOFIA scientific capabilities are unchanged from those that contributed to its high ranking among the moderate missions in the report. As a result, the TGSS discusses SIRTF more extensively than SOFIA. The task group notes, however, that SIRTF's redefinition renders the rationale for complementary SOFIA (and ground-based, IR-optimized 8-m) observations even more compelling. An account of the TGSS's deliberations follows.

II. SIRTF

1. Technical Status

The goal of the SIRTF redesign was to reduce the mission cost from the $1.3B (FY90; equivalent to $1.5B FY94) estimated for the version considered by the Bahcall committee to below NASA's guideline of $388M (FY94), exclusive of launch vehicle costs. All aspects of the mission have been profoundly affected by this major restructuring. The SIRTF team now focuses its scientific program on four areas identified in the Bahcall report as being of major importance in modern astrophysics. This scientific program exploits SIRTF's unique strengths and (along with corresponding cost-benefit trade-offs) has motivated and constrained the redesign of the mission elements as described below. Conceptually, the major aspects of the rescoped mission appear to be well understood, although they are as yet incomplete in detail. The current JPL estimate of the development cost for the project as described is $310M (FY94), which includes a $68M reserve, and is $78M less than the NASA guideline.

A. Orbit

A solar orbit rather than a high Earth orbit is now planned for the spacecraft. The advantages and feasibility of such an orbit have only recently been recognized. It allows greater launch vehicle flexibility, a substantially improved thermal environment, and enhanced sky coverage for observations. Spacecraft control and scheduling of observations will be simplified. The spacecraft will, however, move significantly farther from the Earth and reach ~ 0.3 AU after 2.5 yrs. Communications will require the use of NASA's Deep Space Network (DSN).

B. Spacecraft

The rescoped SIRTF incorporates a cryogenically cooled, 85-cm-diameter telescope with performance over the 3- to 180-μm range limited only by the natural background radiation. The estimated mass of the redefined spacecraft is only 1000 kg, which is less than that of the highly successful Infrared Astronomical Satellite (IRAS), launched in 1984, and only about half that of the Cosmic Background Explorer (COBE), launched in 1989. This very substantial reduction in mass results from modifications in virtually all areas. Liquid helium requirements are much lower because of the improved thermal environment in solar orbit, the significant improvements in telescope and instrument power dissipation, and a decrease in planned facility lifetime from 5 to 2.5 years. Moreover, the telescope will be launched warm, with a potential for cost savings not only in dewar design and fabrication but also in testing and integration. After launch, the telescope will first cool radiatively and, subsequently, via enthalpy of the gas escaping from the liquid helium dewar that cools the scientific instruments.

C. Launch Vehicle

Due to the significantly reduced spacecraft mass and the solar orbit, a much less expensive launch vehicle can be employed. The revised SIRTF will be able to use either an Atlas II or Delta 7925 vehicle, rather than requiring a Titan IV-Centaur.

D. Scientific Instruments

The redefined SIRTF scientific instrument payload incorporates 11 larger-format detector arrays (down from 19 in the previous concept). Three arrays use InSb detector material, three use Si:As IBC (impurity band conductor), and three use Si:Sb IBC; the remaining two use Ge:Ga and stressed lattice Ge:Ga (see Table 1). The number of cryogenic mechanisms has decreased from 23 to 1, leading to substantial reductions in power dissipation. The decreased complexity of the payload minimizes risk as well as cost. The lower number of observing modes combined with the increased pointing flexibility in the solar orbit should result in very high observing efficiency.

TABLE 1
SIRTF Capabilities: Current Concept
Imaging

Wavelength	Detector Format	Detector Technology	Pixel Size	Field of View
3.5 μm	256 x 256	InSb	1.2"	5' x 5'
4.5 μm	256 x 256	InSb	1.2"	5' x 5'
8 μm	128 x 128	Si:As	2.4"	5' x 5'
30 μm	128 x 128	Si:Sb	2.4"	5' x 5'
70 μm	32 x 32	Ge:Ga	9.6"	5' x 5'
160 μm	1 x 16	Ge:Ga (stressed)	19.2"	5' x 20'

Spectroscopy

Wavelength Range	Resolving Power	Detector (array sizes as listed above)
4 - 5.3 μm	100	InSb

5 - 15 μm	100	Si:As
15 - 40 μm	100	Si:Sb
12 - 24 μm	600	Si:As
20 - 40 μm	600	Si:Sb
55 - 100 μm	20	Ge:Ga

TABLE 2
Comparison of Titan SIRTF and Current Concept

Parameter	Titan Version (Bahcall Report)	Current Concept
Wavelength range	2 - 700 μm	3 - 180 μm
Lifetime	5 yrs	2.5 yrs
Aperture	92 cm	85 cm
Pointing stability	0.15 arcsec	0.25 arcsec
Secondary mirror position	6 degrees of freedom	Focus only
Diffraction-limited wavelengths	> 3 μm (0.9" @ 3 μm)	>6.5 μm (2" @ 6.5 μm)
Planetary tracking	High-speed, continuous	Stepwise
Average data rate	120 kbps	40 kbps
Mode	Full observatory	Key project

Important Simplifications

Parameter	Titan Version (Bahcall Report)	Current Concept
Cooled instrument volume	0.8 m^3	0.2 m^3
Cryogenic mechanisms	23	1
Number of detector arrays	19	11
Cryogenic instrument mass	200 kg	50 kg
Cryogenic instrument heat dissipation	17 mW	10 mW
Warm electronics (mass/volume/power)	97 kg/0.5 m^3/150 W	75 kg/0.08 m^3/75 W
Fine guidance	Internal	External

The simplification has been achieved through significant reduction in capabilities. Diffraction-limited imaging in the 3-μm region, polarimetry, 2.5- to 4-μm spectroscopy, and high-resolution spectroscopy in the 4- to 13-μm range and longward of 40 μm are no longer possible. In addition, there will be no bolometers for imaging longward of 200 μm.

Since the filter wheels associated with the imagers have been eliminated, narrow-band imaging will be less efficient, though still viable (by spatial scanning perpendicular to the slits in the spectrographic modes). The technical changes in the currently envisaged SIRTF mission are compared (Table 2) to the earlier version considered by the Bahcall report.

However, there have been significant gains in performance in other areas. Detector technology has matured considerably since the time of the Bahcall report, particularly in the key 27- to 40-μm region. Here, high-quantum-efficiency, low-noise, 128 x 128 Si:Sb IBC arrays have replaced lower-efficiency 16 x 16 extrinsic Ge arrays. At other wavelengths, combinations of array size and performance that were only predicted in 1990 have now been realized in the laboratory. The detector performance is now such that SIRTF observations will be limited only by the fundamental photon noise of the extraterrestrial sky brightness (principally thermal emission from zodiacal dust from our vantage point within the inner solar system), not only for broad-band imaging around 3.5, 4.5, 8, 30, 70, and 160 μm, but also for spectroscopy in the bands from 4 to 40 μm, 13 to 40 μm, and 55 to 100 μm with spectral resolving power of 100, 600, and 20, respectively. Table 3 summarizes the capabilities that have been lost in the new SIRTF concept as well as the gains.

TABLE 3
Changes in SIRTF Capabilities

Improved SIRTF Capabilities	Deleted SIRTF Capabilities
Availability of Si:Sb arrays-improved quantum efficiency, larger format in the 20- to 40-μm range Greater reliability through simplified hardware Solar orbit instead of high Earth orbit results in a. greater observing efficiency-shorter life b. better sky access-improved response to targets of opportunity c. a more stable thermal environment-simpler attitude control	

Deleted SIRTF Capabilities

Imaging

Narrow-band imaging (filter wheels)
Sub-millimeter imaging (180 - 700 μm)
Short-wavelength imaging (2 - 3 μm)
High-resolution imaging (2 - 5.5 μm)
Polarimetry

Spectroscopy

Long-wavelength spectroscopy (40 - 200 μm)
Short-wavelength spectroscopy (2.5 - 4 μm)
High-resolution spectroscopy (4 - 13 μm)

E. Ground Operations

The solar orbit simplifies ground operations and, with the streamlined instrumentation concept, will provide very high observing efficiency, possibly around 75%, but will require support of the DSN. However, the reduced data rate and shorter lifetime demand careful approaches to planning and executing the science program in order to maximize scientific productivity while assuring community involvement. The traditional "observatory" paradigm originally envisaged for SIRTF, in which scientific programs evolve as a wide spectrum of users learn and test the capabilities of the system, is no longer applicable. The SIRTF team now favors an approach whereby much of the observing time is devoted to large-scale projects (Key Projects) that will include large imaging and spectroscopic surveys. In order to ensure optimum scientific returns, the broader astronomical community will be actively encouraged to participate in the definition of these Key Projects well before launch. To enable follow-up activities by the community during the shorter lifetime, Key Project data will be nonproprietary. Very early release of processed and calibrated data products is planned. Such programmatic changes should help counteract the loss of science output due to the shorter mission, particularly in view of the increased coverage of the sky afforded by the solar orbit.

2. Scientific Capabilities

The SIRTF redefinition and operations are driven by four scientific programs: (1) preplanetary and planetary debris disks, (2) brown dwarfs and superplanets, (3) ultraluminous galaxies and active galactic nuclei, and (4) deep surveys of the early universe. By focusing on these important areas in which SIRTF observations can make unique contributions, the SIRTF team has greatly simplified the instrument design and operating modes and has vastly reduced mission costs. The four programs provide a sharp scientific focus that is entirely consistent with the high-priority objectives identified in the Bahcall report. Scientific research conducted since the report's publication has served only to emphasize that these programs encompass some of the most compelling problems in modern astronomy. In addition, as a consequence of the unprecedented sensitivity across the whole 3- to 180-μm band, SIRTF will have strong capabilities for addressing a wide range of other astronomical problems.

