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Science at NASA Field Centers

Findings and Recommendations

on the

Scope, Strength, and Interactions

of Science and Science-Related Technology Programs

REPORT OF THE
NASA CENTER SCIENCE ASSESSMENT TEAM
TO THE
OFFICE OF THE ADMINISTRATOR OF NASA

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NASA Center Science Assessment Team

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Office of the Administrator of NASA

May, 1988

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Letter of Transmittal

May 5, 1988

Dr. James C. Fletcher
Administrator
National Aeronautics and Space Administration

Dear Dr. Fletcher:

The NASA Center Science Assessment Team which you established on October 18, 1986, and which I have had the pleasure of chairing, has completed its task. We now transmit to you, herewith, our report on Science at NASA Field Centers.

During the course of the Assessment, the Team visited seven NASA Field Centers and heard presentations in Washington, D.C. from two others. We were welcomed cordially at each Center and were provided all necessary documentation.

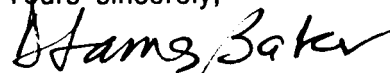
I am pleased to report that the Team found a vigorous and exciting scientific and technical program in NASA. The program is fully competitive and interactive with the outside academic community. Our recommendations, directed both to Field Centers and to Headquarters, are designed to keep the program vigorous. Implementation of these recommendations will not have major budgetary impact. We hope that NASA can continue and enhance efforts to ensure the long-term vitality of the Agency's science effort.

Finally, we note that the review process itself proved to be beneficial to the Team, to the NASA Centers, and to individual scientists and managers. We, therefore, recommend that such a process be made a regular (about every five years) part of NASA science management.

The Team feels strongly that a statement from you in support of science in NASA would make a great difference to the program. NASA's scientific space activities have made remarkable revelations about our Earth, the solar system, and the galaxy. These programs have also provided ways to measure and understand the effect of mankind's activities on global environmental change. We urge you to make a public statement conveying the remarkable scientific achievements to date and the need to continue a strong scientific program in NASA.

On behalf of the Team, I would like to thank you and Frank McDonald for the opportunity to take part in this unique enterprise.

Yours sincerely,



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EXECUTIVE SUMMARY

Introduction

Great achievements by NASA and other space agencies have shown us what opportunities lie in the opening of the space frontier. A broad and vigorous science program in NASA is vital to full U.S. exploitation of these new opportunities. Today, science in NASA Centers is characterized by its breadth, relevance, and excellence. The NASA in-house science program and its links to university programs constitute a vitally important national resource. Maintaining excellence as a foundation for the future is a fundamental responsibility of NASA, one that requires constant attention and effort.

This report by the NASA Center Science Assessment Team documents the current state of science within NASA and recommends actions to maintain a healthy program. NASA scientists have always played key roles in planning, guiding, and conducting national programs in space science. This review of Center science programs is intended to ensure that both NASA and the nation can depend on their continuing contribution in these roles.

Charge and Activities of the Team

The review of in-house science and related technology programs at each NASA Center was organized for the NASA Administrator by the Office of the Chief Scientist. The NASA Center Science Assessment Team was composed of scientists from universities, NASA Centers, and NASA Headquarters.

The charge to the NASA Center Science Assessment Team was to review and develop recommendations on:

- the content and scope of the in-house space science research efforts at each Center,
- the relationships between each Center's space science research programs and its project management responsibilities and science related advanced technology activities,
- the relationships between the Center space science research organizations and their university research counterparts, and
- the nature and extent of participation by Center scientists in the management and planning of Agency programs.

The Team carried out its review during the period January through June 1987. During the course of the review, the Team visited seven NASA Centers for comprehensive discussions with scientists and managers and heard presentations in Washington, D.C. from two additional Centers. In this report, the Team presents findings on the scope and quality of science research in NASA Centers and presents recommendations directed towards improving science careers in NASA, solving certain institutional issues, and ensuring the vitality for the future of the Agency's scientific programs.

Summary of Major Findings and Recommendations

The Team found the NASA science program broad and of high quality. Morale is generally high among the NASA Center scientists and engineers, who are indispensable to the Agency and the nation. To maintain this high level of quality and morale within NASA, innovative ways are needed to provide career flexibility, to stimulate and reward creativity, to provide professional development, and to enable interaction with the broader scientific community.

Throughout its visits to the Centers, the Team found the scientists at the NASA Centers a highly-motivated, creative group of people, who are coping remarkably well with the current tensions and uncertainties of the agency. They are attracted to the Centers by the excitement of space missions, the access to unique facilities, and the opportunity to participate in the creation of new programs. In addition, the Centers provide them with a critical mass of colleagues who have diverse skills. Many Center scientists find the role of intermediary between the project-oriented work of the Center and the basic research of their university collaborators an exceptional opportunity for personal growth and satisfaction. It is important to note that this motivation shows the need for a flexible program of access to space. Without access to space, much of NASA's unique attraction is gone.

Access to Space

Access to space is central to NASA's ability to carry out its science programs and should be accomplished by the most efficient means, including expendable launch vehicles, Shuttle, suborbital programs, and other means. Regular flight opportunities must also be available. At the same time, NASA needs to minimize the time interval between contract award and launch. The Team recognizes that this will not be easy or even appropriate for the largest programs, but emphasizes that provision of flight opportunities on shorter time scales will have an enormous positive impact on those involved, both inside and outside NASA.

The suborbital programs were found to be a crucial aspect of ensuring access to space. The Team recommends that NASA continue to give priority to these balloon, rocket, and aircraft programs which must continue to have a significant place in order to achieve a balanced and productive NASA science program.

Disciplinary Scope

With respect to the disciplinary scope of NASA science, the Team found that science programs are commensurate with the overall breadth of the program NASA is attempting to carry out. The quality of in-house work is competitive with outside groups in most disciplines.

Two areas were singled out for special attention, space life sciences and microgravity sciences. In both cases, the scope of the effort does not appear to be adequate to meet NASA's long-term goals. The Team finds that space life sciences studies are crucial to the expansion of human presence in space and recommends that clear, stably supported long-term goals be developed. Work in this area is central to NASA's long term success. The Team finds that microgravity sciences has developed a new legitimacy and that NASA should ensure access to adequate facilities to carry out basic research and should support, sponsor and otherwise encourage possible commercial applications, as appropriate.

Sustaining Quality

To sustain the high level of NASA science, the Team emphasizes the need for continuing use of a variety of commendable NASA quality checks. In particular, the Team recommends that the use of peer review be continued to maintain and enhance the quality of all Center science programs.

Ensuring quality is a continuing process and a number of steps can be taken to help maintain the quality of work undertaken within NASA. The Team sees considerable merit in carrying out a regular series of disciplinary reviews across all Centers and suggests that all disciplines in NASA be reviewed regularly on a four to five year time cycle. Such reviews would focus on one discipline at a time. They should assess in depth the overall effort at each NASA Center, the distribution of the effort across Centers, and the contribution of each disciplinary program to the achievement of NASA goals. Membership on review teams should include both NASA and non-NASA members.

The Team also recommends that each Center consider conducting reviews of its science by a Center Visiting Committee that reports directly to the Center Director. To provide continuity, such Committees should be standing, rather than ad hoc. They should include non-NASA members and operate so that review of all aspects of Center science can be carried out on a four to five year cycle.

The Research Environment

To ensure the proper climate for conducting quality research at the NASA Centers, an expanded program of awards, research fellowships, and travel funds for scientists to attend meetings and interact with colleagues is strongly recommended. The Team also emphasizes that institutions such as the National Research Council should not exclude NASA scientists from participating fully in national scientific and advisory committees alongside their non-NASA peers.

The system of providing opportunities for career advancement of scientists and engineers in supervisory manager or non-supervisory positions (the "dual career ladder") is important for encouraging active scientists to make long-term careers at NASA. Such a system is in place at all Centers, but its actual implementation is better at some Centers than others. The Team recommends that the system be continued and strengthened at all Centers and that scientists and engineers be made fully aware of it. Management should take active steps to implement the system fully, and data should be collected regularly to ensure that the system is, in fact, working and meeting its intended purpose.

Interaction of Science and Technology

The Team notes the importance and complexity of establishing and maintaining close interaction between science and science-related technology at NASA Centers. The Team recommends that scientists be added to the advisory committees of the Office of Aeronautics and Space Technology (OAST), and that technologists be added to the advisory committees of the Office of Space Science and Applications (OSSA). Similar recommendations are offered to the National Research Council's Space Science Board (SSB) and Aeronautics and Space Engineering Board (ASEB). The Team also recommends the establishment of a NASA-wide Council on Science and Technology to exchange information on activities, needs, and interests in science-related advanced technology on a regular basis.

NASA's Interaction with Universities

The Team discussed at length the relative roles of and the relationship between NASA Centers and universities and noted the major capabilities which are uniquely available to university scientists at the NASA Centers. In considering the question of what is unique about the role of scientists at a NASA Center, the Team concludes that NASA Center science activities should focus principally on the planning, development, and support of large programs which exceed the capabilities of most universities.

At the same time, NASA must provide significant support for innovative small programs of in-house research which can be the seeds for new major initiatives. The Team suggests that NASA carefully nurture its relations with universities to ensure the recruitment of young scientists and maintain the interest of university scientists. The universities play a unique role in the training of young scientists. Given the changing character of space science, NASA needs to carefully consider the appropriate future role of universities in its program in order to ensure that the talent NASA needs to carry out its future programs will continue to be available.

Maintaining Productive Careers

The Team identified a number of critical and unique career roles of scientists at NASA Centers which are central to NASA's ability to carry out its long-term scientific program. These include service as Project Scientists, Facility and Study Scientists, and scientific Mission Specialists. The Team notes that NASA's ability to draw on well-qualified individuals to play these roles is essential to the health and operation of NASA programs.

In view of the long time-scales involved with most missions today and their critical role in the planning and execution of such missions, Project and Study Scientists need be appropriately recognized and rewarded to ensure that capable individuals continue to make such long-term professional commitments. Mission Specialists should be used on a broader range of activities, including science education, technology advancement, and design of major programs involving science on manned missions.

Unnecessary bureaucracy is now evident in NASA, an organization that has traditionally been viewed as a "can-do" agency. The Team recommends that NASA continually assess the administrative environment so that its internal processes do not become obstructive. Specific examples identified include procurement and contract management.

The Team also recommends that NASA review the appropriateness of work being carried out by support contractors (particularly contract scientists) at NASA Centers. Such work should be undertaken in support of Center science programs. It should not extend the programs into new areas not supported internally by the Centers themselves. Scientists' responsibilities should be apportioned carefully between research and NASA service, such as contract management. A careful watch should be maintained to ensure that the service activity does not exceed about 50% of time available.

The Team noted the importance of taking appropriate steps to reduce the time spent on proposal preparation to obtain support for science research. In particular, the number of Research and Technology Operating Plans (RTOPs) and other proposals required for the support of a single scientist's research activity should be reduced. Such action would enable scientists to spend less time on proposal preparation and more time on research, as well as other critical science activities.

Funding Flexibility

A reasonable amount of funding flexibility has been identified in many studies as a key to research success. The Team was impressed with the success of the programs funded by Centers through the Director's Discretionary Fund and recommends a modest increase in the fund. The Team noted that a certain amount of flexibility already exists through authority to reprogram funds in RTOPs and recommends that NASA aggregate science RTOPs to provide some extra flexibility. However, in no case does the Team recommend that such authority be used to replace or distort the work funded through peer-reviewed RTOPs and research proposals.

A long-term goal of a reasonable percentage of the available research and development funds (including the value of the salary support for individuals engaged in such efforts) should be set to permit necessary flexibility in initiating new work. A level of about 10% of the available Research and Program Management (R&PM) and research and development funds would be consistent with the recommendations of various recent reports on research at national laboratories. The case of the Jet Propulsion Laboratory, as a non-government institution for which salary support is not provided, needs special attention.

Computers and Data Centers

The Team examined computing and data center facilities and noted that NASA is a leader in large-scale computing and the development of networks and data systems. The Team recommends that NASA study and evaluate the use of distributed computer facilities and data centers. This will allow the Agency to continue to take advantage of modern communications capabilities in order to realize economies of scale available in large-scale computing. Because of its experience and capabilities, NASA could play a major national role in developing and implementing a master plan for federal networks. A survey of computational facilities across the Agency would be useful for strategic planning.

In considering the establishment of new data centers, the Team recommends careful review of proposals to ensure the cost-effectiveness of any new activities. The reviews should consider wide use of distributed systems and consolidation of data center functions, or at least the user-service functions, at a user-oriented facility, e.g., the National Space Science Data Center (NSSDC).

Strategic Planning

The Team believes strongly that strategic planning is one of the keys to NASA's long-term success. NASA must encourage Center planning efforts and integrate them into an agency-wide plan that takes full account of the available skills and interactions among science, engineering, and technology. In discussing planning with Center management, the Team found the Center Directors to be an impressive group with broad experience, strong leadership, and vision. NASA should use the Center Directors, as a group, more effectively to fashion its agency-wide strategic plans. To provide the appropriate focus for science and technology within each NASA Center, the Team recommends that all Centers consider carefully whether the establishment of Chief Scientist and Chief Technologist positions, reporting directly to the Center Director, would be of benefit.

Summary

The Team has made many recommendations directed to both Centers and Headquarters in support of the NASA science enterprise. A direct link between having a strong science program and exerting strong science leadership is implicit in all of these recommendations. Maintenance of science leadership is a major challenge facing NASA that requires constant attention to the issues discussed in this report.

In the Team's view, implementation of most of the recommendations contained in this report will not have major budgetary impact. Many of the issues which have been identified relate to the scientific environment and to procedural factors rather than to finances. Support of the recommendations will lead towards the establishment and preservation of an appropriate climate for research. Such a climate is necessary to sustain the continued health and vitality of a science enterprise that has served the nation well.

CHAPTER I

INTRODUCTION: REVIEWING NASA CENTER SCIENCE

1. Background

In nearly three decades, NASA has succeeded in carrying out a stunning series of scientific and engineering achievements. These successes have nurtured an increasingly strong science program. The breadth and maturity of the science program are a natural outgrowth of the technological expertise for which the agency has been noted from its beginning.

Science plays a key role in NASA. The successful interplay of NASA science and engineering was nowhere more evident than during Voyager II's encounter with Uranus. By extending the capabilities of the original spacecraft well beyond those available at the time of launch, NASA teams revealed a unique planetary system that has already yielded new insights into planetary evolution.

Looking to the future, NASA and its teams of space scientists anticipate major new opportunities in the flight of the Great Observatories, new planetary missions, advanced satellite studies of the sun and the solar-terrestrial environment, the Earth Observing System (EOS), and new programs in space life sciences and microgravity physics and chemistry. With these opportunities NASA stands poised to make significant new contributions to the nation's science and engineering enterprises.

However, without a continuing strong science base inside NASA, these new opportunities will not be realized. A strong NASA science program is required to support NASA mission and program planning, and to interact with the outside community. It is therefore incumbent on the agency to maintain a vigorous in-house science program. The current reality is that this must be done in the face of the combined effects of the Shuttle flight hiatus and continuing federal budget constraints which have created extraordinary pressures on the NASA-supported science research community, both in U.S. universities and in NASA Field Centers. The Agency is now identifying the appropriate near-term actions to sustain the vitality of space science programs and is developing plans to cope with the backlog of flight missions that will exist when Shuttle launches resume.

In looking towards the future, it is critical for NASA to provide a vigorous institutional base for space science. To assess the vigor and quality of that base, this review of the in-house space science and related technology programs at each NASA Center was organized for the NASA Administrator by the Office of the Chief Scientist in consultation with other appropriate offices. The review was conducted by a team of scientists and managers appointed by the Administrator of NASA. This report is the result of that study.

Such a review had been under consideration even before the Challenger accident as a continuation of a study of NASA-university relations initiated in 1983. The NASA Space and Earth Science Advisory Committee has also identified the Field Center science and technology programs as an important part of the U.S. space science infrastructure. NASA scientists have always played key roles in planning, guiding, and conducting research in space science. The review of Center science programs was intended to ensure that both NASA and the nation can depend on NASA's in-house scientists to continue in such roles in the future.

2. Team Charge, Membership, and Activities

The charge to the NASA Center Science Assessment Team was to review and develop recommendations on:

- the content and scope of the in-house space science research efforts at each Center,
- the relationships between each Center's space science research programs and its project management responsibilities and science related advanced technology activities,
- the relationships between the Center space science research organizations and their university research counterparts, and
- the nature and extent of participation by Center scientists in the management and planning of Agency programs.

In each of these areas, the Team was to identify strengths and impediments, and to develop recommendations on actions that should be taken to enhance the quality of Center science research programs and their contributions to fulfilling Agency objectives.

The Team was composed of representatives from the outside scientific community, the Field Centers with major space science interest, and NASA Headquarters. The non-NASA membership included scientists with broad familiarity of the disciplines of astronomy and astrophysics, planetary exploration, solar-terrestrial physics, earth sciences, space life sciences, microgravity physics and chemistry, and space technology. NASA members of the Team included one representative each from the Headquarters offices of the Chief Scientist, Space Sciences and Applications, and Aeronautics and Space Technology, and from ARC, GFSC, JPL, JSC, LaRC, and MSFC (see end of Chapter for definition of acronyms). NASA members were selected by their respective Headquarters program office Associate Administrators or Center Directors; outside members were selected by the office of the Chief Scientist in consultation with the program offices.

Preliminary work to establish the review began in December 1986 with the identification of review objectives and focus and appointment of Team members. An organizational meeting took place on January 16, 1987 at NASA Headquarters. Site visits were carried out from February through June 1987, and the final meeting was in August 1987. The final report was prepared in consultation with Team members during the period October 1987 through April 1988.

During the course of the review, the Team visited seven NASA Centers and heard presentations in Washington, D.C. from two others. At each of the Centers, the Team received briefings from the Center Director and upper management on the organization and conduct of science at the Centers and heard scientific presentations from selected scientists. The Team also participated in wide-ranging informal panel discussions on strength and weaknesses of work at the Centers with groups of scientists, with groups of managers, and with the Center Directors themselves. As background for these reviews, the Team received comprehensive documentation in response to written questions and further data in response to inquiries made on site.

