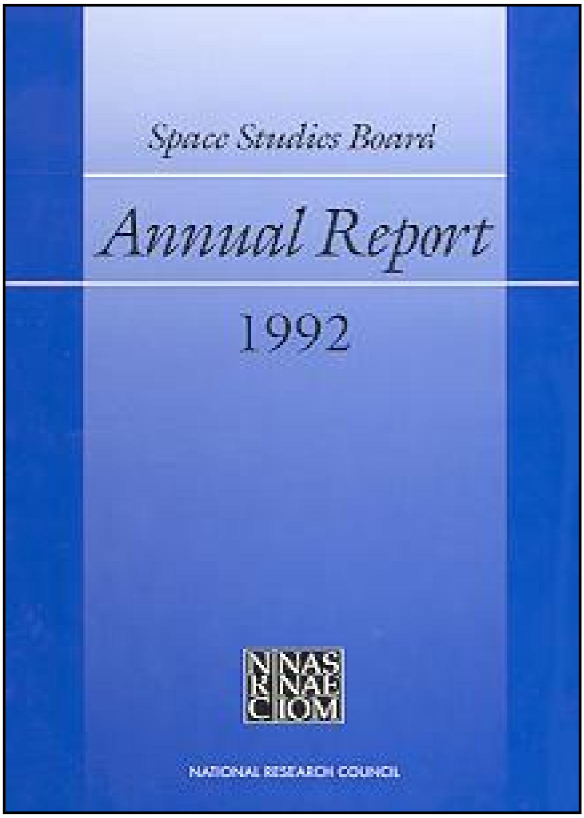
Space Studies Board Annual Report—1992



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

National Research Council

National Academy Press, 1993

Space Studies Board
Annual Report—1992

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 of its committees and task groups was provided by National Aeronautics and Space Administration contract NASW-4627 and National Oceanic and Atmospheric Administration contract 50-DGNE-1-00138.

Space Studies Board Annual Report—1992

From the Chair

Since 1958, the Space Studies Board (formerly the Space Science Board) has provided external and independent research and programmatic advice to the U.S. government on the nation's civil space program. This 1992 annual report of the Board records the activities and principal advisory documents issued by the Board during the year.

The year 1992 was an eventful one for the U.S. civil space program. The leadership of the National Aeronautics and Space Administration (NASA) was changed in the first quarter of the year. The new administrator instituted studies of all aspects of the agency's operations and programs, and initiated major management shifts in key program areas, including science, technology, and applications. Once again, there was energetic congressional debate during the summer on the cost and value of such large civil space program elements as the space station, large orbiting observatories, the advanced solid rocket motor, and new launch vehicle concepts. The joint international meeting of the Committee on Space Research (COSPAR) and the International Astronautical Federation (IAF) in Washington in August was the largest such space gathering to date, with a truly outstanding exhibit of space capabilities and achievements from around the globe. Then, elections in November saw a new administration elected by the American public, as well as sweeping changes in the membership of the Congress and of key committees that oversee space and technology.

Other events also had significant implications for the future of space research in a broader scientific and engineering context. Both the National Science Foundation and the National Institutes of Health reassessed their basic missions, raising deep questions about research priorities and national needs. The National Space Council of the outgoing administration issued several policy reports on fundamental aspects of our national space endeavors, military as well as civilian. Rep. George E. Brown, Jr., chair of the House Committee on Science, Space, and Technology, released a report in which he reflected on the state of the U.S. research enterprise and asked penetrating questions about the purposes and future directions of federal support of research. The President's Council of Advisors on Science and Technology (PCAST) and the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) both issued reports addressing the present and future relationship between the federal government and the research universities. This relationship is visibly stressed, with evidence of declining confidence by the tax-paying public in America's academic institutions.

The year also brought major new accomplishments and results in space research. Some of the highlights included the discovery of large-scale anisotropies in the cosmic background radiation by the Cosmic Background Explorer (COBE) spacecraft, first measurements of Jupiter's magnetosphere by instruments on the joint European Space Agency/NASA Ulysses spacecraft, successful launch and the beginning of data collection by the first Small Explorer—the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX)—nearly complete radar imaging of the surface of Venus by Magellan, and flight of dedicated U.S. microgravity materials and life sciences laboratories on the space shuttle. The Hubble Space Telescope continued its contributions to astronomy, carrying out studies from our solar system to the most distant reaches of the universe. The intrepid Pioneer and Voyager probes continued their lonely journeys away from the solar system, returning data from further than 50 times the distance from Earth to the Sun. The Mars Observer spacecraft was launched and is on its way to studies of the red planet beginning next year, while Galileo flew by Earth for its last time toward a rendezvous in 1995 with the planet Jupiter.

Underlying all of the programmatic changes and research successes in space is the fundamental fact that a major rethinking—some would call it a major shakeout—is occurring in the space programs of all nations. There is a global reassessment of the place of space activities in individual national priorities, and major restructurings are under way everywhere. Some of the most visible include a decision by the European Space Agency to forgo its independent Hermes piloted program for some years, and large uncertainties about Russia's level of commitment to ambitious plans for robotic exploration of Mars. Russia is also actively marketing many components of its once highly secretive space capability.

There is little doubt that access to space over the past four decades, and the data returned from increasingly sophisticated missions, have provided humankind with a profoundly new vision and understanding of our home on Earth, of the solar system, and of the universe. Space research has been tremendously successful. Although it is seldom acknowledged, there is also little doubt that much space activity around the globe was motivated at the most fundamental level by desires to demonstrate national technological and political supremacy. While not yet clearly articulated or universally accepted, the space research activities of nations in a post-Cold War world will need to be aligned to new national goals that remain ill-defined, but that will certainly be different from those that energized them in the past.

Prioritization of research will be demanded across a wider spectrum of opportunities, programs, and disciplines than in the past. International cooperation—true cooperation—rather than competition and duplication, appears likely to be a central part of a new order. Such true cooperation will not be achieved without creative thinking, good will, and genuine flexibility on all sides. Some implications of the future for U.S. researchers, and their students and colleagues, can only be dimly perceived at present. There will be shifts in space research emphases and major changes in programmatic practices, with contraction possible in many, if not most, space research disciplines. Some of the expected pain can be alleviated through efficiency and ingenuity. But this, too, will require real cultural change and tremendous good will on the part of all.

We researchers, and the Space Studies Board, must be active and innovative participants in helping to define our country's space agenda in a rapidly changing national and global environment—not just for the benefit of science and scientists, but also as a matter of civic duty.

Space Studies Board Annual Report—1992

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History and Charter of the Board

ORIGIN OF THE SPACE SCIENCE 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 expanded, leading to the establishment of the National Academy of Engineering and the Institute of Medicine, and of the National Research Council, 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 grew dramatically. Congress created the National Aeronautics and Space Administration (NASA) to conduct the nation's ambitious space agenda, and the National Research Council (NRC) created the Space Science Board. The original charter of the Board was established in June 1958, three months before final enactment of the legislation creating NASA. The Space Science Board has provided independent scientific and programmatic advice to NASA on a continuous basis from its inception until the present.

REORGANIZATION OF THE BOARD—CREATION OF THE SPACE STUDIES BOARD

In 1988, the Space Science Board undertook a series of retreats to review its structure, scope, and goals. 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 Space Applications Board. As a result of these retreats, a number of new task groups and committees were formed, and several committees were disbanded and their portfolios distributed to other committees. The Committee on Data Management and Computation and its activities were terminated. The Committee on Planetary Biology and Chemical Evolution was also dismantled, but its responsibilities were distributed to other discipline committees and task groups. The charters of the remaining committees were revised, and an executive council of the Board was created to assist the chair of the Board in managing Board activities.

Recognizing that civilian space research now involves federal agencies other than NASA (for example, the National Oceanic and Atmospheric Administration (NOAA), the Departments of Energy (DOE) and Defense (DOD), and the National Science Foundation (NSF)), it was decided to place greater emphasis on broadening the Board's advisory outreach. This broadening is fully consistent with the Board's founding charter in 1958.

CHARTER OF THE BOARD

The basic elements of the charter of the Board remain those expressed by National Academy of Sciences President Detlev Bronk to Dr. Lloyd Berkner, first chair of the Space Science Board, in a letter of 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 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 assist in coordination of the nation's space research undertakings. Since its restructuring in 1988 and 1989, the Board has assumed similar responsibilities with respect to space applications. The Board also addresses scientific aspects of the nation's program of human spaceflight.

Recommendations may be prepared either in response to a government request or on the Board's own initiative, and are released after review and approval by the National Research Council. In general, the Board develops and documents its views based on findings of its discipline committees or interdisciplinary task groups that conduct studies of varying duration and extent. These committees and task groups are composed of prominent researchers whose appointments are reviewed and approved by a formal procedure of the NRC. On occasion, the Board itself considers major issues in plenary session and develops its own statements. The Board also provides guidance, based on its publicly established opinions, in testimony to Congress.

The Board's overall scope of activity has several components: 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 numerous subdisciplines of space research, including space astronomy, earth studies from space, microgravity science, solar and space physics, space biology and medicine, and planetary and lunar exploration. This responsibility is discharged through an organization of separate discipline committees, and includes preparation of strategic research plans and prioritization of objectives as well as assessments 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 for many years. Committees also prepare formal assessment reports that examine progress in a discipline 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 in letter format. All committee reports undergo Board and NRC review and approval prior to publication. Board and committee reports are formally issued as reports of the Board and of the National Research Council.

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

INTERDISCIPLINARY STUDIES

While the emphasis over the years has been on discipline research planning and evaluation, the reorganization of the Board recognized a need for crosscutting technical and policy studies in several important areas. To address these needs, the Board creates internal committees of the Board and ad hoc task groups. Internal committees, constituted exclusively of Board members, are formed to carry out short-period study activities or to serve as initial planning bodies for topics that may require subsequent formation of a regular committee or task group. Task groups resemble discipline committees in composition and operation, except that they have predetermined lifetimes, typically two to three years, and clearly delimited tasks.

INTERNATIONAL REPRESENTATION

The Board continues to serve as the U.S. National Committee for the International Council of Scientific Unions (ICSU) Committee on Space Research (COSPAR). The U.S. vice president of COSPAR serves as a member of the Board, and a member of the Board's staff serves as Executive Secretary for this office. In this capacity, the Board participates in a broad variety of COSPAR panels and committees.

As the economic and political integration of Europe has progressed, so also has the integration of Europe's space activities. The Board has collaborated successfully 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 deepen its advisory relationship with this community. To date, the Board's approach has been regular exchange of observers at meetings of the Board and of the European Space Science Committee (ESSC), under the European Science Foundation.

In the future, the Board hopes to initiate cooperative advisory exchanges with the space research programs of Russia and Japan.

ADVISORY OUTREACH

The Space Science Board was conceived to provide space research guidance across the federal government. Over the years, the Board's agenda has 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, it is recognized that the incorporation in a major way of scientific objectives into manned flight programs such as the shuttle and space station programs, and possibly a Space Exploration Initiative (SEI), necessitates additional interfaces with responsible offices in NASA. The Board is attempting to strengthen its links to the space technology office in NASA through collaborative activities, such as joint workshops, with the NRC's Aeronautics and Space Engineering Board. Stronger links to NASA's space operations, international affairs, and commercial programs offices may also be needed in the future.

Second, the Board's assumption of the space applications responsibilities from the dissolved Space Applications Board has implied a broadening of its advisory audience to other agencies; an example is NOAA, which is responsible for operational weather satellites. In response, NOAA has become a cosponsor of the Board's Committee on Earth Studies.

Third, the maturation of some of the physical sciences may lead to progressive integration of space and nonspace elements, suggesting a more highly integrated advisory structure within the NRC. 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" structure with the NRC's ground-based Committee on Solar-Terrestrial Research. Another example is astronomy, where the recently completed report of the NRC's Astronomy and Astrophysics Survey Committee[1] suggests a close relationship between space astronomy and ground-based astronomy, the latter primarily supported by the NSF. The Board therefore established, in 1992, a new Committee on Astronomy and Astrophysics. This committee will operate as a joint committee of the Space Studies Board and the Board on Physics and Astronomy. Other areas of possible future disciplinary association are the general biomedical research community supported by the National Institutes of Health (NIH) and NASA's space biology research program.