Due largely to its advanced detector arrays, the redefined SIRTF retains much of its original scientific capability and preserves its major advantage over other instruments-unprecedented sensitivity in the large, relatively unexplored, and astrophysically important region of the spectrum between 3 and 180 μm. Again, the TGSS stresses that the sensitivity is now limited only by the natural extraterrestrial sky brightness. Moreover, the large-format arrays allow full sampling of the diffraction disk beyond 6 μm, a capability that is essential for minimizing the effects of source confusion in very deep integrations.

The powerful focal-plane arrays have a profound impact on all of the science programs. Photometric and spectroscopic surveys will substantially extend the range of preplanetary and disk characteristics known from IRAS. Imaging programs that can reach much fainter systems will strongly constrain disk models. Targeted searches of nearby stars and young clusters for brown dwarf candidates and surveys for planetesimals in the Kuiper Belt will be facilitated. Studies of active galaxies and the early universe will benefit enormously from the high signal-to-noise ratio and dense spatial sampling that, coupled with sophisticated extraction techniques, will enable deep searches at unprecedented sensitivity. Observations of ultraluminous galaxies out to redshifts of z ~ 10 will be possible. Measurements of the contribution from faint galaxies will be an important complement to COBE measurements of the cosmic background. The TGSS notes that SIRTF's greatest asset is likely to be its potential for discovery. Like IRAS, the task group expects it to open new areas that will then be studied at other wavelengths and at higher spatial and spectral resolution with the upcoming generation of large ground-based telescopes such as Keck, Gemini, and the European Southern Observatory's Very Large Telescope, with airborne instruments like SOFIA, and with future space-based or lunar telescopes.

Although the redesign of SIRTF has been guided predominantly by the needs of the four programs described above, the new instrument will make major contributions in other astronomical areas. Nevertheless, there has been some unavoidable loss of scientific opportunity. The restricted technical capabilities will preclude a number of the programs originally proposed. Eliminating the submillimeter bolometer system will prevent cosmological observations involving the Sunyaev-Zel'dovich effect and the cosmic background anisotropy. Without the far-infrared spectroscopic capability, studies of important cooling lines in the interstellar medium of our own and other galaxies will not be possible. In addition, a number of goals of the planetary program are now unattainable. In particular, investigations of planetary atmospheres that rely strongly on imaging in the near infrared and on high-resolution spectroscopy between 4 and 13 μm cannot be carried out.

In deep searches for distant galaxies, for example, SIRTF will provide orders-of-magnitude improvement over ISO. Figure 1 is a comparison of the relative astronomical capabilities of the rescoped SIRTF and ISO and, when compared with Figure 4.2 in the Bahcall report, highlights the dramatic improvement in SIRTF's detection capability since the time of that report's release. The relative astronomical capability is a figure of merit combining point-source sensitivity, array size, facility lifetime, and efficiency in the following relation:

$$\textit{Relative astronomical capability} = \frac{(\textit{facility lifetime}) \times (\textit{number of array pixels}) \times \textit{efficiency}}{(\textit{limiting flux density})^2}$$

Roughly speaking, this expression gives the number of resolution elements on the sky that can be measured to a given flux level by a facility during its lifetime (see p. 78 of the Bahcall report). Depending on wavelength, the relative astronomical capability of SIRTF will exceed that of ISO by factors of 103 to 108.

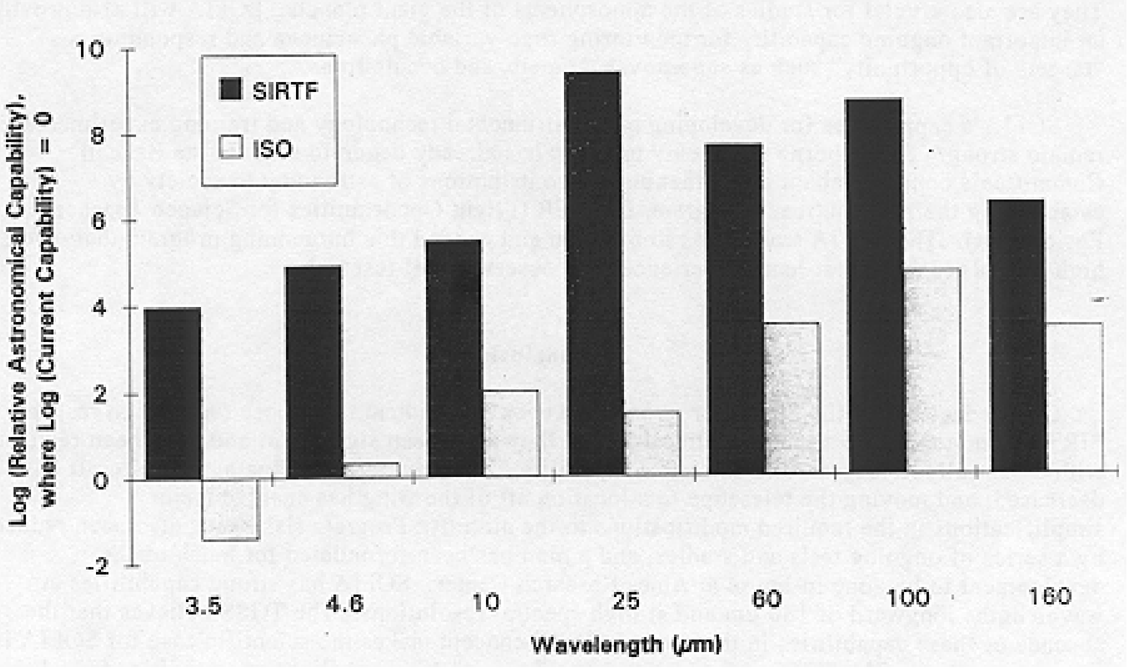

FIGURE 1 Relative astronomical capability of SIRTF and ISO.

3. Conclusions

The TGSS fully endorses the Bahcall Committee's ranking of SIRTF. The proposed rescoped mission remains responsive to the principal scientific objectives of the Bahcall report. In terms of cost, SIRTF has moved into the moderate mission category while retaining much of its scientific capability. The mission has also been much simplified, significantly reducing risk factors. The revised observing program has been tailored to focus on a few well-defined, high-priority objectives that include some of the most important problems in modern astrophysics, but the instrument remains a powerful tool for a variety of other studies. Despite drastic rescoping, SIRTF has maintained an exceptionally high level of scientific potential, largely as a result of dramatic technological advances in the area of infrared detector arrays. The interaction of university-based scientists and U.S. industry in this endeavor has been remarkably successful; the sensitivity of SIRTF observations is now limited only by background photon noise. The TGSS believes that it is imperative that NASA and the astronomy community capitalize on this investment. It appears to the TGSS that the proposed Key Projects program is an excellent way of involving the whole astronomical community in SIRTF. This program and other mechanisms for promoting and coordinating participation by a broad user community are essential for maximizing scientific returns from a shorter mission.

III. SOFIA

1. Technical Status

The current estimate of the cost of SOFIA program development to NASA's Astrophysics Division is $178M (FY94), including vehicle procurement, airframe modification and refurbishment, ground support systems, systems integration and testing, and a $42M reserve. For comparison, the corresponding cost projected in the Bahcall report was $230M (FY90; equivalent to $276M FY94). Neither figure includes the cost of the telescope itself since foreign participation was already assumed at the time of the Bahcall report. Participation in SOFIA is a high priority for the German space agency, DARA, which anticipates supplying the telescope system and ongoing operational support in return for access to approximately 20% of the science flights.

A major portion of the cost reduction has been realized through a redesign in which the telescope system was shifted from a location forward of the wing (the scheme employed in the currently operating Kuiper Airborne Observatory, KAO) to a position between the wing and tail section, allowing important simplifications in the required aircraft modifications. An aft location requires construction of only one new pressure bulkhead, rather than two, and far fewer of the aircraft control systems have to be rerouted around the telescope cavity door. Since the time of the Bahcall report, there has also been a significant decline in the price of used Boeing 747 aircraft.

A series of engineering studies covering a broad range of factors, including aerodynamics, aircraft structural analysis, aero-optics, and telescope design, have reduced uncertainties in the revised concept. Important issues in moving the telescope to the aircraft tail were the effect of the thicker boundary layer on image quality and the magnitude of scattered infrared radiation from the jet engines and hot exhaust gases. These questions have been addressed with both theoretical simulations and in-flight tests. The KAO was used for measurements of seeing and to test a passive boundary-layer control system. Airflow around the telescope cavity has been studied using computational fluid dynamics and wind-tunnel tests on a scale model of a Boeing 747. In-flight vibration tests and measurements of infrared emission from jet engines and exhausts were made using actual 747 aircraft. An aft-mounted telescope appears to meet all of the performance specifications and scientific objectives envisioned for SOFIA at the time of the Bahcall report.

The SOFIA project team has identified several additional studies that are needed prior to final selection of the model of 747 aircraft and its procurement (in particular, further wind-tunnel tests of aft-mounted cavity configurations), but overall the program seems well considered and ready to proceed to Phase C/D development. Ames Research Center now plans to undertake a larger fraction of the SOFIA development in-house. This should minimize programmatic risks by building on the unique expertise of Ames personnel in aerodynamics (especially in the area of boundary-layer control) and in operating science platforms on aircraft.

2. Scientific Capabilities

The Bahcall report emphasized the value of SOFIA for opening up to routine observations the wavelength range from 30 to 350 mm, for training new generations of experimentalists, and for developing and testing new instruments. It also stressed that SOFIA's capability for diffraction-limited imaging and high-resolution spectroscopy at wavelengths inaccessible from the ground would complement SIRTF's great sensitivity.