The Team is pleased to acknowledge the outstanding cooperation received from all participants at the Centers. In every case the reviews were well organized and the Team obtained clear and informative briefings and materials. In particular, the Team found the informal, round-table discussions with separate groups of scientists and managers to be an essential complement to the more structured briefings.

3. Organization of Report

The Team has developed a number of specific recommendations in response to its charge and based on its assessments. Findings, issues, and recommendations are presented in the following seven chapters. In order, these chapters and their recommendations:

- Assess the disciplinary scope and health of NASA Center Science and identify two specific topics -- space life sciences and microgravity sciences -- where the agency must make a special effort to foster development of coherent programs;
- Emphasize the importance of access to space and the use of suborbital platforms as part of a balanced program;
- Describe the role of internal and external review procedures in sustaining the quality of science at NASA Centers;
- Delineate the interactions between research and researchers and science-related technology;
- Review the features of science careers in NASA Centers --the advantages of close affinity to space technology, the significance of unique positions such as Project Scientist, and the importance of factors such as recognition, promotion potential, and support which add to, or detract from, career satisfaction;
- Assess the interactions of NASA scientists and university scientists and the role of NASA with respect to universities;
- Analyze the institutional and management practices at both the Centers and in Headquarters that affect the conduct of scientific research in the Centers; and
- Emphasize the need for strategic planning, retaining leadership, and future reviews in order to ensure vitality for the long-term future.

Note that throughout this report the term "space science" will be used as shorthand for the broad range of NASA-supported science which encompasses (1) the science of space and (2) science in space, and which ranges from earth and life sciences to planetary sciences and astronomy. The NASA Center Science Assessment Team will be referred to simply as the Team. The following acronyms will be used for specific NASA Centers and offices:

ARC	Ames Research Center
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LeRC	Lewis Research Center
MSFC	Marshall Space Flight Center
OAST	Office of Aeronautics and Space Technology
OSSA	Office of Space Science and Applications

CHAPTER II

SCOPE OF NASA SCIENCE: DISCIPLINES

1. Introduction

One of the important charges to the Team was to review the scope and content of in-house space science research activities at each Center. The Team was asked to identify the principal strengths of these space science research efforts, and to note areas, if any, that might require additional support or attention in order to meet overall Agency needs and Agency space science research program needs. This chapter and the next address these issues.

In order to meet this charge, the Team developed a series of questions for each Center that addressed the scope and content of individual Center programs. On the basis of this material and the briefings presented, the Team was able to develop an overview of program scope and the major areas needing attention and support. The material provided will also be useful for any other group that seeks an overview of the full range of NASA science.

The Team found an enormous range of disciplines being pursued in NASA Centers. Astrophysics and astronomy, relativity and cosmology, studies of the sun, and space physics are included. Solar system science includes studies of planets, satellites, comets, asteroids, and meteorites as well as Earth's moon. Earth science includes atmospheric science, oceanography, land processes, and terrestrial geology and geophysics. Work in space includes biotechnology, gravitational biology, space medicine, exobiology, and global biology. Microgravity science includes combustion science, fluid physics, and materials science.

This listing is not exhaustive, but it does give a sense of the range of activities now underway at NASA Centers. As far as the range within Centers is concerned, GSFC, JPL and ARC show the greatest diversity of programs with more than ten areas represented. MSFC and JSC support work in seven and five areas respectively. LeRC, LaRC, and NSTL carry out more focused programs in fewer areas at any one time. KSC normally supports only one or two science programs.

As part of the review, the Team considered each of the major disciplines and asked whether the work was competitive in quality and whether there were major gaps or overlap in the work being done at the various NASA Centers. A short summary of the Team's assessment is provided below for Astronomy and Astrophysics, Space Physics, Planetary Sciences, and Earth Sciences. In each of these disciplines the Team was satisfied that the NASA program is vigorous and that the quality of the work is competitive within the current constraints of lack of flight opportunities and overall budget limitations. The Team also found that scientists at the NASA Centers have strong and productive interactions with the outside communities in these fields.

The Team found issues and questions requiring special attention in the disciplines of space life sciences and microgravity science. A longer discussion with specific recommendations is provided here for these two disciplines. For some of the other disciplinary areas, "disciplinary reviews" are in order. This term refers to a group of experts from a given discipline providing oversight and review of a particular set of programs.

Gaps and potential overlap among programs were discussed at some length. It is easy to simply note programs with similar general titles or aims at different Centers, and then to question whether such programs are redundant. On the basis of a more detailed examination, the Team did not, however, find significant overlap in programs at different Centers. We note that the Centers both compete for programs and missions and cooperate in carrying them out (examples are noted below). Overall, the Centers and NASA Headquarters appear to have achieved through this process a sensible balance of general roles and missions. In general, the Team did not identify any major gaps with the exception of support of space life sciences and microgravity science. These specific needs are discussed at some length below.

2. Science Disciplines in the Centers

2.1. Astronomy and Astrophysics

The NASA Astronomy and Astrophysics program covers a full range of disciplines. Center scientists interact well with the outside academic community. In terms of funding, the program has less than 30% of its activity at the Centers with most of the remainder being for support of work at universities. The Center activity is carried out at GSFC, ARC, JPL, and MSFC. These groups have a critical mass and are fully competitive with the outside community in terms of the quality of the research being done.

GSFC (which has the most comprehensive program) has research groups in cosmic ray physics, infrared (IR) astronomy, gamma-ray astronomy, X-ray astronomy, Ultraviolet (UV)/optical astronomy and solar physics. MSFC has groups in cosmic ray physics, gamma-ray and X-ray astronomy, optical/IR astronomy, and solar physics. JPL has groups in gamma-ray and X-ray astronomy as well as programs in gravitational physics and laboratory astrophysics. Submillimeter and radio groups are also active there. ARC has infrared astronomy and theoretical astrophysics groups.

The activities of these scientists are properly focused on two general areas: providing critical scientific guidance to support flight projects, and developing individual and group science activity on an independent basis to maintain the scientific expertise needed to carry out project roles. The overlap in broad science areas between Centers derives from the major programs being undertaken by each Center. The Team found little, if any, real duplication of effort.

In cosmic ray physics, scientists at GSFC and MSFC operate balloon programs to carry out distinctly different scientific objectives and provide study scientists or project scientists for seven different projects. In gamma ray astrophysics, the group at GSFC provides project management and the project scientist for the Gamma Ray Observatory. A supportive environment for necessary theoretical research in astrophysics is also provided by the large general science activity at GSFC. The GSFC and MSFC X-ray groups are both active on the proposed Advanced X-ray Astronomy Facility (AXAF) with overall AXAF project management being at MSFC and instrumentation and technology development underway at GSFC. GSFC provides principal investigators for instruments on both AXAF and the X-ray Timing Explorer (XTE), is developing the U.S. Science Data Center for the Roentgen Observation Satellite (ROSAT), and has an active sounding rocket program. JPL is involved with development of advanced charge-coupled device detectors for use in X-ray astronomy. Infrared astronomy is pursued in varying degree at all of the Centers mentioned, with the work at different Centers being clearly complementary.

The main UV/Optical activity within NASA is centered at GSFC. GSFC scientists operate the International Ultraviolet Explorer (IUE), are leading construction of a second generation high resolution spectrograph for HST, and carry out a rocket program, some detector development, and a small ground based optical program. Project management for the development of several major projects such as the Hubble Space Telescope (HST) and ultraviolet and soft X-ray instruments for the Shuttle/Spacelab (Astro) are located at MSFC. The project scientists for HST and Astro are provided to MSFC by GSFC.

In the discussion of the astronomy and astrophysics program, the question of the need for enlarging the ultraviolet/optical astronomy group at MSFC arose. Noting that the HST is now completed and will be operated through GSFC, that Astro is also developed, and that the Extreme Ultraviolet Explorer mission is operated through GSFC, the Team notes that the case is not yet made for such an expansion at MSFC. If NASA Headquarters deems that further review is required, the Team suggests that a disciplinary review of NASA's UV/Optical program be undertaken to ensure that adequate scientific support is being provided at all the Centers involved in UV/Optical astronomy and that the relative roles of the involved Centers are consistent with their capabilities and responsibilities. The Team also notes that at any Center scientists must be deeply involved with Center project activities in all stages of development of a project, and those scientists must have peers with whom they can interact. The Agency must recognize that productive scientists cannot develop and mature in isolation.

In summary, the full range of astronomy and astrophysics disciplines is covered in NASA Centers. The Team found that in general these groups are high quality, have a critical mass, and exhibit characteristics of the best university groups. NASA Center science groups make major contributions to NASA flight missions by providing project scientists and scientific input. NASA scientists are also making significant contributions to scientific knowledge as individuals.

Findings and Recommendations:

1. The Team notes that the mix of in-house and outside research arranged by NASA headquarters has worked well in terms of overall quality and productivity, and recommends that NASA continue to support this arrangement.
2. The Team notes no major overlaps in activity, and suggests that a disciplinary review of NASA's UV/Optical program could be undertaken to ensure that adequate support is being provided and that the relative roles of the involved Centers is consistent with their capabilities in this area.

2.2. Solar and Space Physics

The NASA Centers, taken together, provide fairly complete coverage of the physics of the sun, the atmospheres of the Earth and the other planets, and the heliosphere. In the case of the Earth, work underway includes studies of the ionosphere and its coupling to the magnetosphere. Investigations of the Jovian, Saturnian, and Uranian magnetospheres are continuing. The Sun as the source of the magnetized heliospheric plasma (solar wind) receives an appropriate amount of attention. The Team finds no significant overlap in these activities at the various Centers. Space and Solar Physics scientists in NASA are productive, professionally active, and have acted as study managers, project scientists, and have assisted the spaceflight projects in other ways .

The work within NASA is carried on at GSFC, MSFC, JPL, and, to a lesser degree, at ARC. At GSFC, research is ongoing in space plasma, magnetospheric, and interplanetary physics. In recent years, there has been a major effort to analyze Voyager 1 and 2 data, encompassing the magnetic fields, radio waves, and current sheet and plasma observations at Jupiter, Saturn, and Uranus. The torus physics of Jupiter's satellite Io and the interplanetary data from magnetometers and plasma instruments on these spacecraft have also been studied. GSFC scientists also played important roles in project management and construction of instruments for the three-spacecraft ISEE program. The productivity of the NASA groups in terms of publications ranges from good to excellent, and their interaction with the outside academic community has worked well.

At MSFC, the Division of Solar-Terrestrial Physics includes studies of solar science, magnetospheric physics, and atomic physics and aeronomy. Important contributions include the development of the new Vector Solar Magnetograph, which has achieved pivotally new results. The Magnetospheric Physics Branch conducts observations of low energy plasma dynamics and active particle beam experiments to understand the solar wind magnetosphere-ionosphere-atmosphere coupling. MSFC scientists in these groups work closely with the spacecraft projects at MSFC, and the interaction with the engineering side of the Center has been effective. MSFC has a sounding rocket program with Stanford University and works closely with local universities.

At JPL, the space plasma physics and solar physics efforts are relatively small, but the group is active and productive. Studies are carried out on Earth magnetospheric plasmas, the comet-solar wind interactions, physics of the solar wind, and the solar magnetic field. The group contributes heavily to project support through service as study managers and as project scientists. The work at ARC is focused primarily on heliospheric physics and is related to ARC's Pioneer spacecraft program.

Findings and Recommendations:

1. The Team notes that the NASA Center program in solar and space physics covers a full range of activity, and that it has been productive. The scientists at the Centers in this area interact strongly with their colleagues outside NASA.
2. The Team was convinced that the quality of the work in space physics is currently high in the Centers. A general recommendation at the end of this report concerns the usefulness of disciplinary reviews. Given the productivity of this area, there is no immediate urgency for such a review, but it could be a useful exercise as a regular activity of the new Space Physics Division in OSSA.

2.3. Earth Sciences

The Earth Sciences program contributes fundamentally to both basic science and applications. The program is broad, ranging from oceans and atmospheres to land surface processes, geodynamics, and studies of the biosphere. Through this program NASA has provided direct and significant benefits to the public not achievable otherwise. The most dramatic example is the development of the meteorological satellites that now return images and data that are used daily to analyze and illustrate weather phenomena and to increase the accuracy of numerical weather forecasts. NASA's first observations in space were largely devoted to issues in Earth Science, and a major emphasis of the agency in the 1990s will be the Earth Observation System (EOS), designed to yield a comprehensive suite of observations necessary to understand global change.

The NASA program in Earth Science has major comprehensive programs at GSFC and JPL with relatively specialized components at ARC, LaRC, and MSFC. All of these efforts are integrated in a dynamic program that collaborates well with the non-NASA community. NASA scientists are active in developing new technology and providing the interface between satellite data and useful scientific information through development of algorithms and other techniques. The NASA program has resulted in an impressive set of publications, ranging from technical reports to textbooks. The smaller center programs are generally of high quality and represent important NASA capabilities (examples include infrared observations and studies of biogeochemical cycling at ARC, lidar technology and atmospheric chemistry at LaRC, weather systems observation, analysis, and modeling at MSFC, lunar and planetary geology at JSC, and earth remote sensing at NSTL).

The only potential overlap noted was in the area of weather prediction, where several Centers have programs. Each of these is aimed at a different issue, but our review was not deep enough to determine whether there is duplication. A disciplinary review of this particular topic would help to resolve the specific overlaps.

The largest programs are at JPL and GSFC. The JPL program emphasizes observations, instrumentation, and data interpretation. The GSFC program emphasizes use of observations from space in developing theoretical and numerical models for simulation and prediction of terrestrial phenomena. Both Centers are leaders in the development of data handling technology.

The NASA program in Earth Sciences is rapidly developing the satellite-measurement foundation needed for studies of global change. The results of past flight projects will be extended and enhanced by the Upper Atmosphere Research Satellite (UARS), the NASA scatterometer (NSCAT), the Ocean Topography mission (TOPEX/Poseidon), and the Global Geospace Science Mission. The Geopotential Research Mission (GRM), the Tropical Rainfall Measurement Mission (TRMM), and other earth science Explorer missions will be essential preludes to the proposed Earth Observing System (EOS). Resolution of specific earth science issues and development of instruments and methodology will continue to require a strong program of airborne, balloon, and shuttle missions; these often provide the basis for the satellite-based parts of the program.

The data issue is not unique to earth sciences, but the subject serves as a good example of a more general problem facing NASA's space science program. With an ever-increasing amount of data coming from the new satellite programs culminating in EOS, one of the major issues facing the Earth Sciences program is how this data will be collated, stored, and distributed in a way that will stimulate maximum scientific progress. An effective system does not yet exist but is within current technology. The Earth Sciences and Applications Division, in collaboration with a number of the centers, has mounted an aggressive attack on the problem. It will not be solved easily and any satisfactory solution will be expensive. A strong NASA commitment to the innovative and effective management of data resources in all disciplines is essential if the Agency is to continue its tradition of scientific leadership and public service.

Findings and Recommendations:

1. The Team found an active and broad program in Earth Sciences in NASA Centers, with activity at almost every Center. The program has been productive and active. Earth scientists at NASA work well with their university colleagues. The Team notes that in Earth Sciences, as well as other disciplines, a strong commitment to innovative and effective management of data resources is essential for the future.
2. The Team found no major overlaps in programs, but noted that a potential overlap could exist in the area of weather prediction, where several Centers have programs. While each of these is aimed at a different issue, a specific review of this particular topic is probably in order.

2.4. Planetary Sciences

The space program created the interdisciplinary field of planetary sciences. Scientists were drawn into the field from planetary astronomy, meteoritics, atmospheric sciences, and certain aspects of nuclear physics, geology, and cosmology. For all practical purposes, work that NASA supports is the planetary science program for the nation. No significant funding source for this field exists outside the NASA program.

The impact of NASA on planetary sciences has been profound. The planetary exploration missions, which first focused on the moon in the 1960s and then beyond in the 1970s, expanded our knowledge of physical terrains even more than did the voyages of exploration on our own planet. New insights have been provided into many of the processes which led to the formulation and evolution of the planets. As a result, the earth-centered view of geological and atmospheric processes has been given a new planetary context.

Planetary science is housed primarily at JPL, with important but more specialized components at JSC, GSFC, and ARC. Most planetary missions have been managed by JPL, and the depth and breadth of planetary research at JPL matches its role as the lead center for planetary sciences missions.

Because the planetary program had its roots in lunar exploration, specialized capabilities were developed at JSC to support the return and study of lunar samples. JSC is home to the lunar sample collection and to unique facilities to preserve and study extraterrestrial samples. The group of JSC planetary scientists provides expert curation of the unique sample collections and participates in the systematic study of the collection.

At ARC, capabilities developed relative to atmospheres and exobiology lend themselves to involvement in the study of atmospheres of all planets and the building blocks of life in the solar system. Some of these phenomena are most readily studied by infrared astronomical techniques, an ARC strength. The ARC solar system and exobiology scientists have also been the source of innovative experiments for planetary missions. ARC has developed a number of important new instruments, the gas chromatography/mass spectrometry instrument (used on Viking and proposed for the Comet Rendezvous/Asteroid Flyby (CRAF)) being one example. At GSFC, where there is a broad space science program, the planetary science is mostly linked to astronomical missions or instrument building capabilities unique to that center. Two core planetary instrument development groups call GSFC home.

Planetary sciences within NASA have been particularly affected by the lack of recent flight opportunities. The only new data being acquired are from spacecraft such as Voyager which was launched in the 1970s. The major planetary mission started in the 1970s, Galileo, is still on the ground, its launch having been delayed well beyond the original date by various problems associated with the Shuttle. The Galileo project is based at JPL, and the numerous project delays have produced serious morale problems among JPL scientists and engineers. Most of these problems have been subordinated, however, to the team effort which continues with enthusiasm for the present. These issues are not unique to planetary sciences, but are listed here to emphasize the importance of the issue of access to space.