Fourth, it has become apparent that new participants may become involved in space exploration, particularly the DOE and the Strategic Defense Initiative Organization (SDIO). Their involvement originates partly from a shared interest in development of space technology, and partly as a result of declassification of some defense technologies in response to the changing geopolitical environment. The SDIO has recently expressed the intention of conducting several space missions of potential scientific interest; the Board has performed an initial assessment of one of these (the Clementine mission to the Moon and an asteroid) and has begun the process of establishing a sponsorship relationship with the SDIO. The Board expects to continue to reach out beyond NASA to other federal agencies, seeking to establish advisory and corresponding sponsorship relationships, where appropriate.

[1] *The Decade of Discovery in Astronomy and Astrophysics*, Astronomy and Astrophysics Survey Committee, National Academy Press, Washington, D.C., 1991.

Space Studies Board Annual Report—1992

2 Activities and Membership

During 1992, the Space Studies Board and its twelve committees and task groups gathered for a total of 33 meetings. Three full-length, formal reports were issued, and status assessments were carried out for a number of approved or proposed planetary exploration missions. Letter reports were released on planning for NOAA long-term operational satellites and for DOE facilities used for space radiation research. Since a number of long-term discipline research strategies are becoming obsolete, several committees began work on new strategies. Updated strategies were initiated for solar and space physics and for planetary exploration. After release of its first formal report, a discipline status survey, the Board's new microgravity sciences committee began work on an inaugural research strategy of its own.

The following sections present highlights of the meetings of the Board and its committees during 1992. Formal reports and letter reports developed, approved, and released during these meetings are referenced by the section number of this annual report where their summaries are reprinted (in the case of full-length reports) or they are reproduced in full (in the case of letter reports).

SPACE STUDIES BOARD

The Space Studies Board met four times during 1992, in February, June, August, and November. Between meetings, the Executive Committee of the Board, composed of members of the Board, met several times by teleconference and in person.

In the first meeting of the year, the Executive Committee met on January 13 to act on a number of issues. These included Board appointments; an agenda for the forthcoming February Board meeting; and planning for activities of the Committee on Human Exploration, the Joint Committee on Technology, and the new Committee on International Programs.

The full Board held its 105th meeting, the first during 1992, on February 26-28 in Washington, D.C. Members heard about research results of the previous year's Space Life Sciences (SLS-1) shuttle mission and were briefed by officials of the Space Station Freedom office on station program progress, including current plans for the life sciences centrifuge and associated equipment. A major portion of the meeting was devoted to a series of briefings by NASA's Office of Space Science and Applications (OSSA), NASA Legislative Affairs, and the Congressional Budget Office on the budget outlook for space research. This outlook was far from encouraging. NASA was seeking a 4.7% increase for FY93, but contemporary remarks by Congressman Robert Traxler, chair of the House appropriations subcommittee with jurisdiction over NASA, had indicated that this would be hard to attain. The likelihood was (correctly) foreseen that the $500 million (in FY93 alone) shuttle Advanced Solid Rocket Motor might be reinstated without a corresponding increase in the total NASA budget. In the meantime, it was clear that orderly progress on the Advanced X-ray Astrophysics Facility (AXAF), Cassini, and Earth Observation System (EOS) programs would require significant increases by mid-decade.

At the meeting, the Board approved the final report of its Task Group on Planetary Protection (summarized in Section 3.3). Board members also approved a scientific assessment of the Comet Rendezvous/Asteroid Flyby (CRAF) and Cassini missions prepared by a special subpanel of the Committee on Planetary and Lunar Exploration (COMPLEX), chaired by Prof. Peter Stone of the Massachusetts Institute of Technology. The Board drafted an accompanying letter to the Associate Administrator for Space Science and Applications, Dr. Lennard Fisk, based on the COMPLEX assessment (both reproduced in Section 4.4). Based on the status briefing by Mr. Richard Kohrs, Director of the Space Station Freedom Program, the Board also prepared a statement on this program for the Associate Administrator for Space Systems Development, Mr. Arnold Aldrich (4.3).

An additional letter (4.5) summarizing past Board and committee recommendations on AXAF was later approved by the Executive Committee of the Board and released with these other reports; the whole package was forwarded to NASA Administrator Richard Truly under a general cover letter (4.2).

Many of the Board's committees met during the second quarter of 1992, against the backdrop of a very unsettled space research world. Authorizing subcommittees of both houses of Congress marked up their bills, which were very different in structure and funding. An amendment on the floor of the House to delete the space station was defeated after a passionate debate. Interest in acquiring or sharing capabilities of the space program of the former Soviet Union grew both there and in the United States, and the European space program evolved significantly. The appropriations outlook for the U.S. space program remained poor, as the Congress faced more financing needs than it could fully meet. In the meantime, a new NASA administrator was appointed, Mr. Daniel Goldin, who established agency-wide blue and red team reviews directed at improving the quality and efficiency of programs under way. Restructuring of the

Cassini and AXAF missions, begun in 1991 to reduce their funding requirements, continued.

The second 1992 meeting of the Board (its 106th) took place on June 1-3 at the Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Most of the first day was spent on committee business, including review and provisional approval of a number of submitted reports. The Board discussed and approved, pending revisions, a number of letter reports. Two of these, prepared by COMPLEX, assessed the scientific merit of the NASA Office of Exploration robotic lunar precursor missions (4.8) and of SDIO's Clementine Moon/asteroid mission (4.9). A third letter report (4.7), submitted by the Committee on Space Biology and Medicine, discussed the importance of continued operation of the Department of Energy's BEVALAC facility to space radiation biology research. These letter reports were discussed by the Board and received tentative approval, subject to indicated revisions. On the second day of the meeting, NASA officials briefed members on preliminary results of the AXAF restructuring exercise nearing completion, and on the status of the microgravity research program. These briefings were followed by tours of the MSFC AXAF calibration facility and Space Science Laboratory.

The Space Studies Board met for its 107th meeting on August 28-29 at the National Academy of Sciences in Washington, D.C. This one-and-a-half-day meeting was chiefly devoted to committee business, including discussion of plans for initiation of the new Committee on Astronomy and Astrophysics, to be operated jointly with the NRC's Board on Physics and Astronomy. The Board reviewed its international program, with several members planning to attend the September 1992 meeting of the European Space Science Committee (ESSC). During lunch on the first day of the meeting, the Board heard luncheon remarks by NASA Administrator Goldin on the red and blue team reviews in progress and on his goals for the agency. This talk was followed by a briefing by Dr. Fisk of OSSA on the status of the space science and applications program. The Board later reviewed a second COMPLEX letter report (4.10) on the Cassini program, this time considering the capabilities of the restructured mission (CRAF canceled and Cassini redesigned), and returned the report to the committee with provisional approval and directions for revision and augmentation.

Several significant events occurred between the August and late November Board meetings: the conference appropriation bill for NASA and related agencies was passed by the Congress and signed by the President on October 5, and Administrator Goldin announced sweeping changes in NASA's organization on October 15.

The final appropriation for NASA conformed largely to expectations from the debate and legislative activity earlier during the year. In the end, NASA received a total of $14,330 million, which was $663 million less than the President's FY93 request, but only $4 million less than the FY92 appropriation. OSSA, on the other hand, experienced funding growth of $127 million over the FY92 level (about a 4.7% increase). While less than hoped for in the President's request, OSSA's appropriated amount was expected to enable forward progress on major research missions such as Cassini, AXAF, and EOS, with some reductions in scope and capability to each of these programs. The CRAF mission remained terminated, as provided in the President's budget request.

While the implications of the FY93 appropriation could be fairly well understood in October, the consequences of Administrator Goldin's reorganization were less apparent. The major provision of the reorganization affecting space research was the fragmentation of OSSA and the reassignment of Dr. Fisk, its director, to the position of NASA Chief Scientist. The Earth Science and Applications Division was elevated to become the Office of Mission to Planet Earth; the Solar System Exploration Division, Astrophysics Division, and Space Physics Division were gathered into a new Office of Planetary Science and Astrophysics; and the Life Sciences Division and the Microgravity Science and Applications Division remained unassigned for the moment. In view of its charter to provide long-term strategic research advice to the whole of NASA's science and applications portfolio, the Board had a keen interest in both the administrator's reasons for these sweeping changes and the effects they were likely to have on initiation and execution of space research missions.

In response to these developments, the Executive Committee of the Board held a teleconference on November 5 to set the agenda for the Board meeting planned for mid-November. The Executive Committee resolved to invite Mr. Goldin to present the reorganization and his views at the meeting, and also to solicit Dr. Fisk's perspectives as well. The committee met again informally on November 17 to review what had become known about the reorganization and to assemble specific issues for discussion with the administrator at the Board meeting the following day.

The Space Studies Board held its last meeting of 1992, its 108th, at the Beckman Center in Irvine, California, on November 18-20. The agenda for the meeting included committee reports and approvals, consideration of broad policy issues, and discussion of Board plans for 1993. Highlights of the meeting were briefings by Administrator Goldin (in person) and a teleconference with Dr. Fisk. Mr. Goldin gave a broad perspective on his motivations for the reorganization and fielded questions from the members on a variety of space research-related concerns. Dr. Fisk added clarifications in a number of areas the following day via teleconference.

In other activities at the meeting, the Board was briefed by Committee on Solar-Terrestrial Research Chair Donald Williams about the results of the joint study by that committee and the Board's Committee on Solar and Space Physics on trends in research support. In subsequent discussion, the Board approved both a new charge for the Committee on Earth Studies and the Phase 2 report of the Committee on Human Exploration, which describes science objectives that could be enabled or materially enhanced by a human exploration program. The Board was privileged to hear from three members of the ESSC, Drs. Heinrich Všlk, Herb Schnopper, and Fran•ois Becker, who discussed their committee's status and plans, with emphasis on their recent report on satellite Earth observation. The Board viewed several videos on NASA spinoffs into medical technology, heard an analysis of last summer's workshop by the Task Group on Priorities in Space Research, and approved the Board's *1993 Operating Plan*.

Membership of the Space Studies Board

Louis J. Lanzerotti,§ AT&T Bell Laboratories (chair)
Joseph A. Burns, Cornell University
Andrea K. Dupree,* Harvard-Smithsonian Center for Astrophysics
John A. Dutton, Pennsylvania State University
Anthony W. England, University of Michigan
Larry W. Esposito,* University of Colorado
James P. Ferris, Rensselaer Polytechnic Institute
Herbert Friedman, Naval Research Laboratory
Richard L. Garwin,* IBM T.J. Watson Research Center
Riccardo Giacconi, European Southern Observatory
Noel W. Hinners,§ Martin Marietta Civil Space and Communications Company
James R. Houck,* Cornell University
David A. Landgrebe, Purdue University
Robert A. Laudise, AT&T Bell Laboratories
Richard S. Lindzen,§ Massachusetts Institute of Technology
John H. McElroy, University of Texas at Arlington
William J. Merrell, Jr., Texas A&M University
Richard K. Moore,* University of Kansas
Robert H. Moser, University of New Mexico
Norman F. Ness,§ University of Delaware
Marcia Neugebauer, Jet Propulsion Laboratory
Simon Ostrach, Case Western Reserve University
Carle M. Pieters,§ Brown University
Mark Settle, ARCO Oil and Gas Company
William A. Sirignano, University of California at Irvine
John W. Townsend, Jr., NASA (retired)
Fred Turek, Northwestern University
Arthur B.C. Walker, Stanford University

Duane T. McRuer, Systems Technology, Inc. (ex officio)
Donald J. Williams, Johns Hopkins University (ex officio)

Marc S. Allen, Director Betty C. Guyot, Administrative Officer

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*term expired during 1992
§member of the Executive Committee

COMMITTEE ON INTERNATIONAL PROGRAMS

Committee on International Programs (CIP) Chair William Merrell led a delegation consisting of Committee on Earth Studies Chair John McElroy and Board Director Marc Allen to the European Space Science Committee (ESSC) meeting in Budapest on September 23-24. Among other actions, the ESSC heard a briefing on the European Space Agency (ESA) science program and approved a draft report by its subpanel, the European Earth Observation Panel. This report was subsequently published as *A Strategy for Earth Observation from Space* (European Science Foundation, September 1992). Board attendees at the Budapest meeting discussed ways to better coordinate advisory work between the U.S. and European committees.