The report's conclusions regarding SOFIA are rendered more compelling with the elimination of SIRTF's very long wavelength, high spectral resolution, and polarimetric capabilities, and the reduction in its operational lifetime. The angular resolution afforded by SOFIA's large aperture (~ 2.5 m) and the possibility of achieving high spectral resolutions, with corresponding velocity resolutions of up to 1 km s-1, are of particular importance. Both capabilities will enhance dynamical studies of the high-density, moderate-temperature cloud cores where stars form, of the primitive nebulae around newly formed stars, and of the nuclei of infrared-luminous galaxies. They are also crucial for studies of the atmospheres of the giant planets. SOFIA will also provide an important ongoing capability for monitoring time-variable phenomena and responding to "targets of opportunity" such as supernovae, comets, and occultations.

SOFIA's capabilities for developing new instrumental technology and training experimentalists remain strong. The airborne astronomy program has already begun to address the Bahcall Committee's concerns about strengthening the contributions of astronomy to society by establishing the KAO outreach program, FOSTER (Flight Opportunities for Science Teacher Enrichment). The SOFIA team plans to build on and expand this burgeoning program that offers high school teachers first-hand experience with observational research.

3. Conclusions

Cost reductions in the SOFIA program have been less radical than those required to rescope SIRTF from a major to a moderate mission, but they have been significant and have been realized with essentially no decrease in scientific capability. The price of used Boeing 747 aircraft has decreased, and moving the telescope to a location aft of the wing has enabled major simplifications in the required modifications to the aircraft. Program risks have also been reduced by a series of ongoing tests and studies, and a plan has been formulated for much of the development to be done in-house at Ames Research Center. SOFIA has strong capabilities at wavelengths longward of 180 μm and at high spectral resolutions. The TGSS believes that the absence of these capabilities in the current SIRTF concept makes the scientific case for SOFIA more compelling. The TGSS concludes that SOFIA, with frequent flight opportunities for a broad range of state-of-the-art instrumentation programs, remains a uniquely powerful facility for science and continues the airborne program's role of developing technology for future space missions, for training experimentalists, and for educational outreach, as envisaged in the Bahcall report.

[1]The CAA is a joint activity of the National Research Council's Space Studies Board and the Board on Physics and Astronomy.

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On the Advanced X-ray Astrophysics Facility and Cassini Saturn Probe

On July 5, 1994, Space Studies Board Chair Claude R. Canizares and Board Past-Chair Louis J. Lanzerotti sent the following letter to Presidential Science Advisor John Gibbons.

Recent developments in outlay allocations to NASA's Senate appropriations subcommittee are threatening the necessity for very difficult choices in the FY95 budget. As you know, many of NASA's science missions have been closely scrutinized for savings over the past few years. In particular, the two largest space science mission development programs, the Cassini Saturn probe and the Advanced X-ray Astrophysics Facility (AXAF), have been subjected by NASA to budget-driven rescopings. Each of these missions has been accorded the highest priority in its respective discipline.[1] On completion of these rescopings, which significantly reduced total program cost in each case, the National Research Council (NRC) Space Studies Board was asked to conduct scientific reviews to determine if the resulting missions remained scientifically responsive to the opportunities presented by our current state of knowledge. Copies of the final reports on these two assessment studies are enclosed, but we would like to summarize their findings briefly here.

With respect to Cassini, on October 19, 1992, the Board's Committee on Planetary and Lunar Exploration (COMPLEX) stated that:

> Although the Cassini spacecraft has undergone considerable revision, it is COMPLEX's overall opinion that the restructured Cassini mission remains responsive to the scientific priorities set out in its report, *A Strategy for Exploration of the Outer Planets: 1986-1996*. Significant though these changes are with respect to legitimate individual science objectives, the recommended modifications do not substantially compromise the primary mission objectives, which include the intensive study of the saturnian system as a whole.

We also note the significant investment of the European Space Agency in the Huygens Titan probe, which will perform a pioneering first characterization of Titan's atmosphere and surface.

With respect to AXAF, the Board created a task group to evaluate the quality of the program that resulted from AXAF's division into two spacecraft, AXAF-I (imaging), and AXAF-S (spectroscopy). This task group reported its findings, with the endorsement of the NRC's Committee on Astronomy and

Astrophysics, on April 28, 1993, as follows:

> The Task Group on AXAF [TGA] concludes that the revised AXAF program continues to meet the scientific expectations set forth in previous NRC reports, which have recommended AXAF as the highest-priority, new, large-scale program in astronomy. . . . Thus the TGA urges NASA to proceed with the implementation of the restructured AXAF program and to make every effort to ensure the launch of both AXAF-I and AXAF-S before the end of this decade.

The subsequent cancellation of the AXAF-S mission, while dismaying, did not impair the scientific promise of the imaging mission, whose "angular resolution . . . is more than an order of magnitude better than that offered by any other mission under development or even in the planning stages."

The enclosed letter reports on the two missions provide the scientific and technical background that elaborates and substantiates these program reassessments. We realize that science missions must be balanced within the overall objectives of NASA and priorities of the federal R&D budget, but cancellation of either AXAF or Cassini would be a serious reverse for NASA's program of exploration of the solar system and the universe beyond. Please contact us if you have any further questions about these missions or their importance to U.S. science.

NOTES

[1]For Cassini, see *A Strategy for Exploration of the Outer Planets: 1986-1996* (National Academy Press (NAP), Washington, D.C., 1986), page 5; for AXAF, see *Astronomy and Astrophysics for the 1980s, Volume 1* (NAP, 1982), page 15; for AXAF, see also *The Decade of Discovery in Astronomy and Astrophysics* (NAP, 1991), page 65.

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On the Utilization of the Space Station

On July 26, 1994, Space Studies Board Chair Claude Canizares, Committee on Space Biology and Medicine Former Chair Fred Turek, and Committee on Microgravity Research Former Chair William Sirignano sent the following letter to NASA Administrator Daniel Goldin.

Over the past decade or so, the Space Studies Board has issued a series of statements concerning scientific utilization of a space station.[1] Two consistent themes appear throughout the Board's positions on the subject. First, there are national considerations for building a space station other than scientific research: to enhance international leadership and prestige, to stimulate the nation's educational achievement and the U.S. technology base, and to realize the long-term goal of long-duration human space exploration. Second, given that the space station program will have scientific objectives, the station that is built should be designed and equipped to support the two principal scientific disciplines it is best suited to serve, life sciences and microgravity sciences.[2]

In 1993, the Board and its Committees on Space Biology and Medicine (CSBM) and Microgravity Research (CMGR) conducted an assessment of planning for research management in the space station program and of precursor research during the station assembly period on Shuttle Spacelabs and the Russian Mir. The results of this assessment were transmitted to you in a letter dated February 25, 1994.

On April 28 and 29, 1994, the CSBM and CMGR again met jointly to (1) review NASA's response to our letter of February 25, and (2) assess the capabilities of the newly redesigned International Space Station Alpha (ISSA) and its Phase I Shuttle-Mir activities for supporting scientific research. The committees received briefings and written materials from Mr. W. Trafton (Deputy Associate Administrator for Space Station) on an overview of the ISSA and its program management plan; Captain W. Shepherd (Deputy Program Manager for Space Station at the Johnson Space Center) on the details of the ISSA design; Dr. H. Holloway (Associate Administrator for Life and Microgravity Sciences and Applications) on changes since the committees' February letter relating to Spacelab and space station research management; Dr. J. Vernikos and Mr. R. Rhome (Directors, Life and Biomedical Sciences and Applications, and Microgravity Sciences and Applications divisions, respectively) on plans for life and microgravity sciences research on the ISSA; and Dr. A. Nicogossian (Deputy Associate Administrator for Life and Microgravity Sciences and Applications) on the Shuttle-Mir program.

This letter was prepared by the CMGR and CSBM at the conclusion of their April 1994 meeting and subsequently approved by the Space Studies Board.

SUMMARY

In summary, the Board and the CSBM and CMGR have concluded the following:

- Research Management: NASA has responded positively to the committees' recommendations. The appointment of a headquarters-level Research Manager and his or her close relationship with the ISSA Integrated Product Teams promise an effective method for communicating and implementing life sciences and microgravity research requirements.

- Precursor Research: Continued vigorous research in the life and microgravity sciences is required to ensure that ISSA's maximum potential as a life sciences and microgravity research laboratory will be achieved. The CSBM and CMGR conclude, as detailed below, that the current plans do not allow for a sufficient level of space research activity, over the years preceding the availability of the ISSA, to maintain the vitality of research programs in the life and microgravity sciences. The committees recommend that, in order to promote scientific progress over the decade of ISSA construction, NASA should consider additional shuttle flights dedicated to scientific payloads.

- ISSA Scientific Research Capability: Substantial progress has been made in defining an international space station that can, the committees believe, provide an effective laboratory for research in microgravity and life sciences in space if a number of remaining concerns are addressed.

1. Research Management

The CSBM and CMGR were generally pleased with NASA's response to the committees' letter of February 25, 1994. The appointment of a headquarters-level Research Manager reporting to the Office of Life and Microgravity Sciences and Applications (OLMSA) and his or her close relationship with the ISSA Integrated Product Teams promise an effective method for communicating and implementing life sciences and microgravity research requirements.

2. Precursor Research

The committees are concerned about the apparent loss of major elements of the Spacelab program in order to support the Shuttle-Mir and ISSA programs. While a Spacelab module will be employed on 5 of the 10 Shuttle-Mir support flights, it will be severely limited in research capability and will be used mainly for storage and logistical support. These flights are not an adequate substitute for previously planned or proposed science-dedicated Spacelab missions in either the life or microgravity sciences (e.g., SLS-3, SLS-5, 6, and 7, and USMP-5, 6, and 7). While substantial efforts are being made to find alternatives, such as utilizing Mir and flying an occasional Bion (a small Russian free-flying spacecraft), the demise of Spacelab (except for the 1998 SLS-4 Neurolab) will curtail planned research programs prior to research utilization of the ISSA. The present plans of OLMSA to maintain research during this period, while commendable, should be strengthened; a more ambitious plan for science over the interim decade leading to full ISSA utilization should be developed and matched with appropriate budgetary resources. Therefore, to continue the advance of microgravity and life sciences, the committees recommend that additional Shuttle flights be dedicated to scientific payloads in order to promote scientific progress over the decade prior to full ISSA capability.