The other approved planetary projects, the Venus Radar Mapper and Mars Observer, are also based at JPL, but involve the use of commercial sector spacecraft and relatively little in-house development. JPL has developed plans for the high technology Comet Rendezvous/Asteroid Flyby (CRAF) mission which it sees as essential to the health of its planetary program. The Solar System Exploration Committee's plan, promulgated in the early 1980s, focused on creating flight opportunities at the expense of new generations of instruments and spacecraft. Now it appears that the U.S.S.R. will implement a more innovative program than the U.S. in the 1990s. It is essential that NASA support the development of new technology as well as provide flight opportunities.

Findings and Recommendations:

1. The Team finds a healthy planetary science program, but one that is suffering and may deteriorate from a lack of flight opportunities. This lack of missions is especially difficult for JPL as the lead Center for planetary science. The Team recommends that NASA continue its strong efforts to get the planetary program into space.
2. NASA planetary programs need to focus on new generations of instruments and experiments. The Team recommends that NASA ensure that the implementation of such new technology continues as part of the on-going flight program.

3. Discipline Areas Requiring Special Attention

One important NASA role is deliberate and conscious fostering of space-related specialties and support of entirely new areas. In response to the charge to identify areas where additional support or attention is needed to meet Agency program needs, the Team has singled out two specific topics: space life sciences and microgravity sciences. The Team emphasizes the importance of providing adequate NASA support for these disciplines that 1) cut across all of NASA (space life sciences), and 2) are just developing, could lead to major breakthroughs, and are potentially of great importance for expanded space activity in the future (microgravity sciences).

3.1. Space Life Sciences - A Broad-based Agency Need

NASA's Life Sciences program is the key to many aspects of both basic science and operations in space. The program is aimed at advancing basic knowledge in space life sciences and developing medical and biological information and procedures that will enable long-term human habitation in space. In the view of the Team, this area is one of the most important scientific fields for NASA to support because of its fundamental contribution to NASA's goal of sustained operations in space.

In its assessment, the Team considered carefully the ongoing life sciences activities at each Center and asked scientists and managers to give their perceptions of the strengths and weaknesses of the program at the Centers and overall. During the Team's visits, numerous comments were made concerning structural or managerial issues adversely affecting the Life Sciences program. While the Team did not independently examine the validity of such comments, their frequency and strength suggests that further examination is required. In the interest of providing such an examination, those comments which seem to address the most crucial areas are reported here. The Team is aware that an ad-hoc committee of the NASA Advisory Council is completing a major study leading to a recommended strategic plan for NASA's Life Sciences program and will soon release the report "Exploring the Living Universe: A Strategy for Space Life Sciences".

The major activities in space life sciences are carried out at ARC and JSC, with a smaller activity also underway at KSC. ARC's life sciences in both non-clinical and pre-clinical areas are well-established, and ARC work in exobiology is internationally recognized. ARC's medical research concentrates on understanding the basic physiological and biochemical effects of space flight, and on developing future flight program for study of such basic phenomena. JSC's primary role is to develop ground and in-flight experiments to deal with human medical problems and the operational issues associated with such medical problems. Specifically, a primary goal at JSC is to increase the duration of human space flight. In this effort, JSC applies the more basic developments of ARC.

The Team's overall impression was that the activities at ARC and JSC are of high quality and are being carried out with commitment and dedication by highly qualified professionals at each institution. However, if this impressive group is to reach its full potential, a strong commitment from NASA for future life sciences research will be necessary.

The space-related life sciences, like the physical sciences, require space flight opportunities. The lack of observations, particularly long-term observations such as are now possible only in Soviet spacecraft, has precluded an understanding of phenomena which could be of critical importance for sustained human presence in space.

Another fundamental issue is the lack of stable long-term goals for life sciences in NASA. Goals and priorities appear to vary rapidly relative to the time necessary to carry out a coherent research program in space-related life sciences. This is especially true given the long hiatus between space flight opportunities. As a result, ARC attempts to cover too many bases in order to respond to shifting priorities and to stabilize the work environment for scientists.

At JSC as at ARC, uncertainty regarding NASA's long-term goals and life sciences priorities creates difficulties in the planning of a research program. This is particularly true at JSC, given the strong applied focus of life sciences research.

It seems clear that NASA needs to develop a clear set of long-term goals for the life sciences. Such a program must include fundamental scientific research when basic processes are not sufficiently well defined to permit assessment of effects of the space environment. The program should also include that space research critical to the understanding of fundamental processes of unique interest, such as study of the evolution of biogenic molecules. It should provide a useful definition of boundary limits within which NASA's life sciences research should be organized.

3.1a. The Current Program: Issues and Problems

To carry out its program, ARC has a group of life scientists with strong credentials and a variety of facilities for life sciences research, some of which are unique. Despite maintenance problems, most of the facilities are utilized by both in-house workers and by the national and international scientific communities. However, while ARC has put some life sciences projects on spacecraft, ARC is not the flight manager for any life sciences space flight project. In ARC's view, OSSA generally gives insufficient consideration to Centers that are not primarily "OSSA Centers" when it allocates projects. The Team does not take a position on this particular issue, but notes that NASA headquarters should be continually aware of the way in which space life sciences projects are allocated to ensure that the program is carried out effectively with full use of NASA resources.

JSC emphasizes the flight medical side of life sciences. It also has an excellent group of scientists and physicians. Given this emphasis on more applied programs, and JSC's responsibilities for in-flight life sciences operations, it is logical that JSC should have primary responsibility for health maintenance facilities in space flight, including the one intended for the Space Station.

An opinion strongly stated at JSC was that NASA is placing inadequate emphasis on basic research on health in space. The Team concludes that neither basic biomedical research nor health maintenance research has received adequate emphasis, and that each suffers from shifting priorities and funding difficulties. The Team was pleased to note that the newly appointed JSC Director indicated his strong support for increased life sciences flight opportunities and life sciences research. The Team hopes that this attitude may result in amelioration of the scientists' concerns.

At KSC, a temporary activity is now in operation for the study of exercise physiology. The Team notes that this work appears to be handicapped by its isolation in a large operations center and by a staff of sub-critical size. At the very least it needs to be coordinated with related, ongoing work at JSC and ARC. Given the likelihood that the KSC medical staff will become largely occupied with operational responsibilities when Shuttle flights resume, it is not clear that KSC's effort to become actively involved in medical research efforts can or should be sustained. Thus the Team recommends that the exercise physiology program

there be reassessed at that time to ensure adequate coordination and use of resources. KSC management should keep a careful watch on this situation. KSC is also operating NASA's Closed Environment Life Support System (CELSS) experiment--the only such large-scale study. Such work is important in developing the understanding necessary for maintaining life in space and should be coordinated with other relevant NASA activities.

Funding of facilities is a major problem for life sciences. Many of ARC's facilities, initially at the leading edge, now are outmoded or poorly maintained, precluding important research activities. This situation has developed in part from funding arrangements. Life sciences organizations report to OSSA and receive research project support from OSSA. However, OAST, not OSSA, is responsible for plant maintenance and upgrade, including facilities related to OSSA research. The ARC life sciences group perceives itself as being caught in a gap between these offices, with the potential for discontinuity in funding for different facets of the same related activities.

Moreover, for some projects, OSSA requires annual justification whereas the mode of operation of OAST, with larger and fewer RTOPS, appears to provide greater capacity for development of long-term projects. The Team generally supports longer periods for funding for basic research because of reduction of paperwork. It is possible that the development of life sciences research would benefit from some funding awarded on a longer-term arrangement.

In a situation unique to JSC, it was decided after a review twelve years ago that JSC should have very little responsibility or funding for scientific activities. As a consequence, JSC has not had until recently the capacity for new scientific initiatives. In general, discretionary funds have not been employed to alter this situation. Without funding identified for basic science, it seems unlikely that JSC will be able to develop an improved life sciences activity.

There was a particular concern at JSC regarding the lack of JSC life sciences input in Space Station planning. The Space Station represents a step toward more extensive human presence in space exploration and provides a unique opportunity for crucial research in space biology and medicine. The lack of any perceived life sciences priorities in Space Station planning is a distinct impediment to timely planning of JSC activities. Moreover, life sciences studies on non-Space Lab flights depend on the voluntary cooperation of the astronauts. Early involvement of astronauts with experiment planning would be extremely helpful in order to ensure that the valuable resource of flight time is properly apportioned.

Interaction among Centers in the life sciences has not been as strong as it could be. In part, this is a function of travel funding restrictions and competition for programs and funds. There is evidence that the Centers themselves have begun to act to redress this problem: a Biomedical Research Plan has been formulated (but not yet published) by ARC and JSC, and several informal contacts between life sciences personnel have been established.

There has also been a lack of communication between the designers and users of various experimental equipment. The Team is pleased to note that JSC is succeeding in encouraging early participation of mission specialist astronauts in design and ground testing. In addition, interdisciplinary cooperative research is hindered by the problem of different funding sources for the different disciplines.

The ARC life sciences staff has maintained good Center-university relationships. Many maintain some university teaching responsibilities and university-investigator collaborations on projects have not been uncommon. Nonetheless, travel fund restrictions clearly are a hindrance. In addition, several of ARC's major facilities are heavily used by non-Center scientists, thus leading to further useful interaction.

JSC scientists maintain some relations with the university community, but the emphasis is on in-house activity. Co-investigators in life sciences projects often are from the nearby major university medical centers in Houston and Dallas. However, the relatively small scientific staff at JSC does not appear to approach critical mass in most areas and is impeded in outside communication by limitation of travel funds. Several life sciences areas (most notably biochemistry) have scientists who do not feel integrated into the larger scientific community from which they require intellectual support. If the JSC effort is to be optimally nourished by university input, then more funds for travel and visiting scientist interactions must be found.

Mission Specialist Astronauts constitute a resource unique to JSC and should be involved to a greater extent in experiment design. It is the view of the Mission Specialist Astronauts that, while in-flight life sciences experiments often have been scientifically valid, coordination and planning among experiments could be greatly improved. This situation could be remedied by involvement of Mission Specialist Astronauts in the early stages of experiment design. In addition, the Mission Specialist Astronauts related that flight priorities can be bypassed by use of the multiple mechanisms which exist outside of peer review and OSSA channels for getting experiments placed on board space flights. This can lead to loss of flight time for high priority experiments. Finally, the Mission Specialist Astronauts noted that they have little interaction with JSC scientists, despite their assignment to JSC.

Findings and Recommendations

1. The Team finds that NASA Life Sciences activities, and the specialized community in which they are based, are crucial to the expansion of human presence in space. This effort needs to be integrated into overall NASA planning and provided with stable long term goals.
2. NASA needs to determine a clear set of long-term goals for the life sciences. Such a program must include fundamental scientific research when basic processes are not sufficiently well defined to permit assessment of effects of the space environment. The program should also include that space research critical to the understanding of fundamental processes of unique interest.
3. The development of long term, stable programs must include a recognition of the needs for development and maintenance of unique facilities.
4. Mission Specialist Astronauts should be involved as early as possible in the planning of flight experiments in life sciences. Better coordination and planning is needed for flight experiments, beginning with the selection of experiments.

5. If the JSC effort is to be optimally nourished by university input, some NASA effort emphasizing outside interactions through educational travel and visiting scientist interactions must be implemented.
6. Given the likelihood that the KSC medical staff will become largely occupied with operational responsibilities when Shuttle flights resume, the Team recommends that the exercise physiology program there be reviewed to ensure adequate coordination and use of resources.

3.2. Microgravity Sciences - an Emerging Discipline

Microgravity science is an emerging and unique area of space research. It is interdisciplinary and includes scientific inquiry in such broadly divergent fields as fluid physics, materials science, combustion science, biotechnology, cellular biology, biophysics, transport phenomena, colloid chemistry, the physics of critical point phenomena, and gravitational physics. The unifying aspect among these diverse areas is a rich class of phenomena whose characteristics are sensitive to the presence, or lack, of the gravitational force. NASA plays a unique role by providing access to a sustained reduced gravity environment via orbital free fall.

The field of microgravity science is less than twenty years old, having its origins among a few early enthusiasts who were, in the main, located at the MSFC. The basis for much of this enthusiasm was the possibility of creating unique and/or commercially viable material in the low gravity of space. The field has had a difficult beginning, based on early, overstated promises of economic benefit from microgravity materials processing. However, it has developed into a strong scientific and engineering field today. A 1978 report by the National Research Council, "Scientific and Technological Aspects of Materials Processing in Space," stressed the need for NASA to focus its resources on the development of a solid scientific base of knowledge rather than on commercial or "economically justifiable processes."

A more recent report, "Microgravity Science and Applications," was issued by the NRC in 1986, further focusing on the need for scientific quality especially with the current limitations on flight opportunities. This in turn led to the recent NASA report "Review of Microgravity Science and Applications Flight Programs". Distinctions were not drawn between the NASA in-house and external R&D programs in carrying out these reviews.

3.2a. Current Program

The current OSSA program is now concentrating on high quality, ground-based R&D, on selected high payoff flight experiments, and on the development of "third generation" hardware for the space station. OSSA has also broadened its scientific program over the past five years to involve NASA centers other than MSFC more effectively in its program.

The current NASA in-house microgravity science program is distributed among MSFC, LeRC, JPL, LaRC, and JSC. Each of these Centers has developed a special orientation and focus which reflect the presence of certain institutional strengths and capabilities.

MSFC still has the largest program, one which reflects its traditional engineering strength in systems and materials. This important program concentrates on electronic materials, solidification and casting, phase separating systems, space-qualified holography, and organic materials.

LeRC has particular strengths in internal fluid mechanics, high temperature engine materials, and combustion--mainly as OAST supported activities--and has effectively coupled these strengths to a new microgravity effort involving all of these areas.

JPL has talented groups in the areas of acoustics and fluid processing. New programs are underway in containerless processing of materials with special emphasis on glasses and field-controlled fluid management using acoustic, electrostatic, and electromagnetic control.

LaRC has a small microgravity effort, reflecting its interests in electronic detector materials, and continues to be involved in preparation of advanced IR materials using the improvements which may be possible with microgravity processing.

JSC is the home of biotechnology within the microgravity program, and it is also the home of the Mission Specialist Astronauts, some of whom are experts in materials science. These mission specialists represent an important resource to the microgravity program and should be further integrated into the operational planning of experiments on manned missions. The ARC expertise in fundamental areas of cell biology and physiology also needs to be integrated into the program.

3.2b. The Future of Microgravity Research

The Team notes that microgravity science is a relatively small OSSA activity (with current, FY 1988, funding levels of approximately \$65M) which is now poised to take its place among the more traditional space science activities. It should be noted that additional significant investment in microgravity science by non-U.S. space agencies, including, of course, ESA and Japan, is expected. For example, there are plans for an industry-supported microgravity satellite to be launched by Japan in 1993 independently of the Space Station.

Although the microgravity sciences will probably always be considered "science in space" rather than "science of space," their vitality, promise, and relative youth deserve nurture and support by NASA. Microgravity sciences appear to be well distributed and accepted among the NASA Centers described above, and, most importantly, are rapidly coming to be viewed as legitimate applied research fields.

It is difficult to contemplate such extended presences in space as lunar bases, or very large space systems, without a well thought out plan for harnessing extraterrestrial materials. Microgravity science has, therefore, both long-term implications for NASA's future and near-term applications for earth-based processes and systems. Moreover, microgravity scientists and engineers are working at the frontiers of the field, which should itself be accepted as the prime criterion for judging its overall quality, vitality, and impact.

The applied aspects of microgravity science should also be exploited as realistic opportunities for commercialization arise. This is consistent with the President's national space policy aimed, in part, at stimulating private sector commercial activities.

The ground-based and flight facilities in NASA are unique for microgravity: the Team notes that in general the physical facilities for microgravity research are good. This program is new enough that the physical plant, equipment, flight hardware, etc. have yet to show aging problems. The main problem encountered here is the limited size of the program, few flight opportunities, and a need for more sophisticated flight hardware, including significant elements of telescience, robotics, and remote communication and control. The program is still evolving along the steep portion of its learning curve, which is not surprising for such a young scientific field.

The drop tubes and drop towers at MSFC, LeRC, and JPL are specialized facilities for carrying out short duration microgravity materials processing. The MSFC facilities are fast turn-around, highly instrumented, and are equipped for the new high-temperature superconductors. The LeRC facilities can handle larger scale experiments involving fluid mechanics and combustion experiments. JSC has unique laboratory facilities for cell culturing and associated bioreactor developments for cell biology microgravity flight experiments. Finally, the JPL facilities are tailored for studies of hollow sphere formation of glasses and metals.

NASA Centers have also used a variety of aircraft for flights which produce short intervals of low gravity including KC-135's, Lear jets, and F-14's for various sized microgravity experimental packages. Such facilities are essential for testing concepts and hardware before entering the long process associated with formal space flight experimentation.

Findings and Recommendations

1. The Team finds that microgravity science appears to be well distributed and accepted among the NASA Centers described above, and that NASA support to date has led to microgravity science rapidly coming to be viewed as legitimate applied research. NASA should continue such support and augment it as possible.
2. The Team also notes that the applied aspects of microgravity science could well lead to realistic opportunities for commercialization. NASA should ensure that this aspect of microgravity science is encouraged and the results made available to the commercial community.

3. The Team notes that further development of the program could be stifled by lack of proper facilities and the necessary regular access to space. NASA should ensure that the program has access to flight opportunities and adequate, sophisticated flight hardware, which includes significant elements of telescience and robotics, remote communication and control, and other relevant factors.

CHAPTER III

PLATFORMS: ACCESS TO SPACE AND THE SUBORBITAL PROGRAM

1. Access to Space

Access to space is central to the discussion of Center activities in and capabilities for space science. Moreover, a critical issue for space scientists is now, and will continue to be, the fact that the time scales for space flight are incommensurate with the march of scientific accomplishments. Today, the time from design to flight of a major mission can range from ten to twenty years, a length of time that can lead to obsolescence of the scientific thrust of the mission. A single mission can occupy much of the career of a space scientist. NASA needs to make every effort to minimize the time interval between contract award and launch for as many programs as possible. A period of three to four years, at least for the smaller missions, would be desirable. This issue is discussed further in Chapter IX on ensuring the long-term future.