Through the efforts of Board member and U.S. COSPAR Vice President Herbert Friedman, and staff member and U.S. COSPAR Executive Secretary Richard Hart, the Board continued its active participation in international COSPAR activities. The Cospar Bureau met on August 27 and September 4; the COSPAR Executive Council met on August 28 and September 5. Most of the activities during the year were dedicated to organizing the 1992 plenary meeting that was held in Washington, D.C., from August 28 to September 5 in conjunction with the meeting of the International Astronautical Federation. This joint meeting was known as the World Space Congress—a major event of the International Space Year. The congress was attended by over 5000 participants, representing 65 countries. In addition, 135 organizations participated in the exhibit—the largest ever for a COSPAR meeting.

At the congress, a new COSPAR charter and bylaws were approved by COSPAR. If approved by the International Council of Scientific Unions (ICSU), they will go into effect in 1994. The most important change is that, beginning in 1994, all officers will be elected from a slate prepared by a nominating committee.

While COSPAR appears to be in a sound state at present, there are uncertainties for the near future given recent changes in the world. It is not clear that all of the member nations will be able to continue to pay their national contributions. On the other hand, there may be several new members of COSPAR in the near future: both the People's Republic of China and China Taipei seem to be seriously interested; Korea has recently launched a satellite; and a number of the new independent republics of the former Soviet Union are considering joining.

CIP Membership

William J. Merrell, Jr., Texas A&M University (chair)
Herbert Friedman, Naval Research Laboratory
James R. Houck,* Cornell University

Richard C. Hart, Executive Secretary

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*term expired during 1992

JOINT COMMITTEE ON TECHNOLOGY FOR SPACE SCIENCE AND APPLICATIONS

The Joint Committee on Technology (JCT) for Space Science and Applications, a collaborative effort between the Board and the NRC's Aeronautics and Space Engineering Board, held a week-long workshop in June in Annapolis, Maryland. The workshop, which was chaired by Dr. John McElroy, reviewed NASA plans for developing new space technologies in support of future science and applications programs. Twenty-six scientists and engineers met to receive briefings from representatives of NASA's Office of Aeronautics and Space Technology (OAST) and OSSA. A report summarizing the findings of the workshop was prepared and is expected to be released in early 1993. The committee also considered candidate topics for future workshops.

JCT Membership

David A. Landgrebe, Purdue University (co-chair)
John M. Hedgepeth,§ consultant, Santa Barbara (co-chair)
John H. McElroy,* University of Texas at Arlington (workshop chair)
Andrea K. Dupree,* Harvard-Smithsonian Center for Astrophysics
Duane T. McRuer,§ Systems Technology, Inc.
Franklin K. Moore,§ Cornell University
Richard K. Moore,* University of Kansas

Richard C. Hart, Executive Secretary
Noel E. Eldridge, Executive Secretary

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*term expired during 1992
§member, Aeronautics and Space Engineering Board

COMMITTEE ON ASTRONOMY AND ASTROPHYSICS and TASK GROUP ON AXAF

After a hiatus of over four years, astronomy and astrophysics returned to committee status within the Space Studies Board. The NRC determined that a unified space and ground astronomy committee is the best approach to continuing advisory oversight of these disciplines. Establishment of the Committee on Astronomy and Astrophysics (CAA), a new joint activity of the Board and the NRC's Board on Physics and Astronomy (BPA), was formally approved by the NRC Governing Board in May 1992. The CAA will cover ground- and space-based astronomy and astrophysics and will be the NRC's advisory body for these disciplines. A letter signed by Board Chair Louis Lanzerotti and

BPA Chair Frank Drake was sent out to solicit suggestions for CAA nominees, and returned over 100 nominations. Prof. Marc Davis agreed to chair the committee. Other appointments were finalized, and the committee will meet in January 1993. Additional support and sponsorship for the joint committee are being sought from the National Science Foundation.

Simultaneously, the Space Studies Board initiated a Task Group on AXAF (TGA), chaired by Prof. Arthur Davidsen. Anticipating a need for rapid NRC review of the science responsiveness of the restructured AXAF, task group members were appointed and a meeting planned to prepare a letter report. The TGA solicited and received comments from the x-ray astronomy community and held several planning teleconferences. The committee subsequently met on December 10-11, 1992, to review and evaluate the restructured AXAF mission. Participants included NASA managers and head scientists, as well as a number of principal investigators for the mission. The TGA considered whether the restructuring met the scientific rationale as envisioned in previous reports from the Space Studies Board and from NRC astronomy survey committees. The final TGA-approved draft is expected to be ready for Board and NRC review in February 1993. The target delivery date for the letter report is early 1993.

CAA Membership

Marc Davis, University of California at Berkeley (chair)
Arthur F. Davidsen, Johns Hopkins University
Sandra M. Faber, Lick Observatory
Holland C. Ford, Space Telescope Science Institute
Jonathan E. Grindlay, Harvard University
Doyal A. Harper, Jr., Yerkes Observatory
Kenneth I. Kellermann, National Radio Astronomy Observatory
Richard A. McCray, Joint Institute Laboratory for Astrophysics
Jeremiah P. Ostriker, Princeton University Observatory
Bernard Sadoulet, University of California at Berkeley

Robert L. Riemer, Executive Secretary

TGA Membership

Arthur F. Davidsen, Johns Hopkins University (chair)
David W. Arnett, University of Arizona
Hale Bradt, Massachusetts Institute of Technology
Anne P. Cowley, Arizona State University
Paul Gorenstein, Smithsonian Institution
Steven M. Kahn, University of California at Berkeley
James D. Kurfess, Naval Research Laboratory

Robert L. Riemer, Executive Secretary

COMMITTEE ON EARTH STUDIES

The Committee on Earth Studies (CES) met on February 10-12 to consider NOAA's requirements for future polar-orbiting operational environmental satellites. Based on briefings by NOAA managers and committee deliberations, CES prepared a letter report (4.6) containing recommendations for strengthening this planning document. The committee was also updated on NASA earth studies programs, including EOS.

On June 17-19, CES met in Washington, primarily to consider the role of satellite measurements in numerical modeling. A number of briefers from research and operational centers described the use of these data and the impact of improvements in collected data on model outputs. Members heard about the status of NOAA programs from Mr. Russell Koffler and about NASA Earth observing programs from Dr. Shelby Tilford, and witnessed a demonstration of microcomputer-based ground station technology. Members of the committee also discussed the Landsat program.

The committee's final meeting of the year was held November 16-17 at the Beckman Center. In preparation for defining its next major task, briefings were heard about a wide range of Earth remote sensing proposals and programs of the U.S. Air Force, Sandia National Laboratories, DOE, NOAA, and NASA. Recent management changes at NASA Headquarters and their effects on the earth science and applications program were discussed. The committee heard a presentation on the purpose, status, and goals of the congressionally mandated Consortium for International Earth Science Information Network (CIESIN) and discussed various options for its next major task. The resulting proposal, which was submitted to the Board and approved at its November meeting, provides for the committee to update its report, *Assessment of Satellite Earth Observation Programs—1991*, and to conduct a study identifying critical issues in U.S. earth sciences and applications programs.

CES Membership

John H. McElroy, University of Texas at Arlington (chair)
George Born, University of Colorado
Janet Campbell, Bigelow Laboratories
Dudley Chelton, Jr., Oregon State University
Charles Elachi,* Jet Propulsion Laboratory
William J. Emery,* University of Colorado
Diana Freckman, University of California at Riverside
Richard E. Hallgren,* American Meteorological Society
Kenneth Jezek, Ohio State University
Edward Kanemasu, University of Georgia
Vytautas (Victor) Klemas,* University of Delaware
Richard Kott, consultant, Fort Washington, Maryland
Conway Leovy, University of Washington
John MacDonald, MacDonald-Dettwiler Associates

Alfredo E. Prelat,* Texaco Corporation
Clark Wilson, University of Texas at Austin

Joyce M. Purcell, Executive Secretary
David H. Smith, Executive Secretary

*term expired during 1992

COMMITTEE ON HUMAN EXPLORATION

The Committee on Human Exploration (CHEX) met on January 21-22 in Denver to discuss plans for a study on alternative approaches to science management within human spaceflight programs. At this meeting, the committee was briefed on current planning by representatives from NASA's Space Station Freedom and Exploration offices. The committee met again for a summer workshop at the Academy's Woods Hole Center on July 6-10. Members continued work on the science management report, making good progress.

CHEX met at the Academy's Foundry facility in Washington on October 22-23 to complete its second report, *Scientific Opportunities in the Human Exploration of Space*, and to continue work on the science management report. The major action taken to finish the science opportunities report was to ensure that the scientific activities singled out by the Board's collaborating discipline committees as those especially enabled by a human exploration program were consistent with a series of general guidelines for scientific participation in human exploration developed in the committee's first, and completed, report on the science that must be done to enable a program of extended human spaceflight. A draft of the *Opportunities* report was submitted to the Board for approval at its November meeting in Irvine, on November 18-20, and was approved pending minor changes. The report was revised by the committee and forwarded to the Board's Executive Committee, which gave final approval in December.

The committee's first report, *Scientific Prerequisites for the Human Exploration of Space*, is expected to go to the printer in February. The science management report should be completed early in 1993.

CHEX Membership

Noel W. Hinners, Martin Marietta Civil Space and Communications Company (chair)
Richard L. Garwin,* IBM Corporation
Louis J. Lanzerotti, AT&T Bell Laboratories
Elliott C. Levinthal, Stanford University
William J. Merrell, Jr., Texas A&M University
Robert H. Moser, University of New Mexico

John E. Naugle, consultant, North Falmouth, Massachusetts
George D. Nelson,* University of Washington
Marcia S. Smith, Congressional Research Service
Gerald J. Wasserburg, California Institute of Technology

David H. Smith, Executive Secretary

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*term expired during 1992

COMMITTEE ON MICROGRAVITY RESEARCH

The Committee on Microgravity Research (CMGR) met February 24-25 to continue work on its new strategy for microgravity science. The strategy will be a long-range, comprehensive science road map to help guide NASA's future research in the field. The CMGR intends to make an initial presentation of the strategy report to the Board in February 1993. The committee also reviewed microgravity applications activities of NASA's Office of Commercial Programs.

At a subsequent meeting at the Lewis Research Center in Cleveland, Ohio, on May 20-21, members reviewed the microgravity activities and facilities at the center and continued work on their strategy for microgravity research.

The committee met again on July 21-22, September 21-22, and November 16-17, 1992, to work on the strategy report. In addition, at the November meeting, the committee considered NASA's plans for the space station centrifuge facility.

CMGR Membership

William A. Sirignano, University of California at Irvine (chair)
Robert A. Brown,* Massachusetts Institute of Technology
Howard M. Einspahr, The Upjohn Company
Martin E. Glicksman, Rensselaer Polytechnic Institute
Franklin D. Lemkey, United Technologies Research Center
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
John D. Reppy, Cornell University
Thomas A. Steitz,* Yale University
Warren C. Strahle, Georgia Institute of Technology
Julia R. Weertman, Northwestern University

Richard C. Hart, Executive Secretary

*term expired during 1992

COMMITTEE ON PLANETARY AND LUNAR EXPLORATION

The Committee on Planetary and Lunar Exploration (COMPLEX) held a major meeting on February 18-21 at the Beckman Center. The first two days were devoted to briefings on, and a scientific review of, the baseline (pre-restructure, but after deletion of the penetrator) CRAF and Cassini missions. The results of this review were documented in an assessment letter report (4.4) and later released by the Board. The second part of the meeting was devoted to planning for an integrated solar system research strategy to be developed by the committee over the next two years.

The committee met again in Washington on April 27-28. Members were briefed by SDIO and NASA officials on the joint Clementine Moon/asteroid mission. Members of Clementine's science working group described progress in selecting the filters for the mission instrumentation, enabling COMPLEX members to assess the potential science return in a letter report (4.9). NASA Associate Administrator for Exploration Michael Griffin described payload characteristics of the Office of Exploration's proposed lunar precursor missions, which were also compared to previous COMPLEX measurement objectives. These assessments (4.8) were submitted for Board and NRC approval and released.