The CSBM and CMGR have some additional specific concerns about the use of Shuttle-Mir flights as the main opportunities for life sciences and microgravity research prior to ISSA availability:

- NASA should consider including up-to-date equipment on Mir to support plant and animal physiology research. For example, addition of the Plant Growth Facility now under development by OLMSA would permit use of the long-duration microgravity environment of Mir to do important and needed plant experiments. At present, there are no plans to add such equipment to Mir.

- Without an agreement with the Russians for the participation of cosmonauts in human biomedical experiments, there will be an insufficient sample size to enable scientists to draw any firm conclusions about the effects of long-term exposure to microgravity on human physiology.

- The microgravity environment on Mir apparently will not permit high-quality microgravity experiments in many areas of research.

In addition, the CSBM and CMGR urge NASA to make every effort to preserve ground-based research programs in the life and microgravity sciences for identifying and refining those scientific questions that are significant enough to utilize the expensive facilities of space to best advantage. Ground-based efforts are essential also to developing the community of researchers that will exploit the potential of the ISSA.

3. ISSA Scientific Research Capability

The committees support the ultimate goal of an international scientific laboratory in space. A letter from Dr. Charles M. Vest to Dr. John H. Gibbons[3] noted the improvement in the management and the technical aspects of the ISSA program. The presentations to the CSBM and CMGR by Mr. Trafton and Captain

Shepherd likewise addressed the accomplishment of the ISSA as an engineering undertaking. It should be noted that the committees make no judgments on the engineering feasibility of assembly or operations of the ISSA. These may be addressed in studies by the National Research Council's Committee on Space Station of the Aeronautics and Space Engineering Board. The CMGR and CSBM believe, however, that in designing the space station to be suitable for life sciences and microgravity research, NASA has recognized and potentially overcome many significant environment, resource, and scientific problems. If the concerns expressed below are adequately met, the ISSA could provide a productive laboratory for life sciences and microgravity research.

- Dynamic Microgravity Environment: The goal of providing a quasi-steady-state acceleration environment of 1 μg is appropriate and adequate for the conduct of life sciences research and, indeed, this is one of the major reasons for the station. It is not yet clear, however, how scientific experiments will be isolated from disturbances of a dynamic nature (e.g., from machinery, crew activities, thruster firings, and so on). While quasi-static levels of slightly below 1 μg are currently achievable on Spacelab flights operated in a minimum drag configuration, *g*-jitter acceleration spectra show a wide range of intensities over various frequencies resulting from dynamic disturbances. The committees hope that the ISSA will be able to achieve g levels comparable to those of Spacelab and a better overall acceleration environment. In addition, some experiments in microgravity research in the future will require much lower quasi-static *g* values. A free-flyer platform may prove to be necessary in these cases.

- Centrifuge Facility: It must be stressed that a centrifuge for plants and small mammals is central to the conduct of life sciences research. Furthermore, the centrifuge is not just a rotor but a facility including various subject habitats and related equipment. It is important to install the facility in the station as soon as possible. The committees learned that the facility is unfortunately not part of OLMSA's "baseline plan" and that its planned inclusion has slipped further, from 2000 to 2004. At present, it is not clear where the resources to support construction of the centrifuge facility will be found or where the centrifuge facility can be accommodated on the ISSA.

- Cryogenic Capability: NASA should consider including a cryogenic capability on board the station. As currently planned, the lack of such a capability will limit certain kinds of research (e.g., in low-temperature physics) and use of instrumentation based on low temperature (e.g., infrared detectors and superconducting quantum interference device (SQUID)-based instruments).

- Carbon Dioxide: It is important to achieve NASA's stated goal of a 0.37% concentration of carbon dioxide. While such a concentration is generally acceptable, provisions also need to be made for ensuring concentrations of carbon dioxide lower than 0.37% in the immediate environment of sensitive organisms such as plants.

- Data: The projected capability for uplinking of commands and downlinking of data to investigators during space operations appears limited. The limitations on communications capabilities may eliminate many telescience projects. Furthermore, long delays have been encountered to date in the Shuttle program in postflight access to specimens and delayed return of scientific data for analysis. This situation must be corrected in the ISSA program. Thus, the adequacy of plans for ISSA data storage, accessibility, and dissemination needs to be investigated further. These areas remain problematic and would gravely reduce the ISSA's utility to science if not resolved.

- Science Budget Impacts: While the Integrated Product Team approach to defining the space station program is striving to meet science requirements, it appears that OLMSA may be charged for certain necessary environmental accommodations, such as the dynamic vibration isolation system or a lower carbon dioxide environment. Such charges will have an adverse impact on the budgets available for research activities and could materially reduce the quantity and quality of science that can be done on the ISSA.

The CSBM and CMGR wish to thank the NASA personnel who provided information to the committees for this review. The committees believe that the ISSA is important to the future of U.S. life and microgravity sciences and look forward to working closely with NASA to ensure the best possible program.

NOTES

[1]Letter to NASA Administrator James Beggs, September 13, 1982; *Space Science Board Assessment of the Scientific Value of a Space Station*, August 16, 1983; Letter to NASA Administrator James Beggs, September 9, 1983; Testimony of Committee on Space Biology and Medicine Chair L. Dennis Smith to the U.S. Senate Subcommittee on HUD Appropriations, Committee on Appropriations, "Space Biology and Medicine and the Space Station," May 1, 1987; Letter to NASA Associate Administrator for the Office of Space Station, Andrew Stofan, July 21, 1987; Letter to NASA Assistant Associate Administrator for Science and Applications, Joseph K. Alexander, December 12, 1990; Letter to NASA Administrator Richard Truly, March 14, 1991; Testimony of Space Studies Board Chair Louis J. Lanzerotti to the U.S. Senate Subcommittee on Science, Technology, and Space, Commerce Committee, April 16, 1991; Letter to NASA Associate Administrator for Space Systems Development Arnold Aldrich, March 30, 1992; Letter to NASA Administrator Daniel Goldin, February 25, 1994.

[2]The National Research Council's Aeronautics and Space Engineering Board has issued a series of advisory letters and reports on engineering-related aspects of the space station program, viz. National Research Council, *Space Station Engineering and Technology Development*, National Academy Press, Washington, D.C., 1985; National Research Council, *Space Station Engineering Design Issues*, National Academy Press, Washington, D.C., 1989; and

Committee on Space Station, Letter to NASA Administrator Daniel Goldin, May 6, 1993. See also, National Research Council, *Report of the Committee on Space Station of the National Research Council*, National Academy Press, Washington, D.C., 1987.

[3]Letter from Dr. Charles M. Vest to Dr. John H. Gibbons, April 4, 1994. Dr. Vest chaired the President's Advisory Committee on the Redesign of the Space Station that reviewed the redesign in mid-1993. Several members of his committee reviewed the ISSA plans in March 1994 in terms of their addressing the June 1993 advisory committee's recommendations (*Final Report to the President, Advisory Committee on the Redesign of the Space Station*, 1993). The letter to Dr. Gibbons conveyed his personal observations of that review.

CMGR CSBM

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5 Congressional Testimony

5.1 Nurturing Science in an Era of Tight Budgets

Space Studies Board member Anthony A. England delivered the following testimony before the Subcommittee on Space of the U.S. House of Representatives on April 14, 1994.

Mr. Chairman, Ranking Minority Member, and members of the committee: thank you for again inviting the Space Studies Board here to testify this morning. Board Chair Louis Lanzerotti was not able to be here today, and has asked me to come to speak to you on his behalf and that of the Board. My name is Anthony England, and I am a professor of electrical engineering and computer science at the University of Michigan. My research field is Earth science, specifically in remote sensing of land and land cover. I flew as a Mission Specialist on STS-51F in August 1985.

Mr. Chairman, as you know, the Space Studies Board has been the principal independent advisor to the civil space research program since NASA was created by statute in 1958. Today, the Board continues to advise on strategic issues across the agency's entire portfolio of science and applications, now distributed into three separate offices at the agency.

You have invited us here today to address the FY95 budget proposal, its five-year runout, and their impact on NASA's science programs. The FY95 proposal and the long-term projection are two different issues, and I would like to address them separately.

First of all, the FY95 proposal: it is not a perfect budget for science, but it is a good one. My colleagues and I would all like to spend more on science, but as taxpayers and citizens we recognize that hard choices have already been made to preserve many important projects in our space science program in this FY95 budget. It is a good science budget in our present circumstances, and we urge the Congress to approve it.

In the out-years, on the other hand, the situation is bleak for new activities and innovation in science. Some have called it a "going out of business budget" for space science. There are problems with the Earth Probes, with the Discovery program, and with space laboratory science. The budget trend for the Office of Space Science appears to follow the roll-off of development spending for Cassini and AXAF after FY95, with little or no yearly funding freed for new flight mission starts. The other witnesses today have elaborated on many of these problems, so I will not reiterate them; the Board has discussed issues in ShuttleÐMir science in a recent letter report. Additionally, the Research and Analysis (R&A) accounts are predicted flat, except for erosion by inflation. Earth science R&A is being absorbed into the EOS program. It is on the role and importance of R&A that I want to focus today for the remainder of my time, but first I want to comment briefly on the recent report by the Congressional Budget Office, *Reinventing NASA*.

The CBO analyzes the present NASA budget as trying to do too much with too little, and interprets the current budget plan as a strategy of "marginal adjustment." The CBO says some major pieces of NASA's program may have to be jettisoned to keep the remainder healthy. Mr. Brown, himself, has said as much. The Space Studies Board does not have the expertise to improve or contest these assessments of the robustness of the present budget approach. The Board is obviously in favor of a strong science program, however it fits into the agency's overall agenda. It is not certain that if one of NASA's major thrusts were excised, the savings would remain to nourish the survivors. Our working assumption has to be that money for new things will have to come out of today's level of funding, or less.