A flexible program that includes various methods of access to space is essential to maintaining vitality and morale in the face of these longer and longer delays. Such a program must include rockets, balloons, and aircraft. From the beginning, NASA has provided access to space by these means. The suborbital program has worked well, providing both the initial test of instruments that later go into space as well as direct and indirect measurements of profound significance.

The worth of the suborbital program has never been more evident than with the current hiatus in flight activities. If there were no suborbital activities, the Team would have seen far less new science on its visits. The Team was impressed with how the rocket, balloon, and aircraft program has enabled many NASA scientists to continue to do first-rate research and to keep their skills honed until satellite missions resume. The suborbital program also allows for close interaction with university scientists involved in programs of smaller scope than major space missions.

The Team emphasizes the importance of the suborbital program, having been continually impressed with its impact on the science programs of the Agency as a whole. In order to emphasize this importance, this chapter presents a brief review of the airborne science and applications program as an example of what can be done with suborbital platforms. The Team did not review the balloon and rocket programs as comprehensively, but notes the importance of these as well.

2. Airborne Science and Applications Program

The effectiveness of the suborbital science program has been clearly demonstrated by the many successful investigations completed by university and NASA scientists. By virtue of its special scientific and technical capabilities, NASA is uniquely suited to provide broad scientific support for complex interdisciplinary airborne activities.

Like NASA wind tunnels, centrifuges and other experimental facilities, the airborne program research aircraft provide essential opportunities for research and experimentation by NASA and other scientists. The program has been especially useful in providing opportunities for graduate students to participate in hands-on flight experimentation. The long lead time between major space flight projects does not allow this same opportunity.

The airborne facilities support programs in astronomy, earth sciences, ocean processes, air quality, upper atmosphere, meteorology, life sciences, and shuttle and satellite sensor development.

Airborne measurements are particularly important for studies of global environmental change. The investigation of the terrestrial environment requires the gathering of data from many different sources, at a variety of spatial and temporal scales. Exchange processes are usually too transient and localized to be understood from remote space observations alone, yet these are essential determinants of the earth's global environment. For the foreseeable future, developing an understanding of exchange processes that link terrestrial biology, atmospheric and ocean dynamics, and chemistry will require many measurements that can only be made from aircraft.

Aircraft platforms also serve another critical function, that of providing simulation capabilities for remote sensing instruments. Operational details can be thoroughly examined in aircraft simulations to maximize the future return from spacecraft missions and to minimize the risks of failures.

Looking outward is also possible from aircraft. Infrared astronomy from ground based observatories is limited since major portions of the spectrum are blocked by atmospheric water vapor. With airborne observatories working above the tropopause at altitudes in excess of 40,000 feet, the atmospheric transmission difficulties can be minimized. Thus, an airborne observatory such as the Kuiper Airborne Observatory is a powerful tool for science. Aircraft permit flexibility and timely response to new cosmic events such as the currently observed Supernova. They provide access to events, such as solar eclipses or planetary occultations of background stars, that can only be studied from particular locations.

The airborne program is a good example of how NASA can support and implement modest programs. Airborne scientific investigations provide an excellent marriage between NASA science and operational capabilities and the outside community. Two examples, the Amazon Boundary Layer Experiment and the unique contributions of the KAO Facility Scientist, are described below.

The Amazon Boundary Layer Experiment (ABLE-2: 1985, 1987) focused on assessing the role of biosphere-atmosphere interactions on the chemistry of the atmosphere over pristine tropical forests and wetlands. The design and execution of ABLE was a collaboration of U.S. and Brazilian scientists sponsored by the National Aeronautics and Space Administration (NASA) and the Instituto Nacional de Pesquisas Espaciais (INPE), the Brazilian space agency. The experiment was an initial step towards understanding how the tropical rain forests of the world influence global atmospheric chemistry and climate. The program is part of a longer term study of the chemistry of the atmospheric boundary layer supported by the Global Tropospheric Experiment (GTE) component of the NASA Tropospheric Chemistry Program.

ABLE involved scientists and engineers from LaRC and from a number of universities. A critical factor in the scientific success of the experiment was the interdisciplinary effort of engineers and scientists from numerous LaRC organizations in designing, developing, and operating the primary instrumentation. The expedition demonstrated how ground, aircraft, and space technologies must be integrated with theoretical studies to resolve issues of global habitability, and it was a good example of how NASA laboratories can play critical roles in organizing and implementing such efforts.

The Kuiper Astronomical Observatory (KAO) is an important airborne astronomical facility. The KAO is a modified USAF C-141 Starlifter aircraft which carries a 94 centimeter telescope to high altitudes for astronomical observations in the infrared spectrum. The KAO Facility Scientist carries out an active research program on the KAO and is Principal Investigator on one of the KAO focal plane instruments. This instrument was developed under the Facility Scientist's direction and is regularly used by a number of Guest investigators on the KAO.

Because of his direct scientific involvement on the KAO, the Facility Scientist is intimately familiar with the technical and operational aspects of the KAO and is eager to see that the facility is as productive as possible. This involvement and concern make him especially effective in providing scientific and technical input to the KAO project manager and his staff and in providing support for the scientists who come to ARC to observe with the KAO. Researchers from other institutions regularly call on the Facility scientist and his group to help with technical and equipment problems which arise during their observing runs and frequently consult on approaches and techniques for maximum efficiency. In all cases the result of the work by the Facility Scientist has been to make the operation of the observatory much more efficient and productive for outside users.

Findings and Recommendations

1. Noting that access to space is the key to the health of NASA programs, the Team emphasizes that such access should be accomplished by the most efficient means: expendable launch vehicles, shuttle, suborbital programs, or other means. At the same time, NASA needs to minimize the time interval between contract award and launch. The Team recognizes that this will not be easy or even appropriate for the largest missions, but emphasizes that provision of flight opportunities on shorter time scales will have an enormous positive impact on those involved, both inside and outside NASA.
2. The suborbital programs were found to be a crucial aspect of ensuring access to space. The Team recommends that NASA continue to give priority to these balloon, rocket, and aircraft programs which must have a significant place in a balanced NASA science program.

CHAPTER IV

SUSTAINING THE QUALITY OF CENTER SCIENCE

1. Introduction

How quality is measured, recognized, checked, and preserved is important to any scientific institution. Chapter II of this report shows the wide variety of disciplines that must be monitored in NASA. This chapter outlines the current NASA approach and recommends actions to enhance the on-going review process. In its assessment of science at NASA Centers, the Team was impressed with the widespread use of a variety of quality checks and their evident effect on validating, sustaining, and improving the quality of science that NASA supports, whether the work is done inside or outside of NASA.

In the view of the Team, one of the most important checks on the quality of scientific research at the NASA centers is the use of peer review as the basis for decisions concerning the financial support of proposed work. This chapter provides a review of how the NASA peer review process works and additionally describes how one Center, JPL, uses a variety of other quality checks to produce a vigorous and productive science program. Further aspects of recognition of quality are discussed in Chapter VI on Science Careers in NASA Centers.

Finally the Team notes the need for a continuing rigorous process for monitoring quality. There are various ways to do this, and some suggestions for future reviews are included in Chapter IX on ensuring a long-term future. The Team also notes that the review process can be time-consuming and even counter-productive if such reviews are not adequately coordinated; there can be too many reviews over a given period. NASA needs to ensure that the on-going review process is not so burdensome that it becomes a hindrance rather than a help in ensuring the quality of NASA's program.

2. The OSSA Peer Review Process

From a NASA perspective, peer review has permitted the centers to identify areas of weakness and to strengthen the quality of research activities where such strengthening was needed. It has been an invaluable tool in managing NASA's scientific program and in ensuring that the work supported (whether internal or external) is of the highest possible quality.

All NASA scientific work is peer reviewed by the OSSA. The use of such reviews by the various discipline managers at NASA Headquarters helps to ensure that the same standards are applied to the selection and funding of center and non-center based research. This is true for basic research supported by the Research and Analysis program, for guest investigator programs using operating satellites, and for the flight investigations proposed for major new space missions.

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In the case of flight investigations, a formal solicitation and review process -- the Announcement of Opportunity (AO) process -- is used to ensure that all proposed work is subjected to a rigorous screening. Several levels of review and numerous checks are applied throughout this process to ensure that the same standards are applied to all proposals and that all proposals have been treated fairly. Any NASA Center scientific investigation selected for a flight mission must survive an open competition and a thorough review process.

An analogous, although less formal, process is used to evaluate proposals for the support of basic research within the various OSSA discipline divisions and branches. Work which is funded at a NASA Center has been chosen on the basis of its scientific merit and its perceived contribution to the total NASA program. It must survive the same screening undergone by proposals from all other sources.

In the 1970s when the policy for uniform peer review of all work was adopted, there was some suspicion by the scientific community outside of NASA that work being supported at the NASA Centers did not measure up to a national standard and would not be able to withstand critical external scrutiny. At the same time, the NASA Centers felt that they were being burdened with a considerable amount of extra paperwork and that outside reviewers were likely to be biased against NASA's internal activities. With the benefit of more than ten years of perspective on the results of the use of peer review, it is now clear (and was evident during the Team's visits to the Centers) that the scientific work being done within NASA is fully competitive with the work being done elsewhere.

This peer review policy has had an evident and positive impact on the quality of work in the Centers. The Team applauds this strong commitment to peer review, and recommends the continued use of such peer review to enhance and maintain high quality in all Center science programs.

3. Example: Sustaining Quality at JPL

In addition to the peer review process carried out by Headquarters, many of the Centers also take internal actions to monitor the quality of their work. As an example, we have chosen JPL, which monitors the quality of its research by several methods. In the case of JPL the responsibility for the functioning of this system lies directly with the Laboratory Director and the Chief Scientist, illustrating the interest at the highest levels of the Center in assuring the quality of the work undertaken at the Laboratory.

JPL carries out a rigorous peer review of its senior research scientists as part of the promotion system. The requirements for appointment to Senior Research Scientist are similar to the requirements for appointment to the rank of Professor at the California Institute of Technology. Letters of recommendation from the candidate's peers nationwide and worldwide are screened by a joint JPL and Caltech Review Committee. Then recommendations are sent to the Laboratory Director and Chief Scientist for approval; forty-six such appointments have been made to date.

In addition to the above reviews for promotion, the Laboratory's Distinguished Visiting Scientist Program provides another, entirely separate, monitoring process of the laboratory programs. These appointments are made by the Laboratory Director or the Chief Scientist. Each appointee spends from a few weeks to several months working with a particular research team and observing in depth the quality of the research and the people doing the research. These Distinguished Visiting Scientists report their observations to the Division Manager and the Chief Scientist. If they wish, they also write a summary report on their observations to the Director, thereby providing another mechanism for an ongoing critical commentary on program quality. Some Distinguished Visiting Scientists return year after year for continuing interactions and observations.

From time-to-time JPL forms review panels, usually chaired by one of the Distinguished Visiting Scientists, to evaluate an area of research or to consider moving into new areas, as needed.

Finally, there is direct feedback to managers on the results of peer review of proposals. Group Supervisors and Section Managers can and do request and receive summaries from NASA Headquarters on proposals that fail the review process and on ones that are considered marginal. Similarly, papers that are not accepted for publication are brought to the attention of the Group Supervisor or Section Manager. Such feedback is the basis for an identification of areas of weakness and the presentation of strengthened proposals.

These overlapping layers of monitoring have proven effective in maintaining the high quality of JPL research.

Findings and Recommendations

1. The Team recommends that peer review be continued to maintain and enhance quality in all Center science programs, but notes that the review process can be time-consuming and counterproductive if not properly coordinated.
2. The Team commends JPL for having carried out a thorough consideration and implementation of appropriate review procedures, and recommends that other Centers implement such procedures if they are not already in place.

CHAPTER V

INTERACTION OF SCIENCE AND TECHNOLOGY

1. Introduction

The last two chapters have focused on science disciplines and sustaining quality. Now we turn to the importance of the interaction between science and technology in NASA. Possibilities for a strong interplay between science and technology is, in fact, one of the unique attributes of work undertaken at the NASA Centers. There are many issues involved in maintaining a strong relationship. To see what was actually happening, the Team was charged with assessing the relationships between the Center space science programs and the science-related advanced technology programs at the Centers and to recommend actions that could enhance these interactions. This relationship is one of the keys to the future success of NASA, which depends on the appropriate use of advanced technology for the achievement of its mission.

The Team discussed this issue with each Center, and also spent some time with Headquarters personnel examining the various aspects of the interaction. While it is not always easy to match the requirements of science and of technology, on the whole, the Team found that a strong interaction was taking place. The sections below provide an overview of the current situation and recommendations for improving technology transfer.

2. Technology Planning and Development

Technology planning for the long-term, for science missions and applications which are not yet approved programs and whose technical feasibility may not yet have been established, often requires estimates of user needs a decade or more before those programs reach the detailed design phase. The OAST planning process is initiated by systems studies of potential missions to evaluate feasibility and identify enabling technologies needed to ensure system success. A set of technology "driver missions" is developed by OAST in cooperation with user program offices (OSSA for science missions) and agreed to by the program offices (again, OSSA for science). These driver missions provide the basis for joint technology plans which lead to a set of action strategies, joint OAST/OSSA planning workshops or working groups to identify needs, and identification of research programs for inclusion in the OAST program.

The Team found that the process does work. An example of a widely acclaimed successful collaboration between OAST and OSSA in advanced technology is the Sensor Working Group and the resulting sensor research program. The process is based on a multi-Center, multi-office (OAST/OSSA) working group (with inter-agency and academic participation) that evaluates potential sensor research programs. By and large, the funded program is derived from their recommendations. Current sensor research and development is balanced between development of detectors, laser and tunable sources, submillimeter wave devices, and other sensors.

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The extent to which the process can accommodate the needs of the science program is dependent on the needs identified by the OSSA program managers and on the ability of the OAST budget to respond. OAST updates annually a long range technology plan which is published in an OAST Program and Specific Objective document. The technology program is further documented annually in the set of RTOPs (Research and Technology Operating Plans) which commit funds to the current year of the long range plan. The OAST research program has a limited budget and a resultant inability to fund many of the programs recommended by the Centers. This situation has been aggravated by reductions in advanced development budgets in OSSA. To alleviate this problem, NASA should provide budget support and flight priority for some flight demonstrations of selected advanced space technology activities. This will also help to bridge the technology transfer gap between OAST and OSSA (see below).

As future science missions become more firmly defined and nearer to approval, OSSA funds likely candidates for advanced systems with a transfer of technology from the OAST device-level research. Unfortunately, over the last decade, funding in user programs for supporting research has diminished, causing increased demands on the OAST advanced research budget which could not be met. As a result of these budget pressures, the OAST program has become focused on a more limited set of goals. Furthermore, a gap seems to have developed between OAST's carrying out work on device-level technology and the Agency's ability to incorporate such technology into flight systems.

The Team notes with approval that with renewed emphasis on strategic planning, agency-wide joint planning to identify advanced technology requirements for future missions is taking place. The Civil Space Technology Initiative which started in FY 1988 has an active involvement and shared management of its elements with user program offices. The Pathfinder technology program, proposed for FY 1989, has involved joint planning with user groups, particularly in the areas associated with the development of technology to support long-duration missions with humans in space.

The in-house spacecraft projects, particularly at GSFC and JPL, have provided a great stimulus to the development of spacecraft technology. Their presence has no doubt helped in recruiting young scientists who want to "do things in space." On the basis of first-hand experience, the scientists see what can be done in space now and what can be done with further development of spacecraft technology. This hands-on experience stimulates ideas for future missions. The goal of having at least one in-house spacecraft project at major development Centers needs to be maintained as a regular feature of NASA's space science and technology program. For example, a good deal of the success and high quality of GSFC science can probably be traced to the Center's having had this type of experience.

Individual Centers have developed different methods for establishing an environment conducive to the transfer of technology. The Team found that science and related technology organizations are often jointly involved in an RTOP. Similarly, joint proposals can compete for the Director's Discretionary Fund. Another approach utilizes topical meetings such as JPL's monthly mini-retreats and LaRC's periodic Center-wide workshops (e.g., the 1986 and 1987 EOS workshops). JPL has established a position of Chief Technologist to take a broad look at progress in technology and how such technology could be applied to efforts at the laboratory. This appears to be a valuable mechanism for ensuring technology transfer. LaRC has established an Advanced Sensors Program Office to help coordinate future scientific thrusts and advanced technology activities. Individual personal contacts among scientists and advanced technology engineers also play a strong role in the effectiveness of the transfer.

The Team found that an excellent level of interaction and transfer of technology exists between the space science activities and those of the related advanced technology development organizations at each of the individual Centers. This ability to call on the engineering expertise of the Center in the conduct of science activities is one of the unique strengths of the NASA Centers and an important factor in the attractiveness to scientists of the environment for doing science at NASA.

3. Impediments to Technology Transfer within NASA

While technology transfer seems to take place within a given Center, far less interaction occurs at the Center-to-Center level. Some positive actions include the Sensors Working Group and inter-Center topical workshops. The Asilomar Workshops (1982, 1985, and September 1987) on the Large Deployable Reflector (LDR) brought together science and technology staff members to identify the enabling and enhancing technologies for the LDR mission and initiate plans for pursuing these technologies. Personal contacts also play a significant role at this level.

The Team noted that several potential impediments to effective technology transfer and a smooth flow of technology from development to use exist at the NASA Headquarters level. OAST concentrates on selected enabling and enhancing technologies for missions a decade or more in the future, while OSSA has nearer-term instrument and system needs. This difference in emphasis often results in a funding gap in the development of flight-qualified, state-of-the-art instruments, with neither office claiming responsibility for flight demonstrations of prototype hardware. A second possible shortcoming is that each office uses completely independent advisory groups. Thus, a technology program responsive to OAST's advisory structure may either not include, or include at a low priority, technologies that are needed to support the future science program.