COMPLEX members gathered again at the Beckman Center on July 13-17 to begin work on their new project—developing a unified set of scientific priorities for the planetary sciences over the next 10-15 years. This new strategy will replace COMPLEX's existing separate strategies for the inner planets, outer planets, primitive bodies, and search for other solar systems. Rather than dividing the solar system into general regions and examining them separately, this new study will take a comprehensive look at the solar system and divide it into scientific disciplines such as planetary atmospheres, surfaces and interiors, magnetospheres, rings, dust and primitive bodies, and the formation of the solar system and the origins of life. During this July meeting, COMPLEX members also conducted a reassessment of the reconfigured Cassini mission, including the effects of the termination of CRAF, and submitted a draft report to the Space Studies Board at its August meeting.

At a fourth meeting on September 21-23 at NASA's Goddard Space Flight Center, COMPLEX continued work on its integrated research strategy. COMPLEX received briefings on planetary magnetospheres that were omitted from the July meeting agenda because of schedule conflicts. The committee was also briefed on the status of the parallel priority-setting exercise being undertaken by the CSSP/CSTR. In addition to working on its integrated strategy, the committee also tackled a number of other tasks at the September meeting. Other topics included future missions to Mercury, the use of the Hubble Space Telescope (HST) for planetary observations, and the results of a recent study on the mitigation of asteroid hazards. COMPLEX members toured Goddard instrument laboratories, viewed hardware being constructed for the HST repair mission, and visited the control room of the International Ultraviolet Explorer. A portion of the meeting was devoted to minor revisions to the letter report drafted in July on the restructuring of the Cassini mission; the letter (4.10) was subsequently approved and released to NASA on October 19.

As part of the outreach activities for its priority-setting study, members of COMPLEX gave progress reports at a number of international scientific conferences. Prime among these was the October 13-17 meeting of the American Astronomical Society's Division for Planetary Sciences in Munich, Germany. In an evening session on October 15th, COMPLEX Chair Joseph Burns briefed the conference participants on the charge given to COMPLEX by the Board. He outlined events at the summer workshop in Irvine and progress the committee had made so far. Participation of a representative of the ESSC at the July meeting and the desire for additional European participation in the priority-setting study were emphasized. Following a description of the committee's plans for future meetings, Prof. Burns took questions from the audience during the limited additional time available.

COMPLEX made a second progress report (similar in format to the one given in Munich) at a meeting of the American Geophysical Union in San Francisco in December. The presentation was made by COMPLEX member Prof. William Kurth. The next major outreach activity is scheduled to take place at the Lunar and Planetary Science Conference in Houston, Texas, in March 1993.

COMPLEX Membership

Joseph A. Burns, Cornell University (chair)
Reta F. Beebe, New Mexico State University
Alan P. Boss, Carnegie Institution of Washington
Geoffrey A. Briggs, NASA Ames Research Center
Michael H. Carr, U.S. Geological Survey
Anita L. Cochran, University of Texas at Austin
Thomas M. Donahue, University of Michigan
James L. Elliot, Massachusetts Institute of Technology
Larry W. Esposito,* University of Colorado (former chair)
Peter J. Gierasch, Cornell University
John F. Kerridge, University of California at Los Angeles
William S. Kurth, University of Iowa
Barry H. Mauk, Applied Physics Laboratory
Lucy-Ann A. McFadden,* University of California at San Diego
Christopher P. McKay,* NASA Ames Research Center
William B. McKinnon, Washington University
Duane O. Muhleman,* California Institute of Technology
Norman R. Pace, Indiana University

Graham Ryder, Lunar and Planetary Institute
Paul D. Spudis,* Lunar and Planetary Institute
Peter H. Stone,* Massachusetts Institute of Technology
Darrell F. Strobel, Johns Hopkins University
George W. Wetherill, Carnegie Institution of Washington

Richard W. Zurek,* California Institute of Technology

David H. Smith, Executive Secretary

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*term expired during 1992

COMMITTEE ON SPACE BIOLOGY AND MEDICINE

The Committee on Space Biology and Medicine (CSBM) met on February 13-14 and heard presentations on results from the first Space Life Sciences (SLS-1) mission, the first International Microgravity Laboratory (IML-1) mission, and plans for SLS-2. Committee members discussed current life sciences research issues with congressional staff and NIH officials.

The committee met again on May 14-15 in Washington. In an effort to broaden its understanding of the capabilities and research potential of various former Soviet Union space facilities, such as the space station Mir and the Cosmos biosatellite series, the committee devoted a significant amount of the meeting to discussing these topics. Other items discussed were cooperative activities between NASA and NIH and long-term planning for NASA's radiation research program. The committee drafted a letter report (4.7) on the importance of continued operation of the BEVALAC facility for space radiation biology. The letter was later approved by the Board and the NRC and released.

The CSBM met for a third time on September 30 and October 1, at the Beckman Center, and discussed a number of fundamental issues pertinent to the Life Sciences Division's research program, particularly peer review and the status and plans for the division's Discipline Working Groups (DWGs). More results derived from the IML-1 mission were presented and plans for SLS-2 were discussed. A substantial portion of the meeting was devoted to further discussion about use of Russian space facilities such as Mir and the Cosmos biosatellites for U.S. life sciences research. The committee also viewed and evaluated two videos describing NASA life sciences research facilities and claimed terrestrial benefits.

CSBM Membership

Fred W. Turek, Northwestern University (chair)
Robert M. Berne,* University of Virginia at Charlottesville
Robert E. Cleland, University of Washington
Mary F. Dallman, University of California

John R. David, Harvard School of Public Health
Peter Dews,* Harvard Medical School
R.J. Michael Fry,* Oak Ridge National Laboratory
Francis (Drew) Gaffney, University of Texas, Southwestern Medical Center
Edward J. Goetzl,* University of California Medical School at San Francisco

Marc D. Grynpas, Mount Sinai Hospital, Toronto
Robert Helmreich, University of Texas at Austin
James 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
Alan L. Schiller,* Mt. Sinai Medical Center
Tom Scott,* University of North Carolina at Chapel Hill
Warren Sinclair, National Council on Radiation Protection and Measurements
William Thompson,* North Carolina State University
Fred Wilt, University of California at Berkeley

Joyce M. Purcell, Executive Secretary

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*term expired during 1992

COMMITTEE ON SOLAR AND SPACE PHYSICS

The Committee on Solar and Space Physics (CSSP), which operates in a "federated" structure with the Committee on Solar-Terrestrial Research (CSTR) of the NRC's Board on Atmospheric Sciences and Climate, met on March 16-18 at the Beckman Center to continue its study on the balance between "big" and "little" research programs within the committees' disciplines. The resulting *Report on a Space Physics Paradox* will address the question: Why has increased funding been accompanied by increased dissatisfaction in the research community? The federated committee planned for its new research strategy project and reviewed the status of its study on atmospheric electricity. At this meeting, the committees also prepared inputs to the CHEX science opportunities study and to the summer workshop of the Task Group on Priorities in Space Research.

The federated committees met for a week in July (26-31) to finish writing the Paradox report and to begin work on the new strategy. About a dozen outside scientists were invited to attend as guests to help formulate an approach to the strategy.

At a third meeting, held on October 19-21, the committees approved the Paradox report, continued work on the strategy study, reviewed relevant agency activities (NASA, NSF, NOAA, DOD), reviewed a draft report by the Panel on Solar Influences of the NRC's Committee on Global Change Research, reviewed the activities of the U.S. Coordination Office for the Solar-Terrestrial Energy Program (STEP), and discussed the recent reorganizations of the National Space Science Data Center and of NASA. The *Paradox* report was presented to the Board at its November meeting.

Subsequently, CSSP/CSTR organized a special session during the December meeting of the American Geophysical Union (AGU) in San Francisco to solicit suggestions for the new research strategy. Approximately 250-300 members of the AGU Space Physics and Aeronomy Section attended the session, and a number of contributions were received.

CSSP Membership

Marcia Neugebauer, Jet Propulsion Laboratory (chair)
Thomas E. Cravens, University of Kansas
Jonathan F. Ormes, Goddard Space Flight Center
George K. Parks, University of Washington
Douglas M. Rabin, National Optical Astronomy Observatory
David M. Rust, Johns Hopkins University
Raymond J. Walker, University of California at Los Angeles
Yuk L. Yung, California Institute of Technology
Ronald D. Zwickl, National Oceanic and Atmospheric Administration

Richard C. Hart, Executive Secretary

TASK GROUP ON PLANETARY PROTECTION

The Task Group on Planetary Protection (TGPP) published its report, *Biological Contamination of Mars: Issues and Recommendations*, in time for use at the World Space Congress' meeting of COSPAR held in Washington in late August. COSPAR has the responsibility for monitoring and updating planetary protection policy for all space-faring nations. Upon publication of its report, the task group was disbanded.

TGPP Membership*

Kenneth H. Nealson, University of Wisconsin-Milwaukee (chair)
John Baross, University of Washington
Michael Carr, U.S. Geological Survey
Robert Pepin, University of Minnesota
Thomas Schmidt, Miami University
Jodi Shann, University of Cincinnati

J. Robie Vestal, University of Cincinnati
David White, Oak Ridge National Laboratory
Richard Young, consultant, Kennedy Space Center

Joyce M. Purcell, Executive Secretary

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*task group disbanded during 1992

TASK GROUP ON PRIORITIES IN SPACE RESEARCH

Early in 1992, the Board published the first report from its Task Group on Priorities in Space Research (TGPSR), chaired by Board member Dr. John Dutton. This report, entitled *Setting Priorities for Space Research: Opportunities and Imperatives*, was released at a half-day symposium held in the National Academy of Sciences (NAS) Auditorium on January 24. NAS President Frank Press opened the symposium and commented on the desirability of addressing priority issues in science: "One has to do this not simply because there are budgetary constraints, but also as a means of self-examination . . . it gives the public confidence that we're going about our job right if we say to the public, who, after all pays for all of this, that we have examined and ranked our needs and opportunities." Mr. George E. Brown, Jr., chair of the House Committee on Science, Space, and Technology, gave the keynote address. Applauding the endeavors of the task group and the Board, Mr. Brown encouraged them and the scientific community at large to provide policymakers with a best assessment of priority ordering based on "unadulterated peer-reviewed judgment of scientific merit." Board Chair Louis Lanzerotti discussed how and why the Board and the space research community should be involved in recommending priorities. These remarks were followed by an open forum in which members of the audience were asked for their views and reactions to plans for a follow-on study—development of a priority-setting methodology and evaluation criteria.

In February, the Board sponsored a session on the topic of priority setting in research at the American Association for the Advancement of Science meeting in Chicago.

Congressional interest in the topic continued, with Dr. Dutton being asked to testify in April on priorities in space research before the House Science, Space, and Technology Committee's Subcommittee on Science.

During a July 27-30 workshop at Woods Hole, the task group tested and validated its model space research proposal and evaluation instrument. Outside guests, representing some of the major disciplines of space research, evaluated representative projects using the prototype proposal and evaluation instruments to gauge how effective and valid their application to actual projects would be. The task group began work on a first draft of a follow-on report, which will describe possible methods for setting priorities in space research fields and will discuss the committee's prototype instruments.

The task group held a meeting on October 22-23 to discuss further the results and implications of the Woods Hole experiment. Both the proposal questionnaire and evaluation method were modified as a result of the experiment. The group continued working on its follow-on report with the aim of completing the activity by June 1993.

TGPSR Membership

John A. Dutton, Pennsylvania State University (chair)
Philip Abelson, American Association for the Advancement of Science
William P. Bishop, Desert Research Institute
Lawson Crowe, University of Colorado
Peter Dews, Harvard Medical School
Angelo Guastaferro, Lockheed Missiles and Space Company, Inc.
Molly K. Macauley, Resources for the Future
Buddy MacKay,* Lt. Governor of Florida
Thomas A. Potemra, Johns Hopkins University
Arthur B.C. Walker, Stanford University

Joyce M. Purcell, Executive Secretary

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*term expired during 1992

Space Studies Board Annual Report—1992

3 Summaries of Reports

3.1 SETTING PRIORITIES FOR SPACE RESEARCH: OPPORTUNITIES AND IMPERATIVES

A Report of the Task Group on Priorities in Space Research[1]

[Policy] is like a play in many acts, which unfolds inevitably once the curtain is raised. To declare that the performance will not take place is an absurdity. The play will go on, either by means of the actors . . . or by means of the spectators who mount the stage.

Klemens von Metternich, 1880

The U.S. space program and its space research components have produced remarkable achievements in the past three decades and generated a wealth of opportunities for scientific initiatives in the years ahead. As we approach a new century, we must decide: What should we do? How should we do it?