So the hunt for "wedges" is on—in the science accounts, in the human flight accounts. Money is needed for new technology, new instruments, new spacecraft, new launches, and operations. Where will this money be found?

Mr. Chairman, surveying the options brings me to my theme for today:

- If a line item mission is canceled, something specific and visible goes away, perhaps something a lot of money has already been spent on.

- Launch costs are unavoidable, imposed by physics and our present launch technology.

- And there's a limit to how much can be shaved from piloted flight before safety is impacted.

So what about the science budget catch-alls called Research and Analysis (R&A), or Mission Operations and Data Analysis (MO&DA)? Can they be trimmed, maybe a lot? This is a question that is now being asked.

What is R&A, and what is it used for? R&A is largely spent on the underlying ground research in new instrumentation and new analytical capabilities, both physical and theoretical. The R&A dollar is used for doing the background work for space research, for doing what can or should be done on or from the ground. It supports the theoretical basis for science in space, and pays for innovations in instrumentation and data interpretation. In short, it's used for formulating the questions to ask in space, and for advancing our fundamental competence for getting answers in space. Asking a question and making a measurement are the two halves of the scientific method.

Summed up across the three science offices, R&A totals about $425 million in the FY95 budget. It is dispensed in smallish awards to researchers, principally at universities, for soft money salaries, laboratory equipment and support, computing, and students. The Board's report *Assessment of Solar System Exploration Programs—1991* (pp. 31-33) describes the important role of R&A in discovery. Both this report (p. 33), and a companion report, *Assessment of Satellite Earth Observation Programs—1991* (p. 58), caution against raiding these accounts for remedying other shortfalls. The Board's *Assessment of Programs in Solar and Space Physics—1991* (p. 26) likewise warns of a perceived erosion in the research base. Nothing in the present budget climate assuages these fears.

What recent signals do we have about how R&A fits into NASA's strategic thinking in the present budget environment? At its 112th meeting at the end of last February, the Space Studies Board was given a copy of "Draft 6" of *NASA's Strategic Plan*. This useful document is short, direct, and clearly written, and its creation is a giant step forward for the agency. The second entry in its *Mission* statement is to "[a]dvance scientific knowledge." Yet, it is worrisome that the section entitled "The Scientific Research Enterprise" seems exclusively oriented to flight missions. The section mentions "set[ting] the stage for future space ventures," but is silent about theory, ground laboratory work, instrumentation development, or suborbital science in the paragraphs that speak about implementation.

So the Board is concerned about the future of R&A programs. Their present situation is not lavish, their future is projected as stagnant or declining, and their presence in agency strategic thinking is not prominent.

What about Mission Operations and Data Analysis (MO&DA)? Let me digress for a moment from R&A onto this closely related topic. What does MO&DA money support?

MO&DA funding runs the control centers that operate spacecraft; it distributes data to researchers, and it pays for other researchers to study data that have already been obtained and filed away. There are several ways to look at this expenditure.

It is a lot of money. According to the recent CBO report, MO&DA for the physics and astronomy, planetary exploration, and Earth science programs totaled $728 million in 1993—quite a bit. But this category includes some mission-like costs, as well. For example, the COSTAR repair package and servicing expenses for the Hubble Telescope are included in the physics and astronomy MO&DA (the Hubble Telescope claims nearly a third of the agency's MO&DA budget). There are undoubtedly efficiencies possible in MO&DA activities, particularly operations, some of them only now becoming achievable thanks to new engineering and computational technologies.

But MO&DA is the payoff for the investment in designing, building, and launching scientific spacecraft. If the R&A pays to pose and understand the science questions of space research, MO&DA pays to handle and interpret the data for answering them. The CBO report points out that: "Adjusting NASA's program to fit within smaller future budgets by reducing spending for mission operations and data analysis could significantly decrease the benefits of past investments" (p. 13).

Before concluding, there is one more issue I would like to address: This is the notion, which surfaces from time to time, that these programs, particularly R&A, are "entitlement" programs for scientists. This is a pernicious myth that needs to be challenged head-on.

Mr. Chairman, if someone is doing a job that is important, that job is not called an "entitlement." When something is called an entitlement, there's an implication that payment isn't earned, or is rendered for something without value. So the real question is whether what is being done with R&A and MO&DA money is something the country attaches value to—whether as a nation we're paying for a job that we want done.

But we've already seen that R&A and MO&DA are the two pillars of science in space.

This brings us squarely to the issue of the role of science, itself, at NASA. The Board will soon be starting work on a multi-part study on this precise topic in a study originated by the Senate in its FY94 appropriations report. We recognize that NASA is a mission agency. Science is not naturally or fundamentally a mission activity—it has a different style and cadence. Nonetheless, science does provide the discipline and framework to achieve the mission, whether that mission is robotic exploration of the solar system, or human exploration that involves prolonged human exposure to the space environment. As expressed in the Board's report, *Setting Priorities for Space Research—Opportunities and Imperatives* (NAP, 1992), the military metaphor goes back to Apollo, and emphasizes the "penetration of a difficult domain, rather than the information and knowledge to be acquired" (p. 9). Science has had a central role in the first 36 years of the space program, and been a source of pride to Americans and the envy of the world. NASA Administrator Goldin has it right when he talks about the role of the space program as Inspiration, Hope, and Opportunity. For many, space discoveries have been the gateway to an interest in science and technology that has led to a technical education and career on the ground, benefiting our whole society.

In late 1990, the Augustine Committee ranked science #1 in priorities for the space program. Members of this panel were not all scientists, or even mostly scientists. But they looked at past achievements and recognized that science is the best reason for the expense and risk of going into space. They called science the "fulcrum" of the space program, on which all the other elements balanced. The Board's *Setting Priorities* report recommended that "development of new knowledge and enhanced understanding of the physical world and our interactions with it should be emphasized as the principal objective of space research and as a key motivation for the space program" (p. 8). The purpose for going into space must be to learn things, not just to hurl people and machines into the void.

The R&A programs are the intellectual engine that powers space science, and the MO&DA programs provide the results, the traction for forward motion. It is true that individual flight projects are the fundamental means by which new space measurements are obtained, and an adequate new start rate is essential. But if science is to be a significant element of our future in space, the vitality of the R&A and MO&DA programs must be carefully preserved and nurtured.

Thank you for your attention; I would be happy to try to answer any questions that you might have.

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Appendix: Reports of the Panel to Review EOSDIS Plans

On November 22, 1991, NRC Chair Frank Press received a letter from NASA Administrator Richard H. Truly requesting an assessment of the Earth Observing System (EOS) Data and Information System (EOSDIS) in the context of a recently completed restructuring of the flight elements of the program. In response, the NRC Commission on Physical Sciences, Mathematics, and Applications assembled a study group, the Panel to Review EOSDIS Plans, chaired by Mr. Charles A. Zraket. The activities of this panel, which was a collaboration of the Space Studies Board, the Computer Science and Telecommunications Board, and the Board on Earth Sciences and Resources, were managed by the Commission office.

Because the EOSDIS was the subject of a government procurement at the time that the study was initiated, the panel first addressed those issues that could be analyzed without the detailed system design information being developed by the industrial proposal efforts under way. Preliminary conclusions on these issues were presented to NASA in an interim report delivered on April 9, 1992, under letters from Dr. Press and Mr. Zraket. These letters and the interim report are reproduced in Appendix A.1.

Based on agency responses to this initial assessment, panel Chair Zraket prepared and submitted a second (letter) report on September 28, 1992; this letter report is reprinted here as Appendix A.2. By mutual agreement with the agency, the panel then suspended its activities pending completion of the EOSDIS procurement.

After the selection of the vendor for EOSDIS, the panel resumed its work to assess the design presented in the winning proposal. The results of this second phase were documented in a third report, delivered to NASA on January 11, 1994. This third report is reproduced, with a cover letter from NRC Chair Bruce M. Alberts, in Appendix A.3.

A.1 Interim Report of the Panel to Review EOSDIS Plans

On April 9, 1992, the Panel to Review EOSDIS Plans completed the first of three reports and submitted it to NASA Administrator Daniel S. Goldin. Two cover letters accompanied the report. The first cover letter was from NRC Chair Frank Press.

Enclosed is an interim report by the National Research Council on NASA's plans for EOSDIS as well as a transmittal letter from the Chair of the Panel that prepared this report. As you know, EOSDIS is a very complex program, and the demands on the Panel that prepared this interim report were extraordinary—in understanding the program, in coping with a demanding schedule, and in reaching judgements. At the same time, my colleagues and I appreciate the importance of EOSDIS. To quote from the attached report: "If EOSDIS fails, so will EOS, and so may the U.S. Global Change Research Program."

It was against such an understanding that the National Research Council accepted this task, believing that we are obliged to assist the government, even when the time is short, the amount of information to be marshalled great, and the imperative to provide judgements urgent.

I believe the Panel that prepared this report has done an exceptional job, ably assisted by the people of NASA. At the same time, the judgements as well as the limits of this interim report should be clear. While the Panel supports the schedule for procuring a contractor for the EOSDIS Core System, it finds major shortcomings in the actual plans for EOSDIS, and provides substantial recommendations for implementing the program that the Panel believes will help ensure its success. Therefore, this report cannot be construed as an endorsement of NASA's current plans for EOSDIS, but rather a substantial critique of flaws, which, if addressed, will in the Panel's judgement help ensure a strong and responsive program over the long term. The Panel believes that the terms of the contract as stated in the Request for Proposal are sufficiently flexible to accommodate its recommendations.