Closer coordination at the Headquarters would help to improve technology transfer and ensure the optimum use of available funds. The OAST Management Council includes a representative from each Center, as well as OSSA and the other Headquarters offices, and provides an additional mechanism for inter-Center coordination. Although OSSA has been a formal member of the OAST Management Council for a number of years, more active participation by OSSA and OAST staff members in each others' meetings is needed. Top levels of management in both organizations should assign priority to these coordination activities.

To accomplish a regular exchange of information on activities and interests in science-related advanced technology, NASA should establish a Council on Science and Technology consisting of a principal scientist and a principal technologist from each Center and an appropriate representative from NASA Headquarters. The Council should be organized by the Centers, perhaps with the Chair coming from the host Center, but also should permit active participation by representatives from OSSA and OAST.

To facilitate the connection between scientific plans and missions and the development of appropriate technology, there needs to be appropriate scientific advisory input to OAST in addition to purely engineering and technology input. It is appropriate for OAST to have a panel of technologists and engineers advising them, but it seems equally important that some appropriate scientists be included as members of OAST advisory committees so that technologies which support long-range scientific goals are identified and included in the OAST program. Similarly, it is important to have some appropriate

engineers and technologists as members of OSSA advisory committees. In addition, more use should be made of "cross-cut" committees to coordinate new technology developments with space science goals and missions. Such cross cutting studies were carried out in the Agency a number of years ago, but the practice was allowed to lapse. It needs to be revived. Finally, the Team encourages OSSA and OAST to coordinate programs and development of advanced technology with mutual reviews.

Findings and Recommendations

1. NASA should provide budget support and flight priority for necessary flight demonstrations of selected advanced space technology activities in order to bridge the technology transfer gap between OAST and OSSA.
2. NASA should continue the practice of maintaining at least one in-house spacecraft project at major Centers such as GSFC and JPL.
3. It is important that some appropriate scientists be included as members of OAST advisory committees so that the most critical technologies which support long-range scientific goals are included in the OAST program. It is equally important to have some appropriate engineers and technologists as members of OSSA advisory committees. To this end, the Team recommends that NASA add one or two technologists from the academic engineering and aerospace industry communities to the Space and Earth Science Advisory Committee, and add one or two space scientists to the Space Systems and Technology Advisory Committee in order to get timely scientific input into that advisory and planning process. NASA should recommend similar actions to the National Research Council's Space Science Board and Aeronautics and Space Engineering Board.
4. To accomplish a regular exchange of information on activities and interests in science-related advanced technology, NASA should establish a Council on Science and Technology consisting of a principal scientist and a principal technologist from each Center and an appropriate representative from NASA Headquarters. The Council should be organized by the Centers, perhaps with the Chair coming from the host Center, but should permit active participation by representatives from OSSA and OAST.
5. More use should be made of "cross-cut" committees to coordinate new technology requirements with space science goals and missions.
6. The Team encourages OSSA and OAST to coordinate programs and development of advanced technology with mutual reviews.

CHAPTER VI

SCIENCE CAREERS IN NASA CENTERS

1. The Center Science Environment

The Team was charged with making recommendations on actions needed to enhance the quality of Center science programs and their contributions to fulfilling Agency objectives. In this chapter, we address the subject of the science environment and careers in NASA, in Chapter VIII, NASA-wide institutional issues. The Center science environment is a key element in maintaining a vigorous and effective science program. One of the goals of the Team was to assess the effectiveness of the Centers in providing the right environment for carrying out science at NASA.

The Team found that, on the whole, scientists at the NASA Centers are a highly-motivated, creative group of people, coping remarkably well with the current tensions and uncertainties of the agency. They are attracted to the Centers by the excitement of space missions, the access to unique facilities, and the opportunity to participate in the creation of new missions. A further attraction is the critical mass of scientists and engineers with diverse skills found at NASA.

Many Center scientists find the role of intermediary between the project-oriented work of the Center and the basic research of their university collaborators an exceptional opportunity for personal growth and satisfaction. It is important to note that this motivation shows the need for a balanced program of access to space, including a strong suborbital part. Without this, NASA's unique attraction is sharply diminished.

Many NASA scientists, however, appear torn between their responsibilities for accomplishing specific tasks for the agency and the desire to continue to grow in breadth and capabilities as scientists in disciplines of their own choosing. They see conflicts between expectations of independent creativity and the demands of loyalty and service to a large organization and the sometimes conflicting and overly detailed direction ("micromanagement") received from headquarters. While loyal to NASA and grateful for the environment provided, they also seek some tangible evidence that their creativity and individual scientific contributions are respected and appreciated. Recommendations below are intended to address this need.

Despite these comments, almost without exception the scientists the Team talked to at all the Centers believed they were achieving their goal of having a rewarding and productive professional career. They felt this in spite of "higher priorities for engineering," "layers of bureaucracy," and frustrating problems over travel, staff support, hiring, rate of advancement, and procurement. In spite of the bureaucratic restrictions, many of which are inherent in the civil service, the scientists took it as self-evident that a NASA Center was an exciting place to be and often referred to their pride in NASA's achievements.

What then are the important factors that affect space science careers in general and those at NASA in particular? They include opportunities to choose and perform experiments and theoretical analyses; opportunities for regular access to space; support from technical, engineering, and computer personnel; the availability of strong science leadership; a stimulating environment with opportunities for collaboration with colleagues in the Center and nearby organizations; tolerable regulations and restrictions; opportunities for advancement as scientists; peer recognition; the possibility of serving on NASA and national and international scientific committees; and good communication with and response from management.

How well have NASA and the NASA Centers addressed these factors? The scientists at the various Centers often shared the same concerns about opportunities for career development. At the same time, each Center had its own personality, different from that at other Centers, and its own successes and failures.

The situation at GSFC provides a good example of the science environment and its conflicts. GSFC scientists described to the Team numerous matters needing improvement, as well as features that make GSFC a good place to work in science. One scientist found the "essence" of GSFC to be the presence of very able, easily accessible people with whom to swap knowledge and equipment -- somewhat like a "scientific mid-eastern bazaar." The very size and diversity of GSFC makes it difficult to understand, and sometimes communications are difficult. Another person referred to GSFC's "unique culture" -- one that is hard to adapt to, but, once learned, is a powerful "problem-solving" environment.

A similar view came from a senior scientist who emphasized that the diversity of the people at GSFC was an asset of enormous value to science programs. Several of the scientists found the interdisciplinary nature of many of the programs very attractive and a large part of the reason they came to GSFC. There was the pervasive attitude that they came "to do things in space." Several scientists remarked on their good contacts with the science community beyond GSFC. They appreciated the opportunity to work with university faculty members and graduate students who come to GSFC for varying periods of time. The Team found a similar, very positive attitude at the other Centers as well.

The Centers have tried different models for support of innovative research. Notable among these was the Lewis Research Academy. This is not yet fully developed, but the concept of collecting leading Center scientists in a group to foster multidisciplinary research and stimulate Center science is potentially a valuable concept for all Centers. Other innovative approaches also exist at other Centers, and a regular exchange of ideas between Centers on approaches and experience in fostering science should, in the view of the Team, be encouraged.

Overall, the Team found many examples of scientists who are highly active, creative, energetic, and ambitious and who play leadership roles in science both inside and outside NASA. The Team was pleased to note that NASA scientists were recognized on the outside: one bellwether of scientific quality at any institution is the degree to which the institution's scientists are invited to serve in senior positions on the committees of scientific societies or as editors of professional journals. In the case of NASA Centers,

approximately one hundred scientists from all Centers currently serve as editors, associate editors, and society or section officers in scientific societies that span the scope of NASA-supported disciplines. The healthy involvement of NASA scientists in the general activities of the scientific community should be strongly encouraged and increased to ensure further recognition of the contributions of NASA science and scientists by the scientific community.

The Team recognized the importance of the engineers and technologists associated with the scientific groups. They provide NASA with new observing systems in a wide variety of disciplines. Their interests and talents are broad and should not be confined to instrumentation development. Although they do not spend a large fraction of their time addressing scientific problems or analyzing scientific data, they are also motivated by scientific interests and make major contributions to the Agency's ability to undertake significant scientific programs.

2. Scientific Recognition and Professional Interaction

2.1. Acknowledgements of Achievement

For recognition of accomplishments in both science and technology, the NASA awards program is important. Each of the Centers clearly has a commitment to such a program, and each Center has a program to recognize exceptional contributions and accomplishments. The exact way in which this is done varies among the centers; it would be useful for the Centers to compare their programs so that successful approaches could be used more widely. The Team urges each Center to continue to develop an active program to recognize outstanding scientists, both new and experienced, for contributions to science and to projects. Science managers at Centers should be diligent in nominating their outstanding scientists for the awards and honors of professional organizations.

2.2. Research Fellowships or Leaves

The Team notes the importance of instituting and maintaining an active program of research fellowships, interchange programs, or leaves (like university sabbaticals) for productive scientists. The record here could be better; most NASA scientists never have heard of or taken the opportunity for extended collaboration or reflection offered by a leave with pay. Guidelines for granting such leaves might include the preparation of a specific proposal, the demonstration of an invitation to visit a distinguished institution, and the requirement for the reporting of accomplishments. An active program of exchanging personnel among Centers for one-year visits could also be productive. For this to be effective and attractive, steps would have to be taken to minimize logistical problems related to housing.

2.3. Professional Interaction/Professional Travel

The Team emphasizes that in order to maintain contact with their professions and in order to follow rapidly developing trends, scientists need to meet regularly with colleagues from other institutions. This could take place through fellowships and leaves as noted above. Such interactions lead to the critical examination of individual work, creation of new ideas, and a more integrated and effective national science effort. Professional contacts benefit not only the NASA scientists and thus the Agency, but the scientists outside NASA as well. This strengthens the entire space science effort and leads to the more effective planning, development, and operation of space science missions.

Unfortunately, frustration over inadequate funds for travel to scientific meetings and conferences was almost universal. Access to travel funds is clearly more difficult for NASA scientists than for scientists at universities, and bureaucratic regulations make attendance at international meetings difficult. Managers should assist scientists with the administrative requirements, and funds for travel to scientific meetings should be clearly identified and set aside from programmatic and project management travel funds. With the growing emphasis on international collaboration and multidisciplinary science, it is important that NASA find ways for its scientists to participate in international meetings on a regular basis. To stay current in their fields, scientists should be able to attend at least one major disciplinary conference each year.

The Team notes that current constraints on availability of travel funds for NASA researchers are having a significant impact on their opportunities for professional development and on their abilities to do their jobs. Lack of support for scientists to interact with their colleagues has the effect of isolating NASA scientists from the outside community of scientists. This is bad, both for NASA and for the outside community. The Team emphasizes the need for NASA scientists to be able to interact with their colleagues on the outside. Ways must be found to provide for this.

Findings and Recommendations

1. The Team recommends that the Centers continue to develop an active program of awards to foster professional growth, and that Centers regularly exchange information about successful award programs.
2. The Team recommends that Centers more effectively publicize and use existing programs for research fellowships, and also consider instituting a program of personnel exchanges for one-year visits.
3. The Team recommends that NASA and the Centers clearly identify and protect funds for scientists to interact with their colleagues. Provision should be made for scientists to attend at least one major disciplinary conference per year. These funds should be set aside from funds for programmatic and project management travel. Unnecessary administrative barriers for international travel to meetings should be minimized.

3. Participation in Planning

The Team was asked to examine the nature and extent of participation by Center scientists in the management and planning of Agency programs. We found that Center scientists have considerable concern with their exclusion from full participation in a variety of boards, committees, and panels, both inside and outside NASA. Inside NASA, Center scientists perceive themselves as underutilized even after NASA has identified a large initiative, and they perceive NASA as often seeking outside planning advice in preference to input from Center scientists. Center scientists should be included in NASA Headquarters Advisory Committees. SESAC has a good record here -- others should follow the example.

Several Center scientists noted that the communications problem appears to exist in both directions: they are not involved in NASA planning, and NASA planning or priority decisions often are not communicated back to the Centers in adequate time for appropriate response. There is general lack of information on Agency plans and directions. Steps should be taken to improve the flow of information back to the Centers.

There has also been a deliberate exclusion from the National Research Council (NRC) planning and advisory process. Present policy and practice do not allow NASA scientists to be appointed to full membership on the Space Science Board (SSB) and its committees. Noting that NOAA and USGS scientists do serve on various NRC committees, the Team shares this concern. The SSB was organized by the NRC at the request of Congress and the Administration when NASA was established. The SSB develops the scientific strategy that guides the scientific programs of NASA and provides broad policy advice on scientific issues to the agency and other components of the government.

The SSB has created seven standing committees that formulate the strategies for the various disciplines of space science. NASA employees have been excluded from service on the SSB and its committees on the grounds of conflict of interest since they would be giving advice to the agency which employs them. This objection may have some validity where service on the SSB itself is concerned, since it sometimes becomes involved in broad policy issues. However, we again note that other Boards of the NRC do include scientists from the agencies which provide support to those Boards (Board on Atmospheric Science and Climate, Polar Research Board, Ocean Studies Board, and others).

In any case, this objection does not apply to the committees of the SSB. These committees do not give policy advice; they develop scientific strategies and monitor agency performance in implementing those strategies. Furthermore, all of their reports and recommendations must be reviewed and approved by the SSB before it is passed on to NASA. The conflict of interest objection does not appear to apply to membership on these committees.

It is clear that the potential for conflict of interest in the work of these committees is no different for Center scientists than it is for the university scientists who comprise the great majority of committee membership. Furthermore, a very important segment of the space science community is now being excluded from the development of the national space science programs. The Team strongly urges that the NRC leadership be approached with a request that this policy be changed. In fact, the chairman of the SSB, as a member of the Team, has already begun the process, and the Team is hopeful that NRC policy will soon be changed.

Findings and Recommendations

1. The Team emphasizes that national institutions such as the National Research Council should not exclude NASA scientists who have established themselves as outstanding members of the scientific community from participating fully in national scientific and advisory committees alongside their non-NASA peers. Therefore, NASA Headquarters should approach the NAS/NRC with a request that the policy of exclusion of NASA Center scientists from the space science advisory apparatus of the NRC be changed.
2. NASA Headquarters and NASA Centers should make a strong effort to include Center scientists on advisory committees.

4. Critical Roles of Scientists at NASA Centers

The Team was impressed with the way in which NASA has organized itself to carry out its mission. In order to meet the many requirements for the use of advanced technology in large programs with state-of-the-art scientific objectives, NASA has identified a number of special career positions, some of which are unique in the scientific community. These include study scientists, project scientists, facility scientists (see discussion of the KAO in Chapter III), mission specialist astronauts, payload specialists, and the like. A summary of the roles of three of these is presented here to emphasize their importance.

4.1. The Project Scientist

The Team was very impressed by the cadre of Project Scientists they met at the Centers. These people are some of NASA's most experienced and active scientists, and they benefit both NASA and the scientific community through their dedicated work. The role of Project Scientist is central to NASA's ability to execute scientific projects at the Centers. The integration of the Project Scientist position into the project management structure does differ among the Centers, but the following generalizations apply.

The role of the Project Scientist is one of the best ways in which NASA scientists can perform their "service" to NASA and their Center. As liaison between the Project Manager and the community of scientific investigators, the Project Scientist must be an advocate, communicator, and advisor to both. The position of Project Scientist is the highest operational role to which a scientist can aspire. It is a position that commands respect and provides evidence of one's success and expertise and permits a scientist to make a contribution to NASA's large flight projects.

The level of service as Project Scientist and in related capacities varies widely, requiring from less than 10% to 100% of the scientist's time. The average seems to be about 30%, roughly comparable to the service requirements of university faculty who are active in research.

The demands of the position have continued to evolve and expand since the 1960s. A typical project's duration has grown from five or six years to a minimum approaching ten years and an anticipated maximum of perhaps 25 or 30 years (e.g., HST or Space Station). Instrument complexity has increased enormously as have the instruments' demands on the spacecraft. These have led to scientific data analysis which is involved and sophisticated and which often requires the synergistic analysis of data from several instruments in order to arrive at unambiguous conclusions. The Project Scientist on long missions, e.g., Voyager, provides scientific continuity to the internal team and the external community.

NASA's early Project Scientists often served in the role for three or four missions over a twenty year period, at times being Project Scientist on two separate missions at the same time. Today, having attained the prerequisite experience, the Project Scientist might have time for only one mission during his or her working lifetime!

Indeed, in some cases, the task is so demanding that the position needs support from one or two Associate Project Scientists to share the work and/or bring special talents to the project team. For example, there are several instances whereby the project has incorporated an Associate Project Scientist who concentrates on the ground data processing, data transfer and exchange, or who is concerned with the second generation instruments which will be installed five or six years after launch. Such arrangements bring special and different talents to the Project, and help to ensure that the demands on the Project Scientist do not exceed about 50% of the time available. This limit allows the Project Scientist to remain active in research. Positions of Project Scientists on major NASA missions, such as the Space Station, however, are full-time management positions. They are assisted by several Associate Project Scientists (e.g., polar platform or attached payloads) for whom the limitations can still apply.

All NASA Centers should recognize that it is important in achieving project goals that the Project Manager and the Project Scientist work together in a climate of mutual respect. The Project Manager is the leader, but the Project Scientist is a full associate and a trusted advisor. Ideally they should report to different administrators. When the Project Scientist and the Project Manager disagree fundamentally, there must be a higher authority to which they can appeal for arbitration. This arrangement should be the case in all Centers.

As an example of the importance of the Project Scientist, there follows a description of a particular example of such a position, the GSFC Project Scientist for the Space Station.

The position involves the following interaction: during the early stages of the program the Space Station Project Scientist worked not only with scientists and engineers within the GSFC organization but also with those from HQ, JSC, and to a lesser extent, the MSFC and the LeRC, all of whom were participating in design. The Project Scientist's role is not to decide what science should be done on the Station but to assure that the design of the Station elements, data systems, operating procedures, and management practices are compatible with and supportive of potential users. About eight scientists from various laboratories in the GSFC Science Directorate work with the Project Scientist on a part-time

basis to assure a thorough evaluation of the Space Station systems mentioned above. In order to involve the science community at large in this activity, a Space Station Users Working Group was formed, which regularly met in the definition phase of the program both in plenary sessions and as separate panels for attached payloads, platforms, lab module, servicing, and data systems.