Answers to these questions are critical for the future success of the space program and space research (that is, scientific activities concerned with phenomena in space or utilizing observations made in, or from, space). The answers will affect the strength of the national scientific and engineering enterprise, national economic vitality, and the national sense of pride and purpose. Answering the first question is equivalent to setting priorities for space research. Answering the second question requires that we develop a model for our activities that will facilitate accomplishing our highest-priority activities. Priorities, as used here, are rankings in a preferential ordering or agenda, possibly multidimensional, that governs allocation of resources to activities or initiatives.

For some time, the objectives of the space research community and those of the broader space program have been in conflict. Apollo demonstrated national technological superiority at a critical time. A fundamental assumption of the civil space program developed in that era asserts that it is human destiny to explore the universe. As a consequence, the civil space program continues to emphasize the mechanical aspects of flying spacecraft and transporting humans through space. In contrast, scientific vision focuses on the outcome of space activities, insisting that the means of conducting scientific research be determined by the objectives and purposes of that research itself; it emphasizes the information and understanding generated rather than the means of obtaining them.

New realities of international competition, domestic politics, and economics suggest the need to review the contributions of space research to national vitality. The accomplishments of the past and the many opportunities now available, as well as the widely recognized need to provide stimulation and motivation to education, suggest that we reconsider how scientific research in space is conducted. Fundamental assumptions about the objectives of space research and the space program that makes it possible may determine the outcome of research more than judgments about scientific merit, or national values, or imperatives presented by the new realities mentioned above. Thus the issue is not the relative value of the human spaceflight and space research components of the space program. Rather, it is to develop objectives and operating principles that will produce the maximum benefits from the nation's investment in space research and other space activities.

The imperative driving scientific research is the acquisition of knowledge and understanding. The collection of data, the creation of information through its analysis, and the subsequent development of insight and understanding should be key governing objectives for scientific research in space and for the broader objective of the space program. As suggested in the preface, the task group believes that this vision is compatible with the human spaceflight program and that the entire space program itself would be invigorated by concentrating on timely and compelling scientific objectives.

Emphasizing information and understanding will not compromise the overall space program's legitimate interest in the technology of spaceflight because formidable engineering and technical challenges must be met in order for space research to achieve its objectives. It will, however, permit the space research program and the overall space program to concentrate on the development of powerful new techniques for acquiring, communicating, synthesizing, and using information. And because information itself is an increasingly critical and economically valuable resource, this effort can enhance our national technological progress and economic strength while it enhances our scientific accomplishments.

Thus the vision of a space program and a space research effort emphasizing information, knowledge, and understanding presents an ideal format in which to consider priorities for space research. The central thesis of this report is that the space science and applications community should reach a consensus on priorities for scientific research in space. Since we cannot do everything, we should do the most valuable things, with the recognition that a collection of smaller efforts may in sum be more important than a single large initiative. The task group believes that a scientific agenda set forth by the community, with due regard for contemporary political and economic realities, will greatly assist policy makers and will ultimately prevail. Such an agenda, along with the reformulation of assumptions governing space research, will better serve scientific and national goals, achieve maximum return on investment, encourage effective congressional and agency action, and provide benefits for the nation's citizens.

ACCOMPLISHMENTS, PROSPECTS, AND LESSONS FROM THE U.S. SPACE RESEARCH PROGRAM

The accomplishments since 1957 of U.S. scientific research in space have broadened and deepened understanding of our physical environment. As with all science, these accomplishments are but harbingers of even greater future achievements. Past successes have created a multiplicity of opportunities for space science and applications. Moreover, our more than 30 years of experience in space research has provided important lessons on how to operate the program more effectively in order to obtain the maximum possible benefit from available resources.

All disciplines reveal the complexity of the physical and biological world. Things are much more complicated than we thought at the beginning of the space age in 1957. As examples, consider the violent astronomical events, the courses of planetary evolution, the interactions of solar and terrestrial magnetic processes, the interdependence of the various components of the Earth system, and the changes in human physiology that occur in space. We can expect to discover even more variety and more complexity in the years ahead.

Perhaps the most striking accomplishment of the U.S. space program is the demonstration that humans can work in space and on another body of the solar system and can travel to another part of the solar system and return successfully. This demonstration has opened the way for human exploration beyond the Earth for centuries to come.

The value of the unique point of view attainable from space has been demonstrated beyond doubt. We gain more than just a different perspective: operating far from the Earth's surface expands the domain of parameters available to science. This expansion will continue with the return and analysis of samples from planets, asteroids, and comets, with observations that reach back even further toward the origins of the universe, with extended human presence in space, and with comprehensive views of the interactions of the Earth's physical and biological subsystems.

In over 30 years of experience in space research, we have learned that flexibility and multiplicity of opportunity are key requirements. Although large missions may address the most urgent or most comprehensive scientific issues, small or moderate missions and suborbital initiatives can also resolve important scientific questions, and can do so more quickly and less expensively. For space research to produce maximum benefits, the objectives of scientific research should drive the mission rather than constraints imposed by the limitations of a program or a particular launch vehicle.

TODAY'S IMPERATIVES

Recent events at home and abroad require that we reexamine motivations, objectives, and methods of space research to ensure that they are responsive to contemporary imperatives. The key imperatives and their implications are as follows:

- Rapidly changing relationships between nations create new challenges and opportunities. Scientific efforts and space research must contribute to our ability to succeed in a vigorous economic and technological international competition.

- Domestic needs compete with scientific research in space and with the space program and force the nation to choose between research opportunities and other endeavors. Thus a focused and compelling space research agenda that clarifies the value and increases the productivity of both space research and the space program must be formulated.

- Public demand for accountability and for effective use of available resources is increasing. Space research and the space program must be conducted in accord with operating principles that will ensure that objectives are attained effectively. We must distinguish between initiatives in space that contribute to scientific understanding and those that are really aimed at nonscientific public purposes.

- There is widespread concern that our educational systems are not adequately preparing our citizens to participate effectively in an increasingly technological and competitive world. Success in space research can stimulate the curiosity of all young Americans and motivate some to choose careers in science, engineering, and technology disciplines. A vigorous space science program will provide information that interests, and perhaps enlightens, a national audience.

- Opportunities for international collaboration in space research are increasing. They are attractive because of the increasing complexity and cost of acquiring knowledge. But sharing the costs of space research with others cannot alone justify international collaboration; rather, collaboration should be undertaken in space research only to enhance scientific achievement.

OPERATING PRINCIPLES

Space research and the space program must be managed according to operating principles that will ensure that resources are used effectively and that objectives are attained. The following principles are derived from our 30 years of experience in space research; adhering to them will enhance the acquisition of information and knowledge and facilitate the response of space research and the space program to today's imperatives.

- *Enhance the human resource base.* The community of working scientists and students should be maintained and invigorated to strengthen the national scientific enterprise.

- *Acknowledge that choices must be made.* Science raises more intriguing questions than can be answered or even addressed. Thus we should recognize that choices must be made.

- *Capitalize on opportunities.* Special opportunities to perform good research are sometimes offered by technological developments or demands for applications. Wise investments in technological development will create such opportunities, sometimes in unexpected ways.

- *Capitalize on investments.* Having chosen to start valuable projects, we should insist on finishing them, in satisfactory, cost-effective ways. We need to understand better the direct and indirect costs of abandoning projects already begun.

- *Increase program control by principals.* Making principal investigators responsible for quality and giving scientists an increased role in program management offer potentially large benefits.

- *Secure access to space by diverse means.* Access to space through a variety of means appropriate to particular research missions is a recognized requirement of a vital space program.

THE RATIONALE FOR SETTING PRIORITIES

Priorities are needed at several levels within the national scientific enterprise, within the space program, and within space research because the success of science has created a wealth of opportunities for initiatives. Some initiatives will contribute more to scientific knowledge than others, some will enhance national economic and technological vitality, some will advance important applications of information from space, and some will assist in resolving important policy issues. An orderly process is needed to make the necessary choices.

Chapter 2 illustrates the broad range of future prospects for space research that includes large and small missions, projects in different fields, and the need to support both mature fields and untested ideas. Developing priorities for scientific research in space requires a sophisticated approach because it is not possible to rank all scientific research activities in a single list. Any priority scheme should be multidimensional in nature, with certain classes of activities given higher priority than others. There are a number of important criteria: the value of an initiative to science, potential social benefits, costs and readiness to perform it, and the probability of success. A priority scheme should provide for balance and flexibility in the program and for the maintenance of essential, ongoing activities.

Arguments for Setting Priorities

There are two principal arguments in favor of the recommendation of an agenda for space research by the scientific community:

- *Consensus is politically compelling.* An agenda for scientific research in space created and supported by the community would be persuasive. If scientists demonstrate that their agenda responds to scientific imperatives and to national needs, they can argue effectively for an adequate share of resources and for an orderly progression through the suite of initiatives endorsed by the community.

- *If scientists will not act, then others will.* If scientists cannot, or will not, recommend priorities, then others whose goals may differ from those of the scientific community will take the stage and make the decisions. None of the reasons scientists cite for eschewing the strenuous work of reaching consensus prevent federal officials or congressional representatives from making the necessary choices.

Addressing the Arguments Against Setting Priorities

A number of arguments against recommending priorities are sometimes offered by scientists. Some of them are listed below, with explanations as to why the task group does not find them compelling:

- *There will be losers.* Indeed there will be, but there are losers now. In fact, some who now enter the priority-setting process lose for reasons unrelated to the quality of the science. It would seem preferable that the community of scientists help to determine the winners.

- *Recommending priorities is too difficult, too contentious.* Recommending priorities is difficult but can be accomplished through a formal process in which competing initiatives are judged uniformly according to explicit criteria. If scientists find it too difficult to create a recommended program for space research, then, as said above, others will do it for them.

- *The community will not be able to maintain consensus.* Scientists loyal to initiatives not receiving strong recommendations may tend to subvert the process, it is argued, by lobbying for special favor. They would be better advised to develop more exciting initiatives. This argument and the two above combine to make a fourth:

- *Setting priorities will be counterproductive because the community will tear itself apart.* Moreover, the argument goes, at present the losers' rancor is directed at officials outside the community; if the community sets priorities, then the rancor will be turned inward. In essence, this is an argument that the science community is too immature to govern itself. The task group believes the community can behave responsibly and that its best interests will be served by doing so.

- *The low-priority initiatives will not be done.* The argument is that policy makers will take advantage of any list of priorities by eliminating the low-priority activities. That is precisely the reason priorities are recommended. It certainly seems preferable to abandon low-priority activities rather than to starve those with high priority.

- *Scientists cannot make political judgments.* Once scientifically meritorious proposals are put forward, this argument goes, the judgments about relative social benefits and the relevance to national needs are beyond the purview of scientists. But the task group believes that in arguing for initiatives, scientists should be sensitive to national goals and political realities. Because scientists expect support from the public, they should be able to explain why some initiatives better serve public purposes.

Priorities have been successfully set by scientists in a number of contexts. For example, NASA's Office of Space Science and Applications (OSSA) has adopted a structured approach to the assignment of priorities using the priority recommendations of a scientific advisory committee. The result is a program in which annual budget requests are made in the context of a formal five-year plan. Clarifying the components of the program and specifically setting priorities among initiatives appear to have reduced uncertainty and divisiveness in the space research community, strengthened space research, and made the program more attractive to the policy makers who provide the resources for it.

CONCLUSION AND RECOMMENDATIONS

Space research operates within the vision that governs the overall civilian space program. The task group concludes that emphasizing the acquisition and processing of observations and information and the conversion of this information into knowledge and understanding will simultaneously advance science and contribute effectively to national economic and technological vitality. Even with such a vision, the need to determine priorities among the various initiatives is inevitable.

For these reasons the task group makes the following recommendations:

- 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.

- Acquisition and effective management of information derived from space should be a primary objective of our national activities in space. Concentrating on innovation in information management will produce benefits beyond space research.

- The requirements of space research itself should determine policy and programmatic decisions in space research and in the support of space research by the civil space program.

Finally, the task group recommends that the Space Studies Board proceed to the next phase of the Priorities in Space Research study and thereby develop a methodology for assessing priorities for scientific research in space. Such an assessment procedure is possible, and its application will allow the establishment of priorities in space research that will benefit science, the U.S. civil space program, and the nation. The members of the scientific community conducting research in space have a responsibility to the public to undertake this task.