The limits of the report should also be plain. It is an *interim* report, provided in response to requests from NASA and other interested parties for an early alert as to the Panel's views of EOSDIS plans. The Panel's final report this August will offer detailed analyses for these interim judgements, and will also respond directly to the specific issues as posed in the Terms of Reference for this task.

I look forward to your comments on this interim report. And the Panel looks forward to a discussion with NASA officials involved in EOSDIS planning on this report and any further issues to be considered in preparing the final report. We are arranging for your colleagues at NASA with responsibility for the EOSDIS

Project to be briefed by the Panel next week, and intend to release it publicly on April 17th.

Signed by
Frank Press
Chair, National Research Council

The second cover letter to Administrator Goldin for the April 9, 1992, interim report was from panel Chair Charles A. Zraket.

I am pleased to submit the interim report of the National Research Council's Panel to Review Earth Observing System Data and Information System (EOSDIS) Plans. This contains the panel's preliminary observations and recommendations on the current plans for EOSDIS, based on the information provided. The panel looks forward to an early opportunity to discuss these recommendations with NASA and other interested parties, as well as to issuing its final report in August 1992.

On behalf of the panel, I wish to thank all of those at NASA who responded quickly and professionally to our very substantial requests for information and to our many and often difficult questions. We could not have done our work without their full and ready cooperation.

I also wish to express our gratitude for the splendid cooperation from the staff of the National Research Council that enabled the panel's work on this interim report to be completed in less than two months.

Signed by
Charles A. Zraket
Chair, Panel to Review EOSDIS Plans

Panel to Review EOSDIS Plans

Interim Report

This interim report identifies several issues regarding NASA's plans for developing the Earth Observing System Data and Information System (EOSDIS) and offers a number of recommendations that NASA should consider as it proceeds with procuring a contractor to build the system. This report does not respond in detail to the items in the terms of reference—that will be the subject of the panel's final report. Given the short time available for the panel's initial assessment, it has not been able to pursue the issues it identified to the depth it would like. The panel hopes, nevertheless, that NASA will find its interim conclusions and recommendations useful in the negotiations that will take place with the selected contractor to define the ongoing work plans for the EOSDIS Project.

The appendices of this report include NASA's letter of request for this study, the terms of reference for the task, a list of the members of the panel and brief biographies, the work done and the meetings held to enable the panel to write this interim report, a brief description of EOSDIS for readers not familiar with the Project, and a brief description of the U.S. Global Change Research Program and its objectives. [These items are not provided in this annual report.]

The panel was selected to have the competencies demanded by its charge—in understanding the needs of those who will use EOSDIS (including both EOS and non-EOS investigators), in the computer science and technology underlying EOSDIS, in the creation and implementation of large data systems, and in the recent history of large space-based data systems. The fact that the procurement for the EOSDIS Core System was concurrent with the panel's work required extreme care to avoid either the reality or perception of conflict of interest. Thus, in addition to following the National Research Council's standard procedures for dealing with bias and conflict of interest, the panel—and those who provided it information and briefings—took pains to consider only publicly available information. The panel, to the best of its knowledge, has not been provided with nor has it considered any proprietary information related to the procurement.

OBJECTIVES AND MAJOR FINDINGS

In combination with other programs of the U.S. Global Change Research Program, the Earth Observing System (EOS) is intended to reduce the current uncertainties about global climate change. Its Data and Information System (EOSDIS) is essential to the success of EOS. If EOSDIS fails, so will the Earth Observing System and so may the U.S. Global Change Research Program. The panel has been told repeatedly by responsible government officials that EOS is critical to the larger, global change program—one involving many agencies of government, and other national and international participants—and that EOSDIS offers a unique opportunity to begin building a national, and eventually, international, information system for global change research.

To achieve these aspirations, EOSDIS will have to evolve to meet the changing needs of global change research over the next two decades and beyond. The panel believes that the recommendations offered in this report are necessary to ensure that growth and evolution. Specifically, the panel offers its judgments in terms of the following objectives it believes essential to the success of EOSDIS:

- EOSDIS must facilitate the integration of data related to the aims of the U.S. Global Change Research Program. Without this integration, the multidisciplinary and interdisciplinary research objectives of the U.S. Global Change Research Program will not be achieved. The EOSDIS program must be structured and managed to facilitate interactions with the other agencies involved in the U.S. Global Change Research Program so that existing data and future data collected by NASA and by other national and international organizations—using research and operational satellites as well as in situ sources—are available to all global change research scientists.

- EOSDIS must serve a large and broad set of users to facilitate the aims of the U.S. Global Change Research Program in supporting a community concerned with understanding the earth as a system. To serve that larger community, EOSDIS must provide its information in a manner that is simple, transparent, and inexpensive; it also must assure availability of its data to both the earth science community and the larger scientific community.

- EOSDIS must ensure that service to current users—including those involved with Version 0—will not be interrupted as the development of the system proceeds, and that Version 1 and subsequent versions will be implemented as soon as possible to meet the needs of the users, both in the EOS program and in the larger U.S. Global Change Research Program.

- EOSDIS, as it evolves, must maintain the flexibility to build rapidly on relevant advances in computer science and technology, including those in databases, scalable mass storage, software engineering, and networks. Doing so means that EOSDIS should not only take advantage of new developments, but also should become a force for change in the underlying science and technology where its own needs will promote state-of-the-art developments. Flexibility also requires organizational and management structures and processes that can respond to evolving requirements and implement the means for meeting them.

- EOSDIS needs substantive user participation in the design and development of the system, including involvement in the decisions on data acquisition and archiving, standard or ad hoc product generation, and interfaces that directly affect science users.

- The structure of the EOSDIS management organization and the attention it gives to the project should reflect the importance of the program in terms of its role as one of the major and most costly programs NASA has ever undertaken as well as its central role in the U.S. Global Change Research Program.

The EOS program was recently restructured from a mission consisting of two large, orbiting platforms containing a total of 30 instruments to a series of six smaller spacecraft containing a total of 20 instruments. The amount of data expected to be collected from EOS, however, has decreased only slightly: from 330 gigabytes/day to 240 gigabytes/day. The estimate for the total amount of processed data (from the EOS spacecraft and the other missions and instruments that will be flown) that will be managed by EOSDIS changed from

1300 gigabytes/day to about 1100 gigabytes/day, a reduction of only 15 percent. Furthermore, the capabilities of the EOSDIS System are tied to the existence of the seven Distributed Active Archive Centers (DAACs) and the data they contain, rather than to the flight rates. Although the panel will certainly examine this issue further for the final report, it appears that the recent restructuring of the EOS flight program has had little effect on the requirements for EOSDIS and thus does not affect the preliminary conclusions of this interim report.

In general, the panel does not see any serious risk to the EOSDIS program due to unavailable or inadequate technology. The panel believes that the prototyping plans of the EOSDIS Project Office, to be implemented after the contractor is selected, should be accelerated in order to assure that Version 1 is completed in accord with design objectives.

There are risks, however, in two aspects of the planning for EOSDIS. One area of risk derives from the scale and pace of changes in computer and data management technology that can be expected over the long-term life of the program, and from the great diversity of users who must interface with EOSDIS. NASA needs to focus immediate attention on planning how EOSDIS will evolve to continue to be a useful system as the scientific needs and the technology change over time.

Another area of risk concerns the management structure of EOSDIS. EOSDIS is an exceptionally large and complicated project that will cost several billion dollars, involve thousands of people, and continue for many years. The management will involve a complex mix of government, contractors, and a scientific community that is diverse and spread around the world. Each has an important role to play, and each will interact in a variety of ways with the other elements. In its recommendations in this interim report the panel has attempted to provide a number of mechanisms and approaches that it believes will help define these roles and interactions.

NASA, of course, must have the ultimate responsibility for implementing EOSDIS. To do so effectively, however, NASA should first ensure proper internal management attention and also should use its own personnel in earth science and computer science, who can contribute significantly to the successful design of the system. Secondly, NASA needs to bring the scientific user community into the project as a partner, rather than regarding users simply as customers. Finally, NASA must accept the leadership role necessary to provide the essential unity among the user community (including other federal agencies and international participants), DAAC elements (management and scientific), and contractors. The complexity of this project demands that a structure be developed to ensure that all interests are properly integrated into the design of EOSDIS.

The panel believes that NASA can proceed prudently with the procurement process for EOSDIS, *provided* the agency builds in the flexibility to make the adjustments necessary to ensure the success of the project. The conclusions and recommendations offered in this interim report can help NASA to incorporate that flexibility into work plans during the contract negotiations that will soon take place. This flexibility can be accommodated within the scope of the current procurement as long as it is planned ahead of final contact negotiations and the contract terms are compatible with this approach. The panel believes that its recommendations should not materially affect the EOSDIS schedule and that they can be implemented in work plans resulting from the pending contract negotiations. It is important to all users that EOSDIS implementation proceed as closely as possible to the planned schedule.

The panel has divided its assessment into three parts: user interactions, EOSDIS architecture, and EOSDIS management. The recommendations for each area offer actions that NASA should consider in order to meet the objectives of the program described above without halting the current procurement. The panel also recognizes that requirements may change over time and that NASA may have to adjust its work plans over the life of the project.

In order to be of service to NASA during this important stage of negotiating with the selected contractor, the panel believes that it is necessary to provide this advice now, in this interim report. The final report will expand on the issues discussed in this interim report and will respond in detail to the terms of reference.

CONCLUSIONS AND RECOMMENDATIONS

The following are the panel's judgments concerning the user interaction, architecture, and management issues that it believes must be addressed if EOSDIS is to meet the objectives integral to its success. In each instance, the panel points to strengths and weaknesses in the program, and offers recommendations.

User Interactions

Strengths

NASA has stated its intention to incorporate user feedback throughout EOSDIS development and evolution. The panel applauds this approach. The ability of EOSDIS to serve the broad spectrum of users will be the final measure of EOSDIS success. In this context, it should be acknowledged that NASA has led other agencies in developing the Global Change Master Directory, which will be a comprehensive description of all global change data sets. The panel also commends NASA for its plan to share software code and toolkits with users who wish to import them for their own systems.