With the support and participation of the Users Working Group, colleagues at GSFC, and other experts from the science community, the Project Scientist formulated a number of recommendations on behalf of user interests and has forwarded them to the Space Station Control Board for decision. These recommendations covered the selection of the earth normal atmosphere for the pressurized laboratory module, selection of a 20KHz power system over a 400 Hz system, acceptance of users selecting their own programming languages computers contained within payloads they provide, and the modular design of the Space Station Platform.

4.2. The Mission Specialist

The Mission Specialist Astronauts are scientists, engineers, and physicians who combine a knowledge of spacecraft systems with their technical backgrounds to provide a unique perspective for assisting principal investigators, project scientists, and program managers in designing, developing, and carrying out scientific experiments in space. Their interface allows the investigators to maximize the scientific return from an experiment within the design or operational constraints imposed by use of the Shuttle in low-earth orbit.

The Mission Specialist is the user of scientific technology designed to function in the weightless environment. As such, the mission specialists have a unique experience base that must be utilized in the design and development of advanced technology. Their contributions in this area can be maximized by involving them very early in flight experiments as well in as other projects and programs. The Mission Specialist also serves an important additional function in the area of science education through participation in seminars and lectures at technical gatherings and at universities. Moreover, the Mission Specialist Astronauts sponsor visits to the JSC and to the Astronaut Office by investigators in an attempt to facilitate the interchange of scientific and operational lessons learned from experiments that have flown or are being designed to be flown aboard the Shuttle.

In order to maintain scientific proficiency and credibility, the Mission Specialist Astronauts need to continually develop their working knowledge of their various fields of expertise through participation in research projects, independent study, hospital work, or technical colloquia. The Astronaut Office is continually looking for ways for the Mission Specialist Astronauts to pursue scientific, medical, and engineering proficiency in both academic institutions and NASA laboratories.

It is the Team's view that the Mission Specialist could be used on a much broader front of scientific activities that would not only benefit NASA science programs but would contribute toward national goals as well. These activities include science education, scientific research, technology advancement, and the design, development, and implementation of major scientific programs. The Mission Specialist astronauts can usefully serve as role models for high school, undergraduate, and postgraduate students in hopes of awakening, encouraging, and maintaining interest in the space sciences in the very community on which NASA depends to replenish its civil service personnel in science, engineering, and medicine.

4.3. The Payload Specialist

The Payload Specialist, while not a career astronaut, is an invaluable scientific resource for the conduct of space flight experiments. The Team recognizes that the Payload Specialists, who are selected on the basis of their ability, knowledge and experience, are essential members of the Principal Investigator's science team and of the flight team. Additionally, the Team emphasizes that the opportunity for non-astronaut scientists to fly and perform scientific studies in space is an incentive for students and young scientists to pursue careers in the space sciences field. This position is another example of an important NASA contribution to science.

Findings and Recommendations

The Team emphasizes that the critical positions noted above are essential to the health of NASA programs. It recommends the following actions:

1. Centers need to pay explicit attention to ways to nurture and train the next generation of Project Scientists.
2. The role of a NASA scientist as a Project Scientist constitutes a critical contribution of the Centers. The importance of that role needs to be understood by Center scientists and rewarded by Center management.
3. The Mission Specialists have a unique experience base that must be utilized in the design and development of advanced technology. Their contributions can be maximized by involving them very early in flight experiments as well as in other projects and programs.
4. NASA should find ways to use the Mission Specialists on a much broader front of scientific activities, including science education, scientific research, technology advancement, and the design, development and implementation of major scientific programs.
5. Payload Specialists are essential members of the flight team. The opportunity for non-astronaut scientists to fly and perform scientific studies in space is an incentive for students as well as established scientists to start and continue careers in space sciences.

5. The Dual Career Ladder

An area of considerable interest to the Team was the extent to which the NASA Centers make use of the dual career ladder whereby individual scientists may advance in their careers either as managers (GM System) or scientists (GS System). The Team believes that it is important that NASA scientists have the option of advancing along either of these two paths. This allows, for example, individuals who are strong scientists to advance to the GS-14 and GS-15 levels without requiring them to take on the responsibilities of a manager. Without this option, some NASA scientists will find their careers stymied unless they leave NASA or take on supervisory responsibilities for which they are unsuited or in which they are uninterested. Clearly, either of these courses represents a disservice to the agency since it is to NASA's advantage to retain its best scientists and to have highly motivated, capable managers. A similar situation applies to NASA engineers.

The Team found that the dual career ladder concept was recognized throughout all of the Centers and was generally in operation, although some Centers have been better than others in implementing it. Statistical information (see Table below) provided by the Centers on the number of GS and GM scientists and engineers at the higher levels shows that on the whole scientists and engineers do, in fact, have available to them a choice of career paths. In fact, it appears that engineers lag scientists in the relative numbers of GS positions at the higher levels.

The Team noted that the number of senior GS scientists is low compared to the number of senior GM scientists at some Centers. At these Centers, management indicated that they were aware of the discrepancy and were taking steps to provide more career opportunities for the non-supervisory scientists. In addition, there was at least one example of a non-supervisory scientist rising to the ranks of the Senior Executive Service.

The Team recognizes that an overall limitation on the number of senior level positions, both supervisory and non-supervisory, together with a relatively low attrition rate often limits the promotion opportunities of younger scientists. As one junior scientist stated the situation, "the dual career ladder is in place but it is clogged." The Team reiterates its position that if Centers are to retain their younger scientists, it is especially important that the scientific environment provide stimulating and challenging work, access to talented colleagues, and adequate facilities, equipment, and computational support.

The table below shows the extent of the dual career ladder, using data for both scientists and engineers current to September 30, 1986. GS-15 is normally the top position for a research scientist; GM-15 is the managerial equivalent. Higher levels, for example GS-16 and SES, are generally reserved for administrative and supervisory positions. NASA should use this data to ensure that the dual ladder system is truly working.

Findings and Recommendations

The implementation of a dual career ladder system for scientists and technologists should be continued at all Centers and strengthened at Centers where it is not yet fully in place. NASA scientists and engineers should be made fully aware of the system.

**Scientists and Engineers
Analysis of Dual Career Ladders**

The following table shows the number and percent of non-supervisory engineers and scientists at grades 13, 14, and 15 at each center.

	Grade 13		Grade 14		Grade 15		
	Engineers	Scientists	Engineers	Scientists	Engineers	Scientists	
Non-Supervisory/Total %	(273/277) 98	(48/48) 100	(160/224) 71	(47/55) 85	(39/115) 33	(26/39) 66	ARC
Non-Supervisory/Total %	(427/427) 100	(58/58) 100	(148/240) 61	(22/30) 73	(18/132) 13	(1/10) 10	LeRC
Non-Supervisory/Total %	(375/398) 96	(89/89) 100	(188/254) 74	(41/44) 93	(47/137) 34	(13/27) 48	LaRC
Non-Supervisory/Total %	(356/382) 93	(206/209) 98	(197/337) 58	(105/129) 81	(37/200) 18	(49/88) 55	GSFC
Non-Supervisory/Total %	(753/781) 96	(91/91) 100	(213/458) 46	(14/30) 46	(16/158) 10	(0/14) 0	MSFC
Non-Supervisory/Total %	(14/14) 100	(7/7) 100	(1/7) 14	(0/3) 0	(0/2) 0	(0/2) 0	NSTL
Non-Supervisory/Total %	(627/651) 96	(89/90) 98	(187/401) 46	(26/46) 56	(16/219) 7	(26/44) 59	JSC
Non-Supervisory/Total %	(474/477) 99	(12/12) 100	(120/245) 48	(1/3) 33	(0/96) 0	(0/2) 0	KSC
Non-Supervisory/Total %	(3299/3398) 97	(600/604) 99	(1214/2166) 56	(256/340) 75	(173/1059) 16	(115/226) 50	NASA

All Grades:

Engineers (4686/6623) 70%
Scientists (971/1170) 82%

CHAPTER VII

THE INTERACTION OF NASA CENTERS WITH UNIVERSITIES

1. NASA Centers and Universities

From the very beginnings of the space program, NASA has depended on support from its Centers and from universities to achieve its goals in space research. NASA Centers need strong interaction with universities, and universities look to NASA for support in various ways. As a consequence, one of the charges to the Team was to examine the relationships between Center space science organizations and their university counterparts and to make recommendations on how these could be enhanced. In order to examine the relationship between the NASA Centers and the universities, it is helpful to consider the pertinent characteristics of each and to define the similarities and differences.

NASA Centers are able to combine basic research with appropriate engineering and technology development to implement and ensure the success of NASA missions and programs and to lay the groundwork for continuation of a healthy NASA space program. The universities, in contrast, undertake broad theoretical and experimental research programs that often include in-depth investigations of both basic and applied sciences, incorporate results into coherent bodies of knowledge, and educate and train new generations of young scientists and engineers.

In the first few years of the space program, NASA's missions were characterized by relatively simple space vehicles and flight instruments and relatively frequent launches. As scientific objectives became more ambitious, flight instruments became complex, and more instruments were integrated into a single spacecraft. As a result, both spacecraft and missions have become more complex and expensive. Fewer missions are the inevitable result of increasingly costly projects. In the last few years this trend has accelerated, but the Team notes that the balloon, rocket, and aircraft program helps to fill this gap. For example, the Kuiper Astronomical Observatory on the C-141 aircraft involves many university investigators.

Another result of increasing complexity is the long time between the initiation of a concept and its implementation in a flight project. As mentioned in Chapter III, today the time from design to flight of a mission can range from ten to twenty years, a length of time that can lead to obsolescence of the science on missions. NASA needs to make every effort to minimize the interval between contract award and launch for as many programs as possible. A period of three to four years, at least for the smaller missions, would be desirable.

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Fewer opportunities for flight experiments, the long delay between concept and the acquisition of data, and the shift to complex flight instruments have all created problems for universities. Nevertheless, the Team noted a number of positive aspects to the relationship between the universities and the NASA Centers. Some of these are:

- The universities and the NASA Centers continue to work together and to plan missions for NASA. This is true of all OSSA science disciplines and was noted at all Centers.
- All the NASA Centers have summer programs for faculty and students, part-time employment for university researchers, graduate research fellowships, postdoctoral research associateships, and other programs of academic value. The Resident Research Associateship (RRA) program offered through the National Research Council has been of particular value in attracting new scientists to NASA, and it should be kept vigorous.
- Many NASA centers own unique facilities, often of a size or capital cost that render similar facilities rare at universities. Examples are the supercomputing facility at ARC, the JPL Deep Space Network radio telescopes, and various unique test facilities. These NASA facilities are made available to university researchers when not required for NASA work. This arrangement has benefitted the universities and generally stimulated research and development at the involved NASA Centers.
- In the area of remote sensing, NASA technology has been used by universities to open whole new fields. Oceanography from space, for example, started as a NASA technology demonstration and is now an accepted part of the discipline. A similar trend is becoming apparent in land remote sensing.
- There is some competition between university scientists and those at NASA centers for science funds under the peer review process. This competition is not undesirable and is indeed stimulating, provided that the primary NASA Center emphasis is on the larger-scale programs.

As missions become more complex, universities will need more project management support from NASA centers in order to implement programs. Noteworthy examples of successful efforts to date include the support by GSFC to the University of California at Berkeley in the Extreme Ultraviolet Explorer mission (EUVE) and the support JPL is giving to MIT and Caltech on the Laser Interferometer Gravitational Wave Observations project.

Because of the trend towards more complex missions that involve a longer time commitment, university participation in NASA's space missions is shifting heavily into data analysis. If the trend towards data analysis alone continues, it will have undesirable impact both on the universities and the NASA Centers. This trend must be recognized and an effort made to involve university scientists in all aspects of missions. It would help if NASA could contribute more to the training of students in experimental techniques. One way for NASA to do this is through the support of university research that includes student training.

In conclusion, while there are some shortcomings in both the universities and the NASA Centers, their relationship is basically healthy, mutually supportive, and symbiotic. Continuing attention to maintenance of these relationships needs to take into account the changing character of the NASA space missions.

2. The NASA Focus: A Balanced Program

After its site visits and reviews, the Team discussed at length the role of NASA Centers in comparison to the role of universities in space science. It is the view of the Team that the proper role for the Centers in space science is to focus primarily on those mission-related projects involving a larger scale, for example, projects that require extensive engineering, major facilities, or extended continuity in any combination. At the same time, NASA must provide significant support for innovative small programs of research, where creative new ideas are often nurtured. These can be the seeds of major new initiatives, and they offer good opportunities for NASA/University collaboration.

The general focus, however, should be on large programs and mission-related research. Without such a focus, there is the danger that science at the NASA Centers will become an unrelated collection of small, high-quality, research projects. NASA Centers need to guard against pressures for a broader menu of goals than is appropriate for the limited scientific staff and funds available. This can lead to many small projects, being spread too thin (sometimes only one person deep) and a general lack of manpower. With such a large-program focus, the relationships between Center space science organizations and their university counterparts will continue to be strong and healthy. They are currently mutually supportive, for the most part. They serve as recruiting tools and include constructive competition between the two groups.

It is incumbent on each Center and NASA Headquarters to focus the Center activities on the major programs. This is not to say that NASA should not be involved in any small research programs. Successful research programs always have a balance of large and small programs to encourage innovation. The balloon, rocket, and aircraft program is one element here. It is generally accepted that large equipment development and popular lines of research must be balanced by support for individuals working in areas that are not necessarily in the mainstream. There are many reasons why some such activity is necessary -- the experts are in NASA, the work is basic and necessary but no one outside is interested in doing it, or it is a part of a larger program.

Findings and Recommendations

1. NASA needs to make every effort reestablish a three to four year interval between contract award and launch for as many programs as possible. The Team recognizes that this will not be easy but emphasizes that extensive delays have an enormous impact on those involved, both inside and outside the Centers.
2. NASA needs to contribute more to the training of students, particularly in experimental techniques. University participation in NASA's space missions is shifting more heavily into data analysis; if this trend continues, it will have undesirable impact both on the universities and the NASA centers.
3. NASA and universities need to pay continuing attention to the changing character of NASA space missions as they interact: Universities need to help NASA do the large programs, and NASA needs to help universities with smaller programs. The Team suggests that NASA carefully nurture its relationships with universities and university scientists to ensure recruitment of young scientists and maintain the interest of university scientists in the changing climate of space science.
4. Recognizing the major support capabilities (e.g., in engineering expertise and large-scale facilities) which are uniquely available at the NASA Centers, Center science activity should be focused on the planning, development, and support of large programs exceeding the capabilities of most universities. Thus, NASA must have a balanced program of research emphasizing support for large programs, but maintaining significant support for innovative small research programs as well. The latter offer good opportunities for NASA/University collaboration.

CHAPTER VIII

MANAGING CENTER SCIENCE: INSTITUTIONAL ISSUES

1. Introduction

The Team was charged with making recommendations on actions that are necessary to enhance the quality of Center science programs and their contributions to fulfilling Agency objectives. Chapter VI addresses science career issues. This chapter notes several issues of institutional management that potentially affect Center science and were brought to the Team's attention during the review. These include the need for streamlining the administrative environment in which NASA scientists work and making the methods by which NASA scientists are funded, particularly the RTOP process, more efficient. The Team was impressed with the use of funding flexibility by the Centers, particularly the Director's Discretionary Fund, and recommends ways in which flexibility can be increased. Finally, the Team assesses and makes recommendations on NASA-wide computing facilities.

2. The Bureaucracy

In all institutions, bureaucracy or unnecessary administrative impediments tend to grow if not carefully monitored. NASA, which has traditionally been known as a "can-do" agency, is no exception. The Team found many examples where the administrative procedures could be streamlined and improved to help scientists and engineers do a better, more cost-effective job. NASA needs to continually assess the administrative or operational environment so that it does not impede science projects unnecessarily. Examples from several areas are presented below.

3. Personnel and Staff

There was a general opinion among the Centers that civil service hiring ceilings at the very least delay progress on programs. One laboratory director noted that when scientists and engineers move out to industry and universities they are either not replaced, or replacement is greatly delayed. Other managers stressed that the civil service personnel ceiling is continually being lowered while new requirements are increasingly being placed on the laboratories. The work force is not being expanded to meet these new requirements. Also, in areas that demand unique or highly specialized expertise, such as optics, engineers and technicians gain experience that can be obtained in very few other places, and then they leave for higher paying jobs in industry. NASA needs to be able to expand its work force to meet the requirements that are given to the Agency.

A related issue affecting NASA scientists is that the ratio of contract scientists to NASA scientists (civil service plus NRC fellows, etc.) has continually increased in recent years. This situation can lead to problems: it requires more contract management by NASA scientists, and the higher cost of contract scientists can affect the disposition of available research dollars. The Team recommends that NASA review the appropriateness of work being carried out by support contractors (particularly contract scientists) at NASA Centers. Such work should be undertaken in support of Center science programs. It should not extend the programs into new areas not supported internally by the Centers themselves.

A specific concern noted at GSFC and ARC is that the strength of engineering and technician support is waning. Center scientists must have immediate access to such support while developing ideas for flight projects. The rising cost of engineering support is largely due to the replacement of retiring civil service engineers with contract engineers, and the impending wave of retirements will only exacerbate the problem. The traditionally excellent engineering and technical support available, for example, to the Space and Earth Science Directorate makes GSFC a highly attractive place for a science career, but management must make sure this resource is maintained in quality and quantity.

3.1. Contract Management

The level of contract management required of NASA Center scientists has been increasing. It is at such a level in some cases that it interferes seriously with their ability to conduct research. This problem is linked to the lowering civil service ceilings and consequent increased hiring of contract personnel. This situation needs to be assessed carefully by Center management and steps taken to make certain that excessive contract management does not lessen the effectiveness of the Center scientists. The Team recommends that a reasonable balance between research and NASA service activities, such as contract management, is about 50/50. Managers should ensure that service activities do not consume more than 50% of a given scientist's time.