[1]"Summary and Recommendations" reprinted from *Setting Priorities for Space Research: Opportunities and Imperatives*, National Academy Press, Washington, D.C., 1992, pp. 1-8.

[The Executive Summary text of the following two reports is not included; a link is provided to the complete online reports.]

Space Studies Board Annual Report—1992

4 Letter Reports

During 1992, the Space Studies Board and its committees released ten letter reports, which this section presents in full in chronological order of release. Letter reports generally arise out of deliberations by a discipline committee in connection with its oversight responsibility. These reports, which document the consensus of the authoring committee, are submitted to the Board for approval at its next meeting. The members of the Board review the arguments and recommendations contained in the committee submission. Often, the Board writes a cover letter that may address, from a broader perspective, issues raised in the committee submission. In these cases, the final package is structured as a cover letter that summarizes the conclusions of the committee in the context of these broader issues and that is signed by the chairs of both the Board and the authoring committee, and the committee's scientific assessment, which is provided as an attachment. Examples are the flight program reviews of the Committee on Planetary and Lunar Exploration. In other cases, such as the 1992 statements on the space station and AXAF, the Board itself develops a recommendation and submits it to NRC review for approval and release.

In response to a request it received on September 26, 1991, the Committee on Planetary and Lunar Exploration assessed the congruence between NASA's Solar System Exploration Division's 1991 strategic plan document and previous advice of the committee. The letter (Section 4.1) discussing the committee's conclusions was approved and released on January 14. On March 30, the Board sent a letter (4.2) to NASA Administrator Richard Truly with a set of reports on Space Station Freedom, the baseline CRAF/Cassini mission, and AXAF. This package included a space station letter and a scientific assessment (4.3) addressed to Mr. Arnold Aldrich, Associate Administrator for Space Systems Development, and letters to Dr. Lennard Fisk, Associate Administrator for Space Science and Applications, on CRAF/Cassini (4.4) and AXAF (4.5). Following completion by the Committee on Earth Studies of a requested review of NOAA's strategic plan for polar-orbiting operational environmental satellites, the Board sent a preliminary assessment (4.6) on April 30 to Mr. Russell Koffler, NOAA Deputy Assistant Administrator for Satellite and

Information Services.

Later, on August 20 and 21, the Board released to NASA a second set of reports dealing with several proposed planetary missions and with the future of the Bevalac accelerator facility. Prepared by the Committee on Space Biology and Medicine, a letter (4.7) discussing the role of the Department of Energy's BEVALAC accelerator facility was sent to Energy Secretary James Watkins and to NASA Administrator Daniel Goldin. A letter and report (4.8) on the Office of Exploration's proposed robotic lunar precursor missions were sent to Associate Administrator Michael Griffin. A second letter and report (4.9) on the joint Strategic Defense Initiative Organization (SDIO)/NASA Clementine mission to the Moon and an asteroid were sent to SDIO Deputy for Technology, Dr. Simon Worden, and to NASA Director of the Solar System Exploration Division, Dr. Wesley Huntress. On October 19, the Board forwarded a letter and supporting COMPLEX assessment (4.10) on the restructured Cassini-only mission to Dr. Lennard Fisk, Associate Administrator for Space Science and Applications.

[Letter report text is not provided below;
links are provided to the online letters.]

4.1 On the Solar System Exploration Division's 1991 Strategic Plan

The Committee on Planetary and Lunar Exploration sent the following letter to Dr. Wesley Huntress, Director of NASA's Solar System Exploration Division, on January 14, 1992.

4.2 Letter to the NASA Administrator

The Space Studies Board sent the following letter to NASA Administrator Richard H. Truly on March 30, 1992. Included with it were the subsequent letters and assessments on the space station, CRAF/Cassini, and AXAF.

4.3 On the Space Station Freedom Program

The Space Studies Board sent the following letter and attached assessment to Mr. Arnold D. Aldrich, NASA Associate Administrator for Space Systems Development, on March 30, 1992.

4.4 On the CRAF/Cassini Mission

The Space Studies Board and its Committee on Planetary and Lunar Exploration sent the following letter and assessment to Dr. Lennard Fisk, NASA Associate Administrator for Space Science and Applications, on March 30, 1992.

4.5 On the Advanced X-ray Astrophysics Facility

The Space Studies Board sent the following letter to Dr. Lennard A. Fisk, NASA Associate Administrator for Space Science and Applications, on March 30, 1992.

4.6 On NOAA Requirements for Polar-Orbiting Environmental Satellites

The Committee on Earth Studies sent the following letter to Mr. Russell Koffler, NOAA Deputy Assistant Administrator/NESDIS, on April 30, 1992.

4.7 On Continued Operation of the BEVALAC Facility

The Space Studies Board and its Committee on Space Biology and Medicine addressed the following letter to Secretary of Energy James D. Watkins and NASA Administrator Daniel J. Goldin on August 20, 1992.

4.8 On Robotic Lunar Precursor Missions of the Office of Exploration

The Space Studies Board and its Committee on Planetary and Lunar Exploration addressed the following letter and attached assessment to Dr. Michael D. Griffin, NASA Associate Administrator for Exploration, on August 21, 1992.

4.9 On the NASA/SDIO Clementine Moon/Asteroid Mission

The Space Studies Board and its Committee on Planetary and Lunar Exploration sent the following letter and assessment to Dr. Simon P. Worden, *Deputy for Technology of the Strategic Defense Initiative Organization, and Dr. Wesley Huntress, Director of the Solar System Exploration Division at NASA, on August 21, 1992.*

4.10 On the Restructured Cassini Mission

The Space Studies Board and Committee on Planetary and Lunar Exploration sent the following letter and assessment to Dr. Lennard A. Fisk, NASA Associate Administrator for Space Science and Applications, on October 19, 1992.

Space Studies Board Annual Report—1992

5 Congressional Testimony

5.1 Testimony on Priorities in Space Life Sciences Research

Space Studies Board member Robert H. Moser delivered the following testimony before the Task Force on Defense, Foreign Policy, and Space of the Committee on the Budget of the U.S. House of Representatives, on April 28, 1992.

Mr. Chairman, Ranking Minority Member, and members of the Task Force. Thank you for inviting me to testify at these important hearings on behalf of the Space Studies Board of the National Research Council (NRC). The Research Council is the operating arm of the National Academy of Sciences, chartered by Congress in 1863 to advise the federal government on matters of science and technology.

As an M.D., my experience with the NASA spaceflight program goes back to the days of Project Mercury. A biographical sketch of my professional background is attached. Over the years, I have served on a wide variety of panels and committees that advise NASA and the nation about research, health, and safety issues associated with the presence of humans in space. Currently, in addition to serving as a member of the NRC's Space Studies Board and that Board's Committee on Human Exploration, I am a liaison member of NASA's internal advisory Committee on Scientific Utilization of Space Station Freedom.

SPACE STUDIES BOARD OF THE NATIONAL RESEARCH COUNCIL

Established in 1958, the Space Studies Board is the National Research Council's primary advisory body concerning the U.S. civil space research program. It is the Board's responsibility to provide timely and objective advice both when requested to do so or when, in the view of the Board and the NRC, it is warranted and appropriate to do so. In representing the Space Studies Board, my testimony today will be limited to those issues associated with support of biomedical research in space and its role in the nation's space program. It is these issues that the Board has reviewed and assessed as recorded in its published reports, statements, and previous testimony to Congress.[1]

BIOLOGICAL AND MEDICAL RESEARCH IN SPACE

At the outset, let me emphasize that from my perspective, the conduct of biological and biomedical research in space has one primary purpose—to support the national goal of a long-term human presence in space. In the absence of that goal, the space life sciences program would have an entirely different focus. There is an undeniable fascination in studying the effects of microgravity on plants, animals, and humans in space. Life as we know it has evolved in the presence of gravity. Thus, it comes as no surprise that all of Earth's living organisms show various abnormalities when exposed to the microgravity environment of space. Exploring the effects of microgravity on the development and maintenance of living systems is of considerable scientific interest. It is imperative, however, that national goals guide a research endeavor of this magnitude. Purely academic curiosity is an insufficient rationale for investing tax dollars on this scale.

As each of you knows, life sciences research conducted on the ground is expensive. There are a multitude of compelling reasons to make this investment—ranging from improving access to health care for all our citizens and thus improving the quality of life, to supporting the unending search for disease cures. Conducting life sciences research in space adds considerably to the cost and is not likely to help us achieve these notable goals. Thus it cannot be justified on the same grounds as ground-based research, nor should it be. At the risk of becoming repetitious, I would like to emphasize that the primary justification for space life sciences research is a commitment to long-term human exploration. Let me turn to a discussion of those issues on which the Space Studies Board has taken a series of public positions—the relationship to and importance of life sciences research in the U.S. civil space program.

NATIONAL GOALS AND THE CIVIL SPACE PROGRAM

In 1988, then-President Ronald Reagan put forth a Presidential Directive on National Space Policy. The policy, later reaffirmed by President Bush, states that "a fundamental objective guiding United States space activities has been and continues to be, space leadership."

Earlier this year, NASA Administrator Richard Truly issued *Vision 21—The NASA Strategic Plan* (NASA, January 1992). This multiyear plan is an implementation strategy for the goals contained in the Presidential Directive. Among those goals is an expansion of human activity beyond Earth orbit, including long-duration human exploration. The Board has made a number of statements concerning life sciences research in the context of that goal.[2]

In 1987, through its standing Committee on Space Biology and Medicine, the Board issued a comprehensive research strategy that focused on the program, experiments, and instruments that would be required to answer the many fundamental scientific questions that have been identified in this still emerging field of space science. The strategy report recognized the distinctiveness of this area of space research.

> Space medicine is unique in the context of the other space sciences—primarily because, in addition to questions of fundamental scientific interest, there is a need to address those issues that are more of a clinical or human health and safety nature. The authoring committee and the Space Science Board reached an important consensus in approving this report. That is, if this country is committed to a future of humans in space, particularly for long periods of time, it is essential that the vast number of uncertainties about the effects of microgravity on humans and other living organisms be recognized and vigorously addressed. Not to do so would be imprudent at best—quite possibly, irresponsible.

The committee advised that while some space life sciences research is clinical in nature, much of it is also of basic interest—for example, dealing with fundamental questions concerning the role of gravity in life processes. It pointed out that "in a properly framed strategy, basic and clinical research can complement one another." An important conclusion reached by the committee is the following:

> Space biology and medicine is in its infancy. Relatively few biological experiments have been flown, most of them have not been part of a larger research strategy, and few of them have been adequately controlled or replicated.

In 1992, even with the noteworthy achievements of successfully flying Spacelab-I and the International Microgravity Laboratory mission last year, the field is still in its infancy. Yes, there has been progress, but much remains to be done.

PRIORITIES AND BENEFITS

Among other things, you asked me to comment on priorities in health and medical research funding and on the scientific return and cost-effectiveness of space-based life sciences research. The question is asked frequently: What can we learn from exposure to microgravity that will help us in diagnosing and treating disease on Earth? This is not an easy question—nor am I convinced it is appropriate. We know that plants, animals, and human beings are the creatures of gravity. We know that bone, muscle, the heart, lungs, and central nervous system are influenced significantly by gravity. I confess that I do not possess the imagination to envision what can be learned by prolonged exposure to microgravity that will help us solve our earth-bound medical problems. In this context, it would be most difficult for me to justify the enormous expense and risk of space-based life sciences research for that purpose. I am open to being convinced otherwise—but thus far, I have encountered no compelling evidence or arguments.

Discussion of priority setting among and between sciences has been enjoying particular prominence of late—deservedly so. In fact I would be remiss if I did not mention that the Board testified on this topic at another hearing to another committee this very morning.[3] In representing the Space Studies Board, it would not be appropriate for me to take a position on the priority to be accorded to space biology and medicine relative to the overall U.S. health and medical research enterprise. That is well beyond the purview of the Board and, as I have already stated, the goals are quite different. I can, however, discuss some relative priorities within the context of national goals and space biology and medicine in the context of human space exploration.

ASSESSMENT OF PROGRAMS IN SPACE BIOLOGY AND MEDICINE

In 1991, the Board issued a series of assessments of NASA's progress in implementing recommendations made concerning the various space research disciplines, including space biology and medicine. In discussing the major imperatives for research in space biology and medicine, the assessment categorized research topics relative to the urgency that would be dictated by proceeding with a space exploration initiative.