Panel Concerns

In its review, the panel has identified several areas in which an augmentation or strengthening of critical user interactions could substantially improve the likelihood for success of the EOSDIS program. Areas of concern are NASA's Science Data Plan, links with other agencies, use of Pathfinder data sets, treatment of operational and historical data, long-term archiving, involvement of nontraditional communities, and the ability to provide customized data sets.

Science Data Plan. Version 0 science data requirements are being compiled into a Science Data Plan by the EOSDIS Project through regular interactions with the user community. The intent is to solicit regular review of these requirements from the science community to make certain that evolving needs are adequately reflected in the EOSDIS Project planning. Care must be taken to ensure that the Science Data Plan continues to emphasize the links between global change research objectives and the acquisition of individual data sets. A clearer picture of base-level requirements can be achieved by a continuing assessment of science objectives, existing holdings that might meet the objectives, and requirements for future data streams.

> The panel recommends that the Science Data Plan identify the links between global change research objectives and existing and planned data sets.

Interagency Links. The research priorities of the U.S. Global Change Research Program cut across the missions of individual federal agencies. The distribution of current holdings as well as data to be acquired underscores the need for interagency interoperability and cooperation. NASA has been an active participant in interagency efforts for the U.S. Global Change Research Program through a variety of working groups, and is currently a full partner in developing a tri-agency (NASA, NOAA, USGS) data and information implementation plan, of which EOSDIS is a critical component. The panel endorses the efforts of these agencies to work cooperatively.

The Global Change Master Directory is an excellent first step in helping users to identify relevant data sets for global change research. A similar effort is needed in achieving interoperability for access to the data. Success will require both technical developments and leadership in order to integrate and provide broad access to disparate data types currently distributed throughout the agencies. The panel believes that NASA is the logical agency to initiate this step in the context of EOSDIS. Moreover, EOSDIS will be much more effective in broadening its user base if it serves as the vehicle for integrating data.

> The panel recommends that NASA expand its efforts to increase interagency links by assuming an active leadership role among the agencies in achieving interoperability not only at the level of the Global Change Master Directory, but also at the level of providing access to the actual data.

Pathfinder Data Sets. Prototyping has been a routine component of EOSDIS planning and Version 0 implementation by the Project Office. NASA has been successful in establishing prototype earth science data systems that are currently acquiring, processing, distributing, and archiving pre-EOS data. Lessons from such prototyping activities can identify problems associated with the manipulation and distribution of extremely large data sets.

Pathfinder data sets provide an early means to evaluate the handling of large data sets, the development of products, and the distribution of data and products. NASA and NOAA are cooperating in a Pathfinder data program for selected satellite data. This program will be extremely valuable to the U.S. Global Change Research Program and to the prototyping of various functions of the overall data and information system.

> The panel recommends that NASA develop ways to integrate the efforts of existing data centers and centers of data supported by NSF, DOE, and USGS with the NOAA/NASA Pathfinder activities. Further, the Pathfinder data program now under way should be accelerated.

Operational and Historical Data. Data from past and currently operating satellites already are being provided to several DAACs. NASA has shown considerable foresight in recognizing the importance of data streams from NASA, NOAA, DOD, and foreign satellites in establishing long-term data sets for global change research. Although the EOSDIS Request for Proposal addresses data management of NASA's EOS platform instruments as well as NASA's commitment to maintaining data sets acquired by pre-EOS sensors, the panel wishes to emphasize the need for the accessibility of non-EOS instrument data streams to EOSDIS users.

The panel believes that the full benefit of EOSDIS to the U.S. Global Change Research Program will not be realized until an effort similar to that for EOS data is undertaken to manage the immense collection of historical data related to global change research already collected through operational observing systems. This collection includes the routine data from the space-based and surface-based observing systems of NOAA and DOD, as well as the routine and special data collected by USGS, USDA, EPA, DOE, NSF, and the Census Bureau. Integration, interpretation, and synthesis of such data, as part of a modern data and information system for long-term operational measurement, are critical to the goals of the U.S. Global Change Research Program and the interpretation of EOS measurements.

> The panel recommends several ways to address the issue of integrating the operational and research data from other agencies into EOSDIS:

a. NASA should articulate a plan for incorporating operational and non-EOS instrument data streams into EOSDIS. Where EOS and non-EOS instruments have similar functions, NASA should develop a strategy to enhance the use of both data streams. This strategy should also include consideration of cross-calibration between basic radiometric data and higher-level products of an EOS instrument with a non-EOS instrument.

b. To test the interoperability of EOSDIS and to integrate the critical long-term operational data that now exist at Affiliated Data Centers into a global change data and information system, NASA should perform a full-function test of the EOSDIS architecture and software on some of the Affiliated Data Centers, in particular, centers with holdings (such as long-term satellite or in situ data records) critical to the U.S. Global Change Research Program and to the synthesis and interpretation of data from EOS instruments.

c. NASA should articulate its policy on how Affiliated Data Centers will move up through the different levels of interoperability that are specified for linkage with EOSDIS.

Long-Term Archiving. Long-term archiving of EOS data is an issue that has not been addressed. Long-term commitment to maintaining data collected as part of EOSDIS is a critical component of the U.S. Global Change Research Program. NASA, in its response to questions from the panel, correctly pointed out that the issue of maintaining long-term archives is one that must be addressed by all participating federal agencies. Without a concrete plan and agency coordination for establishing permanent data archives, however, the overall objectives of EOS, and, therefore, of the U.S. Global Change Research Program, are jeopardized. As in the case of increasing interagency links, the panel believes that NASA can provide the leadership in addressing this need.

> The panel recommends that NASA develop an adequate plan and technology for long-term data archiving in conjunction with the other federal agencies participating in the U.S. Global Change Research Program.

Involvement of Nontraditional Communities. NASA has identified ways for broadening the user community and providing information about EOSDIS to those unfamiliar with the system through professional journals and newsletters. Such publications may be adequate for reaching users in certain disciplines but may be ineffective for those in other fields, particularly in the nonphysical sciences. For example, one of the science priorities identified in the U.S. Global Change Research Program is to assess the human dimensions of global change. A detailed plan for involving potential user communities beyond the traditional disciplines associated with the earth and environmental sciences has not been clearly delineated for the panel.

Many approaches could be taken to encourage users from nontraditional communities (e.g., legal, educational, political, and social). A useful approach could include the distribution of sample products that would allow users to become familiar with the various types of data sets available and to judge whether those data would be helpful to their research.

The panel recommends that NASA take an active role in facilitating access to EOSDIS by other, nontraditional disciplines through a program that includes representatives from those disciplines in NASA's user advisory groups and develops products useful to them.

Customized Data Sets. NASA clearly recognizes the importance of involving the user community in the development of EOSDIS. An approach to encourage active user participation is to provide customized data integration and synthesis of various products. The availability of software tools that conform to standards in an open architecture environment would facilitate participation by active users. For example, these tools might enable a user to assemble a customized set of specific time- and/or space-averaged data that could not otherwise be assembled without the user having to develop new software.

The panel recommends that NASA encourage broad user participation by providing greater opportunities to create customized data sets.

EOSDIS Architecture

Strengths

The panel in its several lengthy discussions with EOSDIS technical staff was impressed by the staff's competence and motivation. The staff has devised a process for designing the EOSDIS Core System that would rely on open systems, including multiple levels of interoperability for both users and the DAACs as well as the ability to handle evolving international standards. These two approaches—use of an open system and adoption of standards even though they will change over the lifetime of EOSDIS—will strengthen the program.

The Project plans to deliver EOSDIS in incremental stages (via Versions 1 to 6 and Data Product Levels 0 to 6) that are expected to provide the flexibility necessary to meet user needs, to respond to budget uncertainties over the next decade, and to adjust to EOS flight schedules.

Panel Concerns

Design Control. Any large software system requires design criteria that are set by project management and articulated clearly and precisely throughout the project hierarchy. This is particularly true for EOSDIS because of four reasons: (1) the unprecedented size of the system's storage and processing capacity; (2) the extraordinary heterogeneity of both user computation systems and user requirements; (3) the large variation in scale of both the mass stores and the granules of data to be simultaneously managed; and (4) the high degree of evolution expected in the system. The combination of these factors will make the design, implementation, and evolutionary control of the system a substantial architectural challenge.

Although NASA has assured the panel that EOSDIS will serve the needs of global change researchers, the EOSDIS Core System Statement of Work and the Functional and Performance Requirements documents of the Request for Proposal seem to be based on the management of data holdings resident with or owned by NASA or the DAACs and the created data products related to those holdings. It is entirely likely that data and/or data archives that are not within the exclusive purview of NASA or the DAACs will need to be made accessible to users through EOSDIS, without changing ownership of the data or the autonomy of the data repository. In anticipation of the need for accessibility, EOSDIS software should be built in the form of modular components with open, configuration-controlled interfaces so that other national and international agencies will be able to link with the system and provide products and services to the broader global change research community.

The panel believes that responsibility for the design criteria and for their enforcement to guide the system architecture must reside with the government. The government must assure that the contractor's detailed architecture and implementation decisions follow the directions given by the government system architects.

> The panel recommends that NASA produce a clear, concise statement of the design criteria for EOSDIS that focuses on facilitating global change research and that NASA communicate these criteria throughout the Project hierarchy.

The panel recommends that NASA strengthen its internal system architecture team by acquiring additional experienced people and that it give them the responsibility, authority, and budget to ensure that the design criteria are met as the system design and implementation proceed. A technical project of the magnitude and complexity of EOSDIS should have the very best system architecture team possible. NASA should make every effort to acquire such talent.