3.2. Procurement

Slowness of procurement is a growing problem. The time and paperwork necessary to effect a procurement are both increasing. Centers need to interact with each other to find the most efficient mode of action -- interviews revealed a wide disparity in the number of signatures required for a procurement.

Findings and Recommendations

1. NASA needs to continually assess the administrative or operational environment so that it does not impede science projects unnecessarily.
2. NASA needs to be able to expand its work force to meet the requirements placed on the Agency.
3. NASA needs to review the contract science situation: each Center should carefully evaluate taking on new work, especially if it extends their mission or scope.
4. A reasonable balance between research and NASA service activities such as contract management is about 50/50. Managers should ensure that service activities do not consume more than 50% of a given scientist's time.
5. On procurement, Centers need to streamline the time and the paperwork. They should interact with each other to find the most efficient mode of action.

4. Obtaining NASA Resources

The subject of writing Research and Technology Operating Plans (RTOPs) and other research proposals received many comments. It is clear that the effort required has increased. Moreover, some Center scientists and managers believe that the dependence on RTOPs undercuts on-site Center management and involves too much direct control from NASA Headquarters. Another criticism of the present RTOP policy is that it discourages formation of diverse groups of scientists interested in multidisciplinary projects. The Team recommends that RTOP policy be reevaluated to prevent the possible fragmentation of science activities or the impairment of multidisciplinary activities. One approach is to aggregate or to consolidate such proposals, but care must be taken not to impair creativity by such a process.

At JPL, the typical number of research proposals written per year by each scientist is approximately six, and the number has been increasing in recent years. Part of the reason for the increase was, according to a senior scientist, that the funding level of research projects has not risen with increasing research costs. This system has the undesirable effect of forcing scientists to take on a number of small tasks rather than focusing on a few of most interest to them. Efficiency and creativity can be reduced in this way. We recommend that a careful look be taken at ways to improve this system.

Findings and Recommendations

1. The Team recommends that the science RTOP policy be reevaluated to prevent the possible fragmentation of science activities and impairment of multidisciplinary activities.
2. The number of required science RTOPS needs to be reduced so that scientists can devote more time to research and less to proposal preparation. The Team recommends that improvements in this support system be carefully considered.

5. Funding Flexibility

At each Center, funding flexibility was discussed in detail. One aspect of this is the Director's Discretionary Fund (DDF). These funds originate from and are monitored by the office of the NASA Chief Scientist for the Deputy Administrator. The Team was impressed by the techniques used to allocate the funds at the Centers and by the mix of high risk and high quality programs selected. The scientists receiving these funds uniformly regarded the allocations as being fair and greatly appreciated the flexibility given them in their research. In all Centers, there were more good proposals than could be funded with available funds.

The DDF plays a key role in allowing NASA scientists to develop new ideas and in maintaining the vitality of Center science. The Team heard arguments that increasing the availability of such funds for support of scientific initiatives and for improvement or creation of facilities would strengthen the NASA science program and make it more responsive to scientific opportunity. Such funds are often valuable in preparing young scientists to compete for support in a peer review system. In view of its clear success, the Team recommends that the DDF be continued, and that a modest increase in the fund would be cost-effective at all Centers. Creation of a special fund to support Center and university groups working on joint research proposals would stimulate Center-university collaboration.

Funding flexibility is also available to Center Directors from other sources. The RTOP process includes reprogramming authority, which allows flexibility in the larger RTOPs. However, this authority is of little use with numerous small, overly detailed task specifications. It is much easier to provide some discretion in technology RTOPs, where one Center might have only a few very large ones with broad mandates, rather than with the typical science RTOP. While this may provide an additional argument for the aggregation of science RTOPs to an appropriately large size, in no case does the Team recommend that such authority be used to replace or distort the work funded through peer reviewed RTOPs and research proposals.

JPL presents a special case, since it is not a government laboratory. JPL operates in a fully soft-money mode with all activities being directly charged to contracts. Consequently it has much less discretion than the other NASA Centers in terms of all resources available (including, for example, manpower) to tackle new opportunities. We recommend that NASA consider carefully new mechanisms to provide JPL with more discretion in the use of its funds so that it can compete equally with the other Centers. Aggregation of science RTOPs should be considered.

In terms of overall level of flexibility, a long-term goal of a reasonable percentage of the available research and development funds (including the value of the salary support for individuals engaged in such efforts) should be set to permit necessary flexibility in initiating new work. A level of about 10% of the available Research and Program Management (R&PM) and research and development funds would be desirable and consistent with the recommendations of recent reports on research at national laboratories.

Findings and Recommendations:

1. In view of its clear success, the Team recommends that the DDF be continued, and that a modest increase would be cost effective at all Centers. Creation of a special fund to support Center and university groups working on joint research proposals would stimulate Center-university collaboration.
2. NASA should consider aggregating science RTOPS to an appropriately large size, as has already been achieved for engineering research programs, to augment reprogramming authority, but in no case does the Team recommend that such authority be used to replace or distort the work funded through peer-reviewed RTOPs and research proposals.

3. We recommend that NASA carefully consider mechanisms to provide JPL with some additional flexibility in the use of its funds so that its effective level of discretionary authority is comparable to the authority which actually exists at the other Centers.
4. In terms of overall level of flexibility, a long-term goal should be to have total flexibility of about 10% of the available research and development funds, and R&PM funds. This level of flexibility should be understood to be the aggregate value of the DDF, the salary value of manpower working in such discretionary activities and the RTOP re-programming authority.

6. Facilities

The Team did not assess NASA Facilities in general. However, the Team believes that computing facilities are broadly needed across all disciplines in NASA and discussed issues relating to computing at some length.

6.1. Supercomputing Facilities and Networks

The Team heard of recent installations of new supercomputers at ARC, LeRC, and MSFC, plans for new supercomputers at GSFC, and discussions of plans at LaRC and JSC. JPL remains the only major NASA Center without a supercomputing facility. Many of the users of these machines will be involved in tape-intensive efforts that require close interactions in some and the high cost of cross-country lines in others. For some extensive modelling efforts, many users can, however, operate effectively at sites that are remote from the supercomputers. For the most part, distance does not effect the efficacy of a user's interaction with the machine. As a consequence, for large-scale computing, i.e., supercomputing, networks are a key ingredient.

The potential economies of networking are considerable. The Los Alamos National Laboratory is able to add the latest Cray machine to its central computing facility with essentially no additions to the staff of the facility. In comparison, the manpower required to support a single supercomputer at a facility without existing capabilities can cost several millions of dollars a year.

The foregoing arguments concerning cost effectiveness apply as well to a host of other items of hardware, software, and personnel associated with a supercomputer Center. Moreover, a Center on the scale of those at Los Alamos and Livermore becomes a magnet for the best people and the latest capabilities in large-scale computing, and it has the added advantage that upgrades can be implemented without interrupting service to the user community. NASA should consider these examples carefully as it expands its computer capability.

The Team recommends that NASA study and evaluate the use of distributed computer facilities and data centers. This will allow the Agency to continue to take advantage of modern communications capabilities in order to realize economies of scale in large computing facilities. The NASA contributions to networking, such as the Space Physics Analysis Network (SPAN), etc., have been considerable. The federally funded network facilities, in which the nation is investing hundreds of millions of dollars and which includes NASA's Program Support Computer Network (PSCN), is badly in need of a master plan. NASA could play a national role here.

6.2. Other Center Computing Capability and Issues

The research scientists at the Centers are doing well in satisfying computer-related needs that fall within their ranges of options. Thus, for example, they are reasonably well equipped with desk-top computational capability and access to larger facilities, but this varies from Center to Center.

The Team notes that there needs to be a closer interaction between the researchers in their labs and offices and the computer and communications professionals in the groups responsible for the planning, installation, and operation of Center-wide computational facilities. These Center-wide groups need to take better advantage of the capabilities for networking and the development of transparent links from the desktop computers of the Center researchers to the rest of the world. Moreover, there are unused opportunities to connect with computing power outside the Centers and outside NASA. For example, the Team found little awareness of the eligibility of NASA scientists for free time at the NSF supercomputer Centers.

These groups also need to ensure that NASA sponsored researchers at other institutions have access to the facilities and data bases at the Centers and to the desktops of their colleagues at the Centers. It would be useful to carry out a survey of the existing computational facilities across the agency. We are not aware of any such survey to date, and with the rapid development of this technology, such information would contribute significantly to strategic planning.

6.3. Data Centers

NASA has been one of the leaders in data centers, and the National Space Science Data Center provides an example for other agencies to use. The Team heard plans concerning a Southeast data center for astrophysics at MSFC and one for atmospheric sciences at LaRC. Although there is no question that such disciplinary data centers are useful, the question of size and location is one that can be debated. The user services required by a service function of this kind can present a significant cost and require excessive time-commitments from researchers at the home centers. Thus, economies of scale are to be sought here as well, and data centers as nodes on distributed data systems should be used as much as possible.

Accordingly, the Team recommends careful reviews of these proposals to make certain that these data centers will be implemented in the most cost-effective way. The reviews should consider consolidation of these functions, or at least the user-service functions, at a user-oriented facility (the NSSDC, for example) and wide use of distributed data systems.

Findings and Recommendations

1. The Team recommends that NASA study and take note of other successful national laboratory use of computing as it expands its own.
2. The Team recommends that NASA study and plan for use of distributed computer facilities and data centers. This will allow the Agency to continue to take advantage of modern communications capabilities in order to realize economies of scale in large computing facilities. The federally funded network facilities, in which the nation is investing hundreds of millions of dollars and which includes NASA's PSCN, is badly in need of a master plan. NASA could play a national role here.
3. Centers need to provide information about on-line facilities and services, and they should take advantage of new capabilities for networking and linking inside NASA and to the outside world. A survey of computational facilities across the agency would be useful for strategic planning.
4. Center computer management groups need to ensure that NASA sponsored researchers at other institutions have access to the facilities and data bases at the Centers and to the desktop computers of their colleagues at the Centers.
5. Careful reviews of proposals for new data centers must be undertaken to ensure that these data centers will be implemented in the most cost-effective way. The reviews should consider consolidation of these functions, or at least the user-service functions, at a user-oriented facility (the NSSDC, for example) and wide use of distributed data systems.

CHAPTER IX

ENSURING VITALITY FOR THE LONG-TERM FUTURE

1. Introduction

The science accomplished within NASA Centers and the science supported by NASA has been of very high quality. Now we ask: What will NASA have to do to ensure that in the decades to come there will be an adequate internal capability to carry out NASA science? Maintaining the vitality, morale, and excellence of the science groups depends on a host of factors, ranging from flight opportunities to success in recruiting bright young scientists. The various issues discussed in this report will all contribute to maintaining a successful science program. Beyond these considerations, however, there remain the overarching issues of establishing long-term goals for NASA and of NASA's ability to maintain its scientific leadership.

2. Planning and Coordination

A fundamental issue for NASA is the lack of clearly articulated, stable long-term goals and priorities. This is a problem to varying degree in all of the disciplines, but it is seen most clearly in life sciences, where goals and priorities change rapidly relative to the time necessary to carry out a coherent research program, or even a well-developed project. This is especially true given the long hiatus between space flight opportunities. As a result, Centers attempt to cover too many bases in order to respond to funding exigencies caused by shifting priorities and to stabilize the work environment for the scientists.

Strategic planning is the key to providing stable long-range goals and priorities and eventual success in science. Given the increasing costs and long planning and implementation periods for new missions, it is clear that each Center must have a strategic plan in place. This process is now occurring at different rates in different Centers. For example, the Team was impressed with the quality and extent of strategic planning at LeRC, whereas the process at GSFC had just begun. It is clear that the process will be different at each Center, but the important point is that such planning be pursued.

Moreover, Centers are realizing that they must collaborate and not compete for turf. There is some beneficial interaction between Centers on particular projects; this interaction should be strengthened and expanded so that all the Centers interact. On a NASA-wide scale, clear agency goals and planning can provide an effective context for stronger Center collaboration. Strategic planning will help decide specific Center roles and missions, and avoid duplication of effort. In the view of the Team, NASA long-range planning would be strengthened by including the Center Directors as full partners.

Findings and Recommendations

Since strategic planning is one of the keys to success, NASA must encourage Center planning efforts and integrate them into an agency-wide plan that takes full account of the requisite interactions between science, engineering, and technology. NASA should use the Center Directors, as a group, more effectively in fashioning its strategic plans.

3. Retaining Leadership in NASA Science

The Team notes that successful science requires leadership. The NASA centers must be prepared to go to exceptional lengths in order to retain their finest scientists and, if they leave, to replace them in a timely way with scientists of equally high stature. The leadership class of scientist is essential if research programs of the highest quality are to be built and maintained. This class is characterized by such individual recognition as membership in the National Academy of Sciences or receipt of major prizes. Many examples of the positive effects of such leadership exist; the successes in many research areas are due to persons of the highest scientific reputation. Replacing these senior, leading scientists when they leave is a great challenge, but one that must be accepted and met if NASA science is to remain vigorous and innovative.

The Team also notes the importance of the Chief Scientist and Chief Technologist positions in the Centers. This structure has worked well, particularly at JPL, and the Team recommends that all Centers consider such an arrangement.

Findings and Recommendations

1. A strong science program requires strong science leadership. Maintenance of science leadership is a major challenge facing NASA that requires constant attention. Implementation of the recommendations in this report will help solve this problem.
2. The Team recommends that all Centers consider establishing Chief Scientist and Chief Technologist positions.

4. Future Reviews

The Team found that its assessment was valuable for the scientists, engineers, and managers who participated and for the Team itself. As noted earlier, the review process can be an important and constructive element in ensuring and sustaining quality. The Team sees considerable merit in a continuing process of cross-cutting reviews for all centers. At the same time, the Team notes that the review process can be time-consuming and even counterproductive if not adequately coordinated; there can be too many reviews over a given period.

Options for future reviews include the use of a multidisciplinary team, similar to the current Team, or teams that are structured to review one or more disciplines in depth at all Centers. The Team suggests the latter option with timing arranged so that all disciplines in NASA are reviewed regularly on a four to five year cycle. Such reviews would assess in depth the overall NASA Center effort in the discipline, the distribution of activity across Centers, and the contributions of in-house discipline programs to NASA goals. Membership on the teams should include both NASA and non-NASA members.

The Team also recommends that each Center consider reviews of its science by a Center Visiting Committee, including non-NASA members, that reports directly to the Center Director. Such Committees should be standing, rather than ad hoc, to provide continuity and should operate on a four to five year cycle.

5. Summary

The NASA science program has been and can continue to be a highly productive national resource, and the Agency nurture both its basic and applied aspects. Access to space is essential to maintain the strength and momentum of the program. NASA scientists and engineers working on the science programs in the NASA Centers are also central to NASA's success. To ensure that the talent NASA requires will be available in the Agency, continued attention must be devoted to innovative ways of providing career flexibility, to stimulating and rewarding creativity, and to providing for a close interaction with the broader scientific community.

The Team has made many recommendations directed to both Centers and Headquarters in support of the NASA science enterprise. In the final analysis, the quality of NASA's science program will depend on the quality of scientific talent within the agency. Steps must be taken to sustain a science environment in which the necessary talent can be attracted and nurtured. Implementation of the recommendations in this report will not have major budgetary impact and will ensure the continued health and vitality of a national science enterprise that has served the nation well.

APPENDIX 1

TEAM OPERATIONS

The Charge to the Team:

The Purpose of the review was to establish a broad overview of the content and scope of the in-house space science research efforts at each Center. The specific charge to the Team was to review the following:

1. The scope and content of in-house space science research activities at each center;
2. The relationships between the Center space science research programs and science-related advanced technology programs;
3. The relationships between Center space science research organizations and their University research counterparts;
4. The relationships between the in-house space science research capabilities and the flight project management responsibilities at each Center; and
5. The nature and extent of participation by Center scientists in the management and planning of Agency programs.

Based on these reviews, the Team was to identify the principal strengths of the in-house space science research efforts at each Center and areas, if any, that require additional support or attention in order to meet Agency space science research program needs.

Upon completion of the Center reviews and complementary discussions with appropriate Headquarters program officials, the Team was to develop recommendations to the Administrator in the following areas:

1. Principal long-term capabilities in space science research programs for each center;
2. Center actions, if any, that may be appropriate to enhance Center-University relationships;
3. Actions, if any, that may be appropriate to enhance the complementarity of space science and advanced science-related technology activities at the Center; and
4. Other action, as appropriate, to enhance the quality of Center space science research programs and their contribution to fulfilling Agency objectives.

Composition:

The Center Science Assessment Team was composed of representatives of NASA Headquarters, the major space science centers, and the outside research community. It was chaired by Dr. D. James Baker, President of Joint Oceanographic Institutions Incorporated. The non-NASA membership includes scientists who have broad familiarity with the disciplines of astronomy and astrophysics, planetary exploration, solar-terrestrial physics, earth sciences, life sciences, microgravity physics and chemistry, and space technology. NASA members of the Team included one representative each from the Headquarters offices of the Chief Scientist, Space Sciences and Applications, and the Aeronautics and Space Technology, and from ARC, GFSC, JPL, JSC, LeRC, and MSFC. NASA members were selected by their respective Headquarters office Associate Administrators or Center Directors; outside members were selected by the office of the Chief Scientist in consultation with the program offices. Appendix 2 lists the Team members and affiliations.

Operating Procedure:

Preliminary work to establish the review began in December 1986 with the identification of review organization and focus and the appointment of Team members. An organizational meeting took place on January 16 at NASA Headquarters, and the Team established the general guidelines for the review. The Agenda for this meeting is included in Appendix 3.

The Team agreed to proceed as follows:

1. To visit all centers with major science programs to receive briefings and to conduct interviews with scientific and managerial staff.
2. To arrange for informative material to be received prior to each site visit. This would include the responses to specific questions formulated by the Team on Center organization and management objectives and on the quality and success of strategic planning.

The schedule of site visits and detailed agendas are listed in Appendix 3, and the written questions for the field centers are included in Appendix 4. In every case, the Team received excellent, highly informative briefings and materials, as well as enthusiastic, well-organized programs. In particular, the Team found the informal, round-table discussions with separate groups of scientists and managers to be a very useful and essential complement to the more structured briefings.