> The Space Exploration Initiative (SEI) envisions a sequential progression of human activities in space of many years duration. This places increased emphasis on implementation of the appropriate research strategies. Ironically, since a small number of Soviet astronauts have survived in low earth orbit for as long as a year, the perception has developed that there are no major physiological or psychological problems likely to preclude longer-term human exploration beyond low earth orbit. The fallacy of that assumption has been documented in previous reports and the current document reaffirms that conclusion.

Concerning physiological and psychological problems associated with an extended human presence in space, the committee presented them in a rough order of priority, relative to their importance to extended human space travel:

bone, muscle, and mineral metabolism; cardiovascular and homeostatic functions; and sensorimotor integration. Psychosocial perturbations and exposure to radiation rank as equally important.

All physiological change in microgravity represents a homeostatic accommodation to this new environment. In reality, such an accommodation represents a maladaptation to Earth's gravity. Thus, although crews may do reasonably well during a long voyage, problems may arise when they reenter Earth's gravitational field.

The bone and muscle atrophy that occurs in the microgravity environment is a severe hurdle to overcome in achieving an extended human presence in space. While the cardiovascular system appears to function normally during short-term exposure to microgravity, clinically significant dysfunction is often apparent during readaptation to 1-G and is likely amplified with prolonged spaceflight. In addition, prolonged exposure to the altered loading conditions of microgravity is considered to be a potential cause of irreversible functional and structural changes. Results from experiments flown on SLS-I and reflown on SLS-II will help us to begin to understand these effects. Hormones that affect the cardiovascular system are of great importance and should be considered in the context of the cardiovascular changes that occur in space.

The changes in gravity-sensing nerve tissue that inevitably occur during a space mission lead to disturbances of sensorimotor function, including impaired spatial orientation as well as instability of gaze and motion systems. Provided a constant environment is maintained, the central nervous system adapts to these environmental changes within a few days. However, there are caveats to this assessment of relative risk. One is that gravito-inertial changes occur at the most critical parts of a mission—during takeoff or landing. This would be an issue, for example, for crews landing on Mars, where a gravitational field about one third that of Earth will be encountered.

In addition to describing the physiological effects of microgravity on humans in space, a host of reports have discussed the recognition of psychosocial problems during long-duration missions such as those planned for Space Station Freedom, a manned lunar base, a voyage to Mars, or a martian outpost.4 Current research using analogue environments and other means do not provide convincing evidence that missions longer than one year will be tolerated in the closed-limited environments that are contemplated for prolonged space missions. Psychosocial issues may be critical limiting factors in the exploration of space. This is another area that calls for much research.

Another category that requires investigation before humans embark on any long-duration space voyage is the effects of the radiation environment beyond the magnetosphere. The radiation environment of space is considerably less benign than that on Earth. Planning for extended human sojourns in space mandates that we have quantitative knowledge about the dose rates, and the types of radiation that will be encountered, and the shielding that will be required. Here again, research on Earth and in space will be required.

The areas I have just discussed are those that the Board and its Committee on Space Biology and Medicine have determined to be most urgent and critical to supporting a Space Exploration Initiative.

To summarize what I have said in this part of the testimony—there are several critically important areas in space biomedical and behavioral research that must be adequately supported so that the United States can safely and successfully realize a goal of long-term human space exploration. I want to emphasize that a long period of time and effort will be required for the satisfactory pursuit and resolution of all these problems. As the Board indicated in both its March 1991 and March 1992 statements concerning Space Station Freedom, we concur with the recommendation of the Augustine Committee that the primary objective of a space station should be life sciences research.[5] That is, "A space-based laboratory is required to study the physiological consequences of long-term spaceflight."[6]

COOPERATIVE RESEARCH

One way to maximize the return on investment in research is through various modes of cooperative research, with foreign partners, private concerns, and between federal agencies. To the extent that there are shared or compatible goals, the Board and its Committee on Space Biology and Medicine strongly endorse this approach. For example, the National Institutes of Health is this nation's primary supporter of the biomedical research enterprise. Over the past several years, there have been increasing efforts between NIH and NASA to identify and collaborate in support of areas of mutual benefit to the two agencies. Dr. Bernadine Healy, director of the NIH, testified before the House Committee on Science, Space, and Technology last October:[7]

> NASA's life sciences program and the biomedical research activities at the NIH are complementary in that both are concerned with human health. NIH's research focuses on the full range of sciences relevant to improving the health of Americans on Earth. NASA's life sciences efforts are centered primarily on the health of astronauts today and tomorrow. . . . While examining the direct effects of space flight on the human body is the primary concern of NASA's medical researchers, NIH conducts and supports a wide range of studies relating to these many important phenomena. In particular, both cardiovascular research and studies on bone demineralization or osteoporosis are major and important focuses for NIH investigators because of their devastating effects on the health of Americans here on Earth. . . . Bone demineralization is of great interest to NIH researchers. It is pervasive among elderly women. The problems of osteoporosis and bone demineralization affect an estimated 24 million

individuals here on Earth and indeed it is a debilitating condition which is pervasive among long-term space travelers as we have determined.

Another example for potential collaboration between federal agencies are facilities supported by the Department of Energy such as the BEVALAC, which has the capability of providing for study of very high-Z particles and their biological effects.

With respect to our foreign partners, including the former Soviet Union, Europe, Japan, Canada, and others, we believe it would be mutually beneficial and of utmost importance to seek ways to enhance cooperative efforts and exploit all available spaceflight opportunities. Resources are limited for all of us.

CONCLUSION

In the early days, most physicians involved in monitoring orbiting Mercury and Gemini astronauts were nervous. Human experience in the microgravity environment, even for short periods, was terra incognita. There was no precedent, no background of information about human physiological and psychological performance in the weightless state.

Thus we were obliged to monitor physiological function. We asked the brilliant engineers at NASA to give us two leads of EKG, and the capability to monitor blood pressure, heart rate, respiration rate, and body temperature. Psychological performance was observed by listening to communications—rarely by speaking directly with astronauts. As a result, there was a forced-draft effort to create equipment that would enable us to observe—in real time—psychological performance. From this endeavor, we learned about telemetering ECGs. We developed miniaturized diagnostic equipment. New, strong, lightweight materials were created, and many other developments occurred. All these discoveries had significant spin-offs related to Earth-bound medicine. But it is critical to realize that these remarkable devices and materials were created to monitor astronauts—not to improve the well-being of Earth-bound patients. It is essential to appreciate this distinction. The primary purpose of physiological, psychological, and radiation-effect research in space is to learn enough to provide some reasonable assurance that crews can survive and function in this most unforgiving of environments. Prolonged space faring, as would be involved in any human mission to Mars, remains terra incognita.

Of course we have learned things from U.S. and [then] Soviet missions. This information has raised many alarms—emphasizing that as responsible medical scientists we must conduct much more Earth-based and space-based research before we can commit crews to prolonged spaceflight, and still be able to sleep at night ourselves.

Undoubtedly, there will be benefits derived from space life sciences research that will be beneficial to patients on Earth. But again, this will be information largely peripheral to the sole purpose of space medicine—to learn enough to ensure reasonable lack of risk to space-faring crews. Benefits derived for Earth-bound medicine must not be construed as the primary driver of space medicine.

Finally, if indeed the people of this nation decide not to send crews to explore the universe, I personally will no longer remain involved in this adventure. Without prolonged human spaceflight remaining as a high priority on the American agenda, there is no compelling justification for space medicine.

5.2 Testimony on Setting Priorities in Space Research

The following testimony was delivered by Space Studies Board member John A. Dutton before the Subcommittee on Science of the Committee on Science, Space, and Technology of the U.S. House of Representatives, on April 28, 1992. Dr. Dutton is also chair of the Board's Task Group on Priorities in Space Research.

Mr. Chairman, members of the Subcommittee. Thank you for inviting me to testify at these important hearings on behalf of the Task Group on Priorities in Space Research, a committee of the Space Studies Board, National Research Council.

As you know, we have just released a report, *Setting Priorities for Space Research—Opportunities and Imperatives* (National Academy Press, Washington, D.C., 1992). That report is the culmination of a two-year study which focused on whether the space research community should have a role in setting priorities for those scientific objectives and initiatives which comprise the space science and applications component of the nation's civil space program. Our conclusion was a resounding "Yes." Not only is it desirable—it is imperative. That it took nearly two years to convince ourselves, the Board, and other colleagues from the space community of the validity of this conclusion indicates the sensitivity and difficulty of this issue.

In our deliberations, we were inspired by a quotation from Metternich brought to us by a task group member, Buddy McKay—one of your former colleagues, now Lt. Governor of Florida. [Policy] is like a play in many acts, which unfolds inevitably once the curtain is raised. To declare that the performance will not take place is an absurdity. The play will go on, either by means of the actors . . . or by means of the spectators who mount the stage.

In my remarks today, I will set the context for our report, give a brief overview of its conclusions, and outline how we plan to approach the second phase of this study—by far the more difficult enterprise.

THE KEY QUESTIONS IN SETTING AN AGENDA

Each of you is well aware that, in sum, the requirements and opportunities competing for federal support far exceed available funding. We know that too. We also know that scientific research is an investment in this nation's future, not an entitlement program.

In our report, we document a wide array of remarkable achievements of the U.S. space research program over the past thirty years. We go on to describe some of the abundant opportunities that exist now and for the future. NASA charts depicting funding levels required just to complete the ongoing program, let alone begin new projects, are a graphic reminder of the very real need to make difficult choices. The community of scientists engaged in research in space must reach a consensus on priorities and contribute to the formulation of an agenda for space research and for the space program. Such an agenda and the priorities it represents must respond to national needs and to the larger priorities imposed by national goals.

The two key questions in space research, as in most continuing endeavors, are: What should we do? How should we do it? We set our agenda with the answers to these questions—the priorities that we choose reflect our goals and our values. Careful consideration and formulation of assumptions and priorities for the scientific research program and the overall space program that supports it will enable us to better serve national goals, compel effective action, achieve the maximum return on our national investment, and foster public pride and confidence.

THE HIERARCHY OF PRIORITIES

Let me state my personal view of how the issues addressed by our report fit within the context of the national decision-making process that creates the agenda for scientific activities. These ideas will be discussed as we proceed with the second phase of our study. Priorities for space research or for a national science program appear within a hierarchy that ranges from national goals to specific research projects.

- *National Goals*—At the top of the hierarchy are national goals and objectives, such as developing deeper understanding of the world around us, strengthening education of young citizens, enhancing economic vitality, and preserving the environment. Priorities for such goals obviously evolve, but the time scale on which they are pursued will usually be decades or longer and may extend to centuries.

- *Strategic Endeavors*—Next are the strategic endeavors or initiatives that encompass or facilitate a collection of activities intended to contribute to the achievement of national goals. Examples might include the fight against disease, the study of global change induced by human activities, the development of enhanced computer and information technology, the scientific exploration of the solar system, or the conservation of energy. Strategic endeavors are pursued over time scales of years or decades.

- *Specific Initiatives and Activities*—At the third level are the initiatives and continuing activities through which we actually achieve the aims of strategic endeavors. These include specific research programs, space research missions, technology development programs, or development of new research facilities. The conceptualization, development, and implementation of these initiatives may take years, or, perhaps, more than a decade.

In order to consider priorities effectively, we must divide these specific initiatives into two categories: conceptual or potential efforts and programmatic activities. We formulate the agenda for future programmatic activities by selecting those potential efforts to pursue—we thus decide what we shall do. In setting a programmatic agenda, we determine how we shall do it.

In space research, programmatic activities include ongoing research and the design, construction, and flight of spacecraft and the use of data from such flights. Examples of programmatic activities include implementing mature mission proposals such as those for the Advanced X-ray Astronomy Facility (AXAF) or the Earth Observing System (EOS). Conceptual efforts concentrate on developing new ideas and new approaches for attacking scientific questions; they examine the possibilities for utilizing technological advances to obtain scientific information from space. In brief, they explore mission concepts, refining them until they evolve into proposals for programmatic activities. Developmental or conceptual efforts might be typified by studies of an astronomical facility on the moon, a suite of robotic missions to install scientific instruments on Mars, a mission to Pluto, or a constellation of geosynchronous satellites for continuing surveillance of the Earth and its atmosphere.