Logically Distributed System. The research that will be possible through the resources provided by EOSDIS is difficult to characterize at present. Some research will focus on narrow disciplinary questions, while other work will be interdisciplinary. Since we cannot, indeed should not, attempt to specify the future directions that earth science research will take, EOSDIS must be flexible enough to respond to a wide variety of approaches. Furthermore, EOSDIS will be only a part, albeit a major one, of the efforts directed at managing data and information for global change research.

The EOSDIS development plan provides for centralized control over the specification and implementation of the system. Each DAAC will implement an Information Management System that will be centrally developed by a single contractor. Although a centralized system is desirable for the management, operation, and control of the satellite and its instruments, the data will be distributed and dispersed among geographically separate and discipline-specific DAACs. Achieving the proper balance between the common elements that should be developed centrally and those that should be developed in a distributed fashion is critical to the success of the overall U.S. Global Change Research Program. At present, it appears as though the EOSDIS development plan is too heavily oriented toward a centralized approach.

The panel recommends that the EOSDIS Project adapt its development plan to ensure a more logically distributed system, including:

a. Designing EOSDIS so that all users (EOS and non-EOS investigators, DAACs, other data centers) can easily build selectively on top of EOSDIS components. EOSDIS should not constrain local implementation of diverse functions by users and DAACs. The development plan should reflect a philosophy that it is "easy to interact with EOSDIS" with minimum loss of autonomy. EOSDIS must be able to tolerate different versions of functionality and partial sharing of the components and toolkits it exports.

b. Identifying those areas of interdisciplinary research that will require special interfaces among discipline-specific products and formats. The Project should specify the interfaces, build prototypes, and run simulations to exercise them, permitting users to evaluate them prior to developing final specifications and proceeding to full implementation. A contractor team that resides at each DAAC and works closely with the DAAC as well as the contractor's "central core" team should facilitate the development of these prototypes.

This type of distributed development can be accomplished within the scope of the current procurement as long as it is planned ahead of final contract negotiation, and contract terms are compatible with this approach.

Incremental Prototyping. The current EOSDIS development plan closely ties the availability of the distributed archive and product generation functions to the EOS flight schedule. There is much work that should be done, however, prior to the first scheduled launch of EOS instruments in 1998 to strengthen prototyping efforts already under way. For example, there are both existing archives and data expected from pre-EOS satellites that will be invaluable to the U.S. Global Change Research Program. Although the EOSDIS Project team has initiated the early prototyping effort for Version 0, more can and should be done to benefit current global change research and to enhance user feedback for final system design.

The panel recommends that EOSDIS Project management extend its incremental development plan so that all user interfaces, all toolkits, and the end-to-end network system are:

a. Specified in detail early in the development of Version 1 and prototyped or simulated sufficiently, and

b. Evaluated in depth by users and DAACs prior to full implementation in Version 1. This will require a system network simulation and sufficient testing tools for users to assess and validate the specified functionality.

Usability Evaluation. Prudent practice in the design of complex data management systems ordinarily includes a means of measuring the usability of the data. To the extent possible, such measures should be quantitative. Early evaluation exercises should be designed to measure ease of use, quality of interface specifications, and convenience of interoperability of heterogeneous system components. These exercises should ensure that individual users and data archivers can acquire piecemeal both functional capabilities and data sets. It is also prudent practice to involve independent judgment by having this evaluation performed by a group other than those responsible for developing the system.

The panel recommends a usability evaluation program starting as soon as possible that involves:

- Selecting key functions, interfaces, and system behavior attributes for evaluation;
- Defining a set of metrics and expected values of those metrics for each parameter to be evaluated;
- Creating prototypes, simulations, and test suites to stress aspects of usability;
- Using the evaluations to guide final specification of system components; and
- Implementing this program so that most of the evaluation and validation is done by groups other than the prime contractor.

EOSDIS Management

Strengths

NASA is to be commended for developing the plans for EOS as its flagship for U.S. participation in global climate change research. NASA and the EOS Project are further to be commended for their dedication to producing an adequate data system for EOS and for its user community. The unprecedented level of funding allocated for EOSDIS and the high level of planned contingency funding are evidence of the commitment NASA has made to this important national research effort. The panel is impressed with the degree of dedication and commitment of the EOSDIS Project team. The team is working diligently and competently toward both prototyping key system and subsystem capabilities and planning for the procurement of the full EOSDIS system.

Panel Concerns

Visibility and Management Attention. Although EOSDIS appears to receive substantial attention from management at NASA Headquarters, in the panel's view, EOSDIS lacks the attention of senior management at the Goddard Space Flight Center. The EOS Project is the largest single development effort the Goddard Center has undertaken. Even without the flight hardware components, EOSDIS by itself probably satisfies that description. EOSDIS is an extremely complex interdisciplinary science project and must integrate the most advanced data and system technologies. EOSDIS also contains both the flight operations segment and the ground data system. The fact that schedules overlap and that the prime contractor probably will use different groups of personnel to implement these two very different elements will amplify the government's oversight and management challenge. Yet the panel has heard substantial evidence that from the management standpoint, EOS and EOSDIS are treated like an ordinary project within the Goddard Center. For example, the Project Manager for EOSDIS is two management levels down within the Flight Operations Directorate, which is only one of ten directorates at the Goddard Center. In addition, the Project Office is quite small for the task at hand, with plans for only 45 government employees when fully staffed. This small core of dedicated staff provides inadequate programmatic and managerial depth and expertise in the development of large, distributed data systems and in computer science and technology.

Given the preeminent position of EOS and EOSDIS in the U.S. Global Change Research Program, the panel believes that it is essential to increase the level of management visibility of the Project and the size and skills of the Project staff. In addition to learning from other government agencies that have had experience in the development and operation of large distributed data handling systems, NASA could, as needed, add to the Project experienced systems development personnel from other parts of the government.

The panel suggests that greater flexibility in defining success criteria and in using the process for setting award fees for direct feedback from the Project Manager to senior-level contractor management would help to assure that the contractor will do an outstanding job on EOSDIS. The panel commends NASA for including users in its performance board for contract evaluation and urges the active participation of users in setting award fees.

The panel recommends that the EOSDIS Project Manager have higher management visibility within Goddard Space Flight Center. The staff authorizations and skills should be sized to the scope and complexity of the Project. Further, the Project could augment its staff with experienced personnel from other parts of the government in addition to NASA.

The panel recommends that the EOSDIS Project use the award fee process to best advantage through greater differentiation of success and failure criteria for evaluating contractor performance and by involving users in determining award fees.

Scientific Involvement at Goddard Space Flight Center. The Goddard Center's in-house earth scientists have a very limited role in the management and operations aspects of the EOSDIS Project. Although NASA has established a variety of science advisory and data working groups, such groups cannot replace the continuing and even daily involvement of the external scientific community and the Goddard Center staff to ensure that the eventual system is responsive to user needs.

Likewise, the nation's computer science community currently has very limited involvement in the Project, despite the fact that EOSDIS, to be successful, must implement the latest advances in scientific data management technology and, in some cases, stimulate the development of new technologies. The development of EOSDIS would benefit from substantive use of expertise in systems design and exploitation of information processing technology. Because underlying technologies, such as storage density, processor speeds, and transmission rates, are doubling roughly every three years, EOSDIS must be able to exploit rapidly expanding capabilities during its lifetime of a generation or more.

EOSDIS will also stretch the limits of what can be done by a mammoth database management system shared by a very diverse and demanding user community. Certainly, many of the underlying technologies such as storage will evolve on their own. Other technologies, however, will have to be encouraged, such as large-scale data management, visualization, and integration of heterogeneous information. Possible ways to stimulate technology include establishing an intramural computer science research capability comparable to those in other sciences, supporting and using the external computer science community, and using DAACs to establish formal and informal links with the computer science research community in their neighboring universities.

The panel recommends that NASA involve Goddard Space Flight Center earth scientists to a greater degree in the management and operations of EOSDIS and also involve computer scientists both inside and outside of NASA to explore research and technology in those areas where EOSDIS will stress the state of the art in science and technology and where EOSDIS will evolve most rapidly.

DAAC Involvement. The DAACs are not well integrated into the EOSDIS management structure, particularly during the development phase. The DAAC managers do not have well-defined authority or accountability in building EOSDIS. DAACs should be involved early, in contrast to the current plan, in which their primary role appears to be to operate the hardware and software at their sites after delivery, and to deliver data products to users.

There should be mechanisms for feedback on scientific utility and operational effectiveness from the individual DAACs and associated archive centers to the central Project since the DAACs will be the primary sites for user interaction. There should be a coherent overall development, management, and science advisory structure that includes the DAACs. The panel understands that DAAC managers and scientists are involved in advisory roles. Advisory roles, however, are not sufficient for developing capabilities for and at the DAACs.

Overall, the centralized management of the design and implementation of EOSDIS functions at each DAAC is not conducive to active user involvement and responsiveness to changing technology. What is needed is a structure that strengthens the local role of each DAAC beyond the present DAAC advisory group and thus enhances the responsiveness of each DAAC in meeting the needs of its user community, gives the DAAC some control over its destiny, and yet ensures that an interoperable system is developed to meet the requirements of EOSDIS.

> The panel recommends that NASA create, at each DAAC, a Development Team of full-time staff and active science users to address DAAC and user concerns. These teams should evaluate EOSDIS planning and implementation, including architecture, DAAC interface definitions, and other deliverables essential to ensuring that the DAACs will be responsive to user needs and that the EOSDIS system will be interoperable. In accomplishing these tasks, the teams should monitor the contractor's activities on behalf of user communities and prepare test data sets to verify system interfaces. Each DAAC Development Team should validate that DAAC's operational capability to use the evolving EOSDIS system as each of the program releases is implemented. Finally, NASA should provide the DAACs with modest funding to respond to specific user needs so that the DAACs will be able to parallel the evolution of the user community's ability to manipulate, integrate, and model data.