Within space research, priorities for programmatic activities have been developed in recent years by the Space Science and Applications Committee using a methodology created by its predecessor, the Space and Earth Science Advisory Committee.[8] So far, there has been no formal effort to set priorities among developmental efforts across all of space research. The disciplinary committees of the Space Studies Board have regularly set forth long-range research strategies with scientific goals and objectives for each of the subdisciplines of space research. These have not, however, been refined into an overall development plan with clear priorities. It is the difficult task of recommending priorities for such a long-range development program that we address in our report, *Setting Priorities for Space Research*. We need to develop a procedure for creating our agenda a decade or so in advance so that we know with confidence precisely what we intend to do, so that we can concentrate on the highest-priority endeavors.

I would argue that the extent to which the scientific community and public officials can shape an effective national program in space research depends in part on how clearly we understand and can enunciate the higher-level goals or objectives which we hope to serve. If we are vague about our national goals and strategic priorities, then it is difficult to focus development and programmatic activities to achieve them. If our national goals and strategic priorities shift about from one emphasis to another, then we shall waste money and effort in program development and execution as we start projects and then later cancel them. In our report we discuss the importance of fundamental assumptions in shaping priorities—these assumptions elucidate the basic motivations for what we are trying to accomplish and they must derive from, and serve the higher purposes of, space research or science. The more clearly those purposes are formulated, the more effective our system of priorities for scientific endeavors will be.

The remainder of my remarks are based on discussions and conclusions of the Priorities Task Group.

INFORMATION, KNOWLEDGE, AND UNDERSTANDING

We examined the role of fundamental assumptions in shaping the civil space program. For some time, the objectives of the space research community and those of the broader space program have been in conflict. Apollo demonstrated national technological superiority at a critical time. A fundamental assumption of the civil space program developed in that era asserts that it is human destiny to explore the Solar System and perhaps beyond. New realities of international competition, domestic politics, and economics suggest the need to examine our assumptions to ensure that space research and the space program contribute effectively to national vitality.

We believe that the imperative driving scientific research is the acquisition of knowledge and understanding. Thus the collection of data, the creation of information through its analysis, and the subsequent development of insight and understanding should be the key governing objectives for scientific research in space and for the broader space program. We believe that the nation would benefit if space research and much of the space program emphasized the acquisition of information and knowledge and the development of insight and understanding. Adopting the acquisition of information that cannot be obtained on Earth as the primary purpose of space activities is compatible with national needs to develop advanced technologies and capabilities. Most significantly, such a purpose provides clear objectives for future development of the human spaceflight program.

ECONOMIC REALITIES AND THE MANAGEMENT OF AVAILABLE RESOURCES

Today, as federal dollars become increasingly scarce, demands for clear benefits from public investments and for effective use of available resources confront the space science and applications community.

Two trends in public policy offer both challenge and opportunity to space science. First, there appears to be an increased willingness to support activities primarily producing broad social benefits, as evidenced by policy and action motivated by concerns for clean water and air, for protecting the environment, and for maintaining wilderness, wildlife, and habitats. Second, there is an increasing demand for publicly supported activities to provide explicit evidence that the benefits to be achieved merit the costs. Responding to these demands requires careful thought to demonstrate how space research or other scientific effort that fundamentally serves to augment knowledge and understanding contributes to society; it requires careful analysis to answer questions such as: In what way and by how much does space research further national objectives?

Economic benefits have been cited as a rationale for space research since the inception of the U.S. civil space program, yet the precise meaning of "economic benefit" has not always been clear. The narrowest definition would include strictly commercial activity that is profitable in the business sense. The case most often cited is that of commercial communications satellites, in which economic benefits can be defined as the value consumers place on the service and are measured by industry revenues.

We do not offer a formal cost-benefit analysis for scientific research in space. That was both beyond our charge and is difficult to do. However, from the perspective of setting priorities for space research initiatives, many requirements of cost-benefit analysis are instructive. Both those who propose research initiatives and those who review them should, as far as possible, identify all costs and benefits, determine the necessary conditions for success, estimate the probabilities and the consequences of failure, and specify the expected outcomes. While we are aware that many people object to any attempt to quantify science and knowledge, we believe this sort of analysis must be factored into any effective priority-setting procedure.

In parallel with demonstrating the benefits of space research, we must be sure that we use the available resources wisely and efficiently. Many observers have emphasized that space research efforts seem to cost too much, take too long, and all too often fail to meet their original objectives. In recent years, we have forced scientific missions into launch modes that dramatically increased their costs and reduced their effectiveness. We diffuse our support for science by attributing scientific motivations to efforts that, while they serve legitimate public purposes, are essentially nonscientific. In our report, we discuss some of the lessons we have learned in three decades of space research and some of their implications for the future.

RATIONALE FOR SETTING PRIORITIES

We argue that there are two principal justifications for working toward a consensus and recommending priorities: First, consensus is politically compelling. If scientists can demonstrate that their agenda responds to national needs and to scientific imperatives, then they can argue effectively for an adequate share of resources and for an orderly progression through the suite of initiatives endorsed by the community. Second—as Metternich said—if the players will not act, then the spectators will take the stage. If scientists engaged in space research cannot, or will not, set priorities among opportunities, then others whose own goals may be quite different will take the stage and make the decisions. Passivity or disarray on the part of the scientists presents the political process with the opportunity, indeed the necessity, to make choices, some of which may not be in the best interests of science.

In order to prepare an effective developmental agenda, we will need a sophisticated system of priorities. A simple ranked list will not be sufficient. We envision a hierarchical scheme, with certain categories of activities given a higher priority than others. The categories in such a scheme might include support for basic research and scientific infrastructure, followed by mandatory efforts, large initiatives, and incremental efforts that are part of the forward march of science. The relative priorities in such a scheme can be presented as a matrix, with the columns representing categories and containing activities listed by relative priority within the category.

There are not now, nor are there ever likely to be, sufficient resources to do everything we would like to do. It is time for the proponents and the recipients of federal research support to step up to the challenge of participating in the decision-making debate. As scientists and engineers, we have the unique capability of examining our own scientific and technological goals and objectives from a vantage point as experts in the field. We must, as encouraged by Congressman Brown in a recent address at the National Academy of Sciences, provide policy makers with our best assessment of priority ordering based on "unadulterated peer-reviewed judgment of scientific merit."

COUNTER-ARGUMENTS TO THE COUNTER-ARGUMENTS

In the course of our study and since the publication of our report, we have encountered a remarkably uniform set of arguments against scientists participating in setting priorities. Not surprisingly, some find the notion of setting priorities threatening. Anticipating counter-arguments, we offered a response to those arguments in our report. Below, I list some of the objections, and then our counter-arguments to them.

- *There will be losers.* Yes, there will be, just as there are losers now. Consensus in the scientific community along with effective advocacy will, in all likelihood, produce more funds and stable funding patterns and hence strengthen science and increase opportunities for the recommended initiatives. Without a process that identifies and promotes good science and strong initiatives, resources are scattered and the strong subsidize the weak.

- *Recommending priorities is too difficult, too contentious.* Yes, it is difficult. But we believe it can be accomplished through a formal process in which competing initiatives are judged uniformly according to explicit criteria, preferably on the basis of written material that specifically addresses the stated criteria. Again, if scientists find it too difficult to create an agenda for space research, then, as argued above, others will do it for them.

- *The community will not be able to maintain consensus because those who lose will subvert the process by lobbying policy makers and Congress directly.* We argue that rather than seeking to restore initiatives that have been abandoned, those who lose out in the process would be better advised to develop more competitive initiatives.

- *Setting priorities will be counterproductive because the community will tear itself apart.* We believe that insisting on a fair, open, and formal process will, in the end, serve both individual scientists and science at large. If the space research community is to be taken seriously by others, then it should accept responsibility for its own future.

- *The low-priority initiatives will not be done.* Exactly—that is the purpose of setting priorities. When resources are limited, they should be directed toward the highest-priority endeavors.

- *Scientists cannot make political judgments.* We believe that in arguing for initiatives, scientists should be sensitive to national goals and political realities, just as we expect that politicians in considering scientific initiatives should be sensitive to scientific merit. Since scientists expect support from taxpayers, they should be willing to explain to the public why some initiatives better serve national purposes.

THE DIFFICULT PART

Having begun the second phase of our study, we are well aware that the most difficult aspect of our endeavor lies ahead. Over the next year, we will be developing a procedure for recommending priorities that will contribute to the creation of a vigorous long-range space research agenda. We understand that for such a procedure to be successful, it must be accepted by the space research community at large while at the same time serving as a meaningful source of practical, reasoned advice to decision makers. It is our intention to actively involve the space research community in the development and testing of the methodology and implementation plan we create. That dialogue began earlier this year at a symposium marking the release of our phase-one report.

Many issues and questions must be addressed and answered. For example:

- What are the appropriate criteria for determining priorities in developing a long-range agenda for space research or for other scientific endeavors?

- Who should be responsible for administering the process that is finally recommended?

- What will be the time schedule for the evaluation process and subsequent priority recommendations?

- To whom should evaluators' recommendations be directed: Congress, NASA, the Space Council, or . . . ?

- How will the process provide for making choices within disciplines as well as across space research disciplines?

- Is it realistic to suggest that science can be subjected to any sort of cost-benefit analysis?

- How can we determine what budget limits (minimum and maximum), if any, should be placed on the totality of efforts considered in a developmental agenda?

- To what extent should we narrow the choices as we approach setting the programmatic agenda?

These are just a few of the questions we must answer. There will be more questions and more criticisms. Clearly, we have set ourselves a difficult task. However, we believe it would be a serious mistake not to try. Helping to fashion the appropriate criteria for making these difficult choices is, we believe, a responsibility of the space research community. The community is capable of making the sophisticated judgments necessary to foster a vital and robust space research program. We believe it must do so.

[1]For examples of previous Space Studies Board positions on biomedical and life

sciences research, see: *A Strategy for Space Biology and Medical Sciences for the 1980s and 1990s* (NAP, 1987); *Assessment of Programs in Space Biology and Medicine—1991* (NAP, 1991); "Space Studies Board Position on Proposed Redesign of Space Station Freedom" (March 1991); "Space Studies Board Assessment of the Space Station Freedom Program" (March 1992); and testimony to the Senate Subcommittee on HUD Appropriations, Committee on Appropriations, by L. Dennis Smith, chair, Committee on Space Biology and Medicine, Space Science Board (May 1987).

[2]See reports, statements, and testimony cited in endnote 1.

[3]See statement of John A. Dutton, chair, Space Studies Board Task Group on Priorities in Space Research, to the Subcommittee on Science, Space, and Technology, U.S. House of Representatives, April 28, 1992.

[4]*Life Beyond the Earth's Environment—The Biology of Living Organisms in Space* (NAS, 1979); *A Strategy for Space Biology and Medical Science for the 1980s and 1990s* (NAP, 1987); *Leadership and America's Future in Space* (NASA, A Report to the Administrator by Sally K. Ride, August 1987); *Exploring the Living Universe—A Strategy for Life Sciences* (NASA, Washington, D.C., June 1988); and *Space Science in the Twenty-First Century—Imperatives for the Decade 1995-2015—Overview* and *Life Sciences* volumes (NAP, 1988).

[5]*Report of the Advisory Committee on the Future of the U.S. Space Program*, Superintendent of Documents (GPO), December 1990.

[6]Committee on Space Biology and Medicine Strategy previously cited and Space Studies Board letter to Joseph Alexander, assistant associate administrator, Office of Space Science and Applications, NASA Headquarters, December 12, 1990; Space Station Summer Study Report, SESAC Task Force on Scientific Uses of a Space Station, NASA, March 1986.

[7]Hearing before the Subcommittee on Space of the Committee on Science, Space, and Technology, U.S. House of Representatives, October 23, 1991.

For a description of this methodology see: *The Crisis in Space and Earth Sciences—A Time for a New Commitment* (NASA Advisory Council, 1986); also John A. Dutton and Lawson Crowe, "Setting Priorities Among Scientific Initiatives," *American Scientist* **76**:599-603 (1988).

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1996	1995	1994	1993	1992
1990-1991	1980s	1970s	1960s	

Back to "What's New"
Back to top

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Attachment 1 Attachment 2 Attachment 3 (2.3MB)

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Back to top