APPENDIX 2

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APPENDIX 3

SCHEDULE AND AGENDAS OF SITE VISITS

NASA CENTERS	DATES VISITED
Ames Research Center Moffet Field, CA	March 30 and 31
Dryden Flight Research Facility Edwards, CA	
Goddard Space Flight Center Greenbelt, MD	June 2, 3, and 4
Jet Propulsion Laboratory Pasadena, CA	April 1, 2, and 3
Johnson Space Center Houston, TX	May 20, 21, and 22
Kennedy Space Center* KSC, FL	June 23
Langley Research Center Hampton, VA	March 18 and 19
Lewis Research Center Cleveland, OH	May 12 and 13
Marshall Space Flight Center Huntsville, AL	April 15 and 16
Michoud Assembly Facility New Orleans, LA	
National Space Technology Laboratories* Bay Saint Louis, MI	June 23
Wallops Flight Facility Wallops Island, VA	

* KSC and NSTL presented their programs to the Team on June 23, 1987, at NASA Headquarters

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
NASA HEADQUARTERS
January 16, 1987

9:00-10:00 OPENING REMARKS

F. McDonald
D. Myers
D.J. Baker

10:00-12:00 PROGRAM OFFICE OVERVIEW

Science Project Management Responsibilities at the Centers
S.W. Keller
Experiment Selection and RTOP Review Process
J.D. Rosendhal
Overview of Advanced Technology Programs
L.A. Harris

LUNCH

1:00-4:00 GROUP DISCUSSION AND PLANNING

4:00-4:30 SUMMARY

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
LANGLEY RESEARCH CENTER
March 19-20, 1987

March 19, 1987

8:00-8:30 COMMITTEE SESSION

8:30-9:30 CENTER DIRECTOR'S WELCOME, CENTER OVERVIEW, AND SUMMARY
QUESTIONS
RESPONSES

9:30-12:30 ATMOSPHERIC SCIENCE PROGRAM

Overview

D. Lawrence

Atmospheric Models

B. Grose

Satellite Observations of Atmospheric Gases

J. Russell

Observations of Stratospheric Aerosols and Ozone

P. McCormick

Differential Lidar Observations of the Atmosphere

E. Browell

Atmospheric Chemistry

R. Harriss

LUNCH

1:15-1:45 ATMOSPHERIC SCIENCE PROGRAM (cont.)

Radiation and Clouds

B. Barkstrom

2:00-3:30 ATMOSPHERIC SCIENCE RELATED SENSORS AND INSTRUMENTS

3:40-5:00 LARGE SPACE STRUCTURES TECHNOLOGY

Precision Segmented Reflectors

Assembly Concepts

Robotics Assembly

Control of Flexible Structures

8:00-10:00 COMMITTEE SESSION

March 20, 1987

8:00-8:30 COMMITTEE SESSION

8:30-10:30 TOURS/DISCUSSIONS

10:45-12:00 COMMITTEE SESSION

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
AMES RESEARCH CENTER
March 30-31, 1987

March 30, 1987

8:15-8:30 LOGISTICS, AGENDA

A.B. Chambers

8:30-9:00 ROLE OF SPACE SCIENCE AT AMES

W.F. Ballhaus, Jr.

9:15-10:15 OVERVIEW OF SPACE SCIENCE AT AMES

A.B. Chambers

11:00-11:45 PHYSICAL SCIENCES OVERVIEW

L. Colin

LUNCH

1:00-2:00 FACILITY TOURS

2:00-4:45 KEY SCIENTIST PRESENTATIONS - SPACE SCIENCE DIVISION

Theoretical Modeling of the Interstellar Medium

D. Hollenbach

New Observational IR Astronomy Results

E. Erickson

Is There a Continuum Between Rings and Moons

J. Cuzzi

Radiative Transfer Studies in Earth's Atmosphere

F. Valero

The Antarctic Ozone Hole

B. Toon

March 31, 1987

8:00-9:00 LIFE SCIENCES OVERVIEW

J. Billingham

9:00-11:15 KEY SCIENTIST PRESENTATIONS

Carbon and the Ancient Biosphere

D. Desmarais

Remote Sensing and Biogeochemical Cycling

D. Peterson

Perceptual and Neuromuscular Recalibration
to Altered Gravity

E. Morey-Holton

11:15-11:30 SPACE HUMAN FACTORS RESEARCH

D. Nagel

11:45-12:15 KEY SCIENTIST PRESENTATION

Crew Factors Research

C. Foushee

LUNCH

12:15-12:35 MISSION-RELATED SPACE TECHNOLOGY
V. Petterson

12:50-1:00 UNIQUE FACILITIES
M. Knutson

1:15-3:00 COMMITTEE/SCIENTIST ROUNDTABLE

3:15-5:00 COMMITTEE/MANAGER ROUNDTABLE

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
JET PROPULSION LABORATORY
April 1-3, 1987

April 1, 1987

8:30-9:00 WELCOME

M. Goldberger
Review of Agenda
J. Baker
M. Chahine

9:00-9:45 THE INSTITUTIONAL VIEW
C. Gates

10:00-10:30 SCIENCE: ROLE AND SCOPE
M. Chahine

10:30-11:00 CAREER OPPORTUNITIES FOR JPL SCIENTISTS
C. Elachi

11:00-11:45 ROLE AND RESPONSIBILITY OF JPL
D. Rea
RESEARCH AND ANALYSIS PROGRAM
D. Nash/(J. King)

11:45-12:00 CURRENT PROGRAM/STATUS
Mars Observer
A. Albee/(W. Purdy)

LUNCH

1:00-3:00 CURRENT PROGRAM/STATUS (cont.)
Voyager Neptune
E. Stone/(N. Haynes)
Galileo
T. Johnson/(J. Casani)
Magellan
S. Saunders/(J. Gerpheide)
Ulysses
E. Smith/(W. Meeks)
MARINER TEMPEL 2 (CRAF)
M. Neugebauer/(R. Draper)
FUTURE PROGRAMS
Cassini
W. Huntress/(J. Beckman)
Mars Sample Return
D. Pieri/(R. Bourke)
DETECTION OF EXTRASOLAR PLANETARY SYSTEMS
R. Terrile

3:30-5:00 PANEL: CAREER CHALLENGES FOR PROJECT SCIENTISTS

A. Albee, W. Huntress, T. Johnson, M. Neugebauer,
S. Saunders, E. Smith, (M. Chahine)

6:00 WORKING DINNER

April 2, 1987

8:00-10:00 EARTH SYSTEM SCIENCE OVERVIEW

C. Elachi
MLS/Ozone Sensing
J. Waters
Laboratory Studies
M. Sander
Ocean Surface Winds/NSCAT
M. Freilich
Ocean Currents/TOPEX
L. Fu
West Coast Series
M. Abbott
Acid Rain
B. Rock
Red Sea Rift
T. Dixon
San Andreas Movement
M. Golombek
Geodynamics
J. Dickey

10:30-11:30 ASTROPHYSICS

C. Elachi
IRAS/IPAC
G. Squibb
Submillimeter
S. Gulkis
Gamma Ray
A. Jacobson
Solar
E. Smith

11:30-12:00 SCIENCE AND THE DEEP SPACE NETWORK

N. Renzetti
Radio Science
R. Preston
Gravitational Wave Detection
J. Anderson

LUNCH

1:00-1:30 MICROGRAVITY SCIENCE

T. Wang

1:30-3:00 PANEL: INTERACTION OF SCIENCE AND TECHNOLOGY

C. Gates
Flight Instruments
H. Press
Sensors
J. Cutts
Large Deployable Reflectors (LDR)
P. Swanson
Radar
D. Held
Advanced Microelectronics Program
T. Cole
NASA Technology
W. Weber
Defense Program Technology
R. Mackin

3:30-5:00 PANEL: VIEWS OF JPL SCIENTISTS

M. Chahine
Atmospheric Radiation Transfer
D. Diner
Radar Science/Geology
C. Elachi
Atmospheric Physics/IR Spectroscopy
C.B. Farmer
Ocean Wind and Waves
M. Freilich
Planetary Radio Astronomy
S. Gulkis
IR Remote Sensing
D. McCleese
Microgravity Science
T. Wang
Atmospheric Microwave Remote Sensing
J. Waters
Atmospheric Laser Spectroscopy
C. Webster

April 3, 1987

8:00-9:30 ROUNDTABLE DISCUSSION WITH TECHNICAL DIVISION MANAGERS

C. Gates

Systems Division

J. Jordan

Earth and Space Sciences Division

C. Elachi

Telecommunications Sciences and Engineering Division

R. Mathison

Electronics and Control Division

R. Stephenson

Mechanical and Chemical Systems Division

L. Dumas

Information Systems Division

T. Thornton

Institutional Computing and Mission Operations Division

E. Davis

Observational Systems Division

K. Casani

9:30-10:30 DISCUSSION WITH DR. LEW ALLEN

11:00 OPEN/COMMITTEE BUSINESS

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
MARSHALL SPACE FLIGHT CENTER
April 15-16, 1987

April 15, 1987

8:00-8:30 COMMITTEE SESSION

D.J. Baker

8:30-9:00 WELCOME AND CENTER OVERVIEW

J.R. Thompson

9:00-9:50 SCIENCE AND TECHNOLOGY OVERVIEW

Odom
Tandberg-Hanssen
McDonough

9:50-10:10 SCIENCE SUPPORT TO CENTER PLANNING

Gierow

10:30-11:15 EARTH SCIENCE AND APPLICATIONS

Fichtl

11:15-12:00 SOLAR-TERRESTRIAL PHYSICS

Chappell

1:15-2:15 TOUR/SOLAR TERRESTRIAL PHYSICS AND EARTH SCIENCE AND APPLICATIONS

Chappell, Fichtl

2:15-3:00 ASTROPHYSICS

Decher

3:00-3:45 LOW-GRAVITY SCIENCE

Naumann

3:45-4:45 TOUR/ASTROPHYSICS AND LOW-GRAVITY SCIENCE

Decher
Naumann

4:45-5:45 KEY SCIENTISTS PRESENTATIONS

SOLAR-TERRESTRIAL PHYSICS DIVISION

Plasma Outflow and Energization in the Magnetosphere

H. Waite

Measurements of Stratospheric Hydroxyl by High-Resolution Spectroscopy

M. Torr

Evolving Solar Magnetic Fields

R. Moore

April 16, 1987

8:30-8:50 SCIENCE SUPPORT TO PROJECTS

Downey

8:50-11:50 KEY SCIENTISTS PRESENTATIONS

EARTH SCIENCE AND APPLICATIONS DIVISION

Atmospheric Moisture and Dynamics

P. Robertson

Cooperative Huntsville Meteorological Experiment

J. Arnold

Geophysical Fluid Flow Cell

F. Leslie

ASTROPHYSICS DIVISION

Time Variability of Galactic X-ray Sources

R. Elsner

Gamma Ray Bursts

G. Fishman

Science with the MSFC Mid-IR Array

C. Telesco

LOW-GRAVITY SCIENCE DIVISION

Drop Tube Experiments

M. Robinson

Aircraft Study of Low-G Alloy Solidification

P. Curreri

Protein Crystal Growth

D. Carter

LUNCH

1:00-2:00 SCIENCE PANEL DISCUSSION

Baker, Arnold, Frazier, Leslie, Szofran, Telesco,

Torr, Waite, Weisskopf

2:15-3:45 MANAGEMENT PANEL DISCUSSION

Baker, Lee, Odom, Downey, Geirow, Snoddy, Tandberg-

Hanssen, McDonough, Fichtl, Naumann, Chappell, Decher

3:45-4:00 COMMITTEE SESSION

Baker

4:00-4:15 CLOSEOUT WITH CENTER DIRECTOR

Thompson

Baker

4:15-5:00 FINAL COMMITTEE SESSION

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
LEWIS RESEARCH CENTER
May 13, 1987

8:00-8:30 COMMITTEE SESSION

D.J. Baker

8:30-9:45 OVERVIEW OF THE LEWIS RESEARCH CENTER

J.M. Klineberg
Office of the Chief Scientist
M.E. Goldstein
Office of University Affairs
F.J. Montegani

10:00-12:15 OVERVIEW OF SPACE RESEARCH AND TECHNOLOGY

J.S. Fordyce
Integration of Microwave and Optical Functions in Space
Communication Systems
K.B. Bhasin
Space System - Plasma Interactions
C.K. Purvis
Electrothermal Propulsion Research
F.M. Curran
Microgravity Science and In-Space Technology Program Review
W.J. Masica
Microgravity Materials Science
H.R. Gray
Microgravity and Combustion Science and Fluid Physics
J.A. Salzman

LUNCH

1:00-1:45 TOUR

1:45-2:45 OVERVIEW OF SPACE RESEARCH AND TECHNOLOGY (cont.)

Binary Alloy Solidification: Ground-Based Experiments
V. Laxmanan
Simulation of Fluid Flows During Growth of Organic Crystals
in Microgravity
G.D. Roberts
Ignition and Flame Spread Involving Liquid Fuel Pools
H.D. Ross
Flame Spread Over Solid Fuels: Effects of Gravity, Oxygen
Concentration, and Fuel Bed Thickness
S.L. Olson
Statistical Mechanical Understanding of the No-Slip
Boundary Condition
R.A. Wilkinson

2:45-3:45 PANEL DISCUSSION WITH SCIENTISTS

3:45-4:45 PANEL DISCUSSION WITH MANAGEMENT

4:45-5:00 CLOSE OUT WITH CENTER ACTING DIRECTOR

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
JOHNSON SPACE CENTER
May 19-22, 1987

May 20, 1987

8:00-8:30 COMMITTEE MEETING

8:30-9:00 WELCOME AND OVERVIEW

A. Cohen
P. Weitz

9:00-9:30 SPACE AND LIFE SCIENCES OVERVIEW

C.L. Huntoon

9:30-10:45 MEDICAL SCIENCES

S.L. Pool
J. Charles
M. Reschke
N. Cintron

10:45-11:30 MAN-SYSTEMS

C. Perner
B. Woolford
M. Rudisill

LUNCH

12:30-1:45 SOLAR SYSTEM EXPLORATION

M. Duke
D. McKay
C. Meyer
J. Gooding

1:45-2:30 ADVANCED PROGRAMS

W. Mendell

2:30-3:30 SCIENTIST ROUNDTABLE

3:30-4:30 MANAGEMENT ROUNDTABLE

4:30-5:30 MISSION SPECIALISTS ROUNDTABLE

5:30-6:00 CENTER DIRECTOR WRAP-UP

A. Cohen
P. Weitz

8:15 COMMITTEE DISCUSSION

May 21, 1987

8:00-8:15 COMMITTEE MEETING

8:15-10:00 TOURS

10:00-12:00 COMMITTEE WORKING SESSION

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
GODDARD SPACE FLIGHT CENTER
June 2-4, 1987

June 2, 1987

8:00-9:30 INTRODUCTIONS AND OVERVIEW OF GSFC

J. Bakar
N. Hinners

9:30-10:15 SPACE AND EARTH SCIENCES DIRECTORATE

J. Trainor

10:30-10:45 UNIVERSITY, DDF AND RELATED SUBJECTS

J. Soffen

10:45-12:15 EARTH SCIENCE DIVISION CHIEFS

M. Geller
V. Salomonson
J. Hansen
E. Mollo-Christensen

LUNCH

1:15-2:00 TOUR OF NSSDC

J. Green

2:00-2:45 EARTH SCIENCE PRESENTATIONS

J. Garvin
C. Parkinson
M. Schoeberl

3:00-3:45 EARTH SCIENCE PRESENTATIONS

M. Prather
L. Uccellini
C. Koblinski

3:45-5:00 PANEL DISCUSSION, EARTH SCIENCES

5:00-6:00 TOUR, IMAGE PROCESSING AND MPP, B28

B. Price

June 3, 1987

8:00-9:30 SPACE SCIENCE AND DATA DIVISION CHIEFS

S. Holt
T. Gull
J. Hillman
M. Halem

9:30-10:15 SPACE SCIENCE PRESENTATIONS

R. Ramaty
C. Bennett
F. Marshall

AGENDA
NASA CENTER SCIENCE ASSESSMENT TEAM
NASA HEADQUARTERS
June 23-24, 1987

June 23, 1987

8:00-8:30 COMMITTEE MEETING

8:30-10:30 KSC PRESENTATIONS

Overview
Operations Technology
Biomedical Research Program
Controlled ENV Life Support System
J. Spears
W. Knott
A. Koller
J. Aliberti

10:30-12:30 NSTL PRESENTATIONS

NSTL Earth Resources Lab. Activities
C.A. Whitehurst
A. Joyce

LUNCH

1:30-5:00 COMMITTEE DISCUSSIONS

June 24, 1987

8:00-8:30 COMMITTEE MEETING

8:30-10:00 DISCUSSIONS WITH AA'S FOR OSSA AND OAST

10:00-12:00 DISCUSSION WITH OSSA DIVISION DIRECTORS

LUNCH

1:00-2:30 COMMITTEE DISCUSSIONS

2:30-3:30 DISCUSSION WITH R. PETERSON, DIRECTOR LARC

3:30-6:00 COMMITTEE DISCUSSIONS

APPENDIX 4

WRITTEN QUESTIONS FOR FIELD CENTERS

As part of its activity, the Field Center Assessment Team will visit each Center and conduct reviews of the Center science and science-related activities. The reviews will be most efficiently carried out if the Centers prepare information in response to a set of questions that the Team has developed. The questions fall into three categories:

- Center Organization and Management
- Goals, Objectives, and Measures of Quality and Success
- Strategic Planning: Opportunities and Impediments

The set of questions developed is not unique, and is not necessarily comprehensive. The Center should feel free to provide material in a different format if it would be more illuminating, provided that the same issues are addressed, to add material, or to suggest other questions that would be helpful.

A final question in each category: What didn't we ask that we should have?

A. Center Organization and Management

Note: As part of this section, the Team requests a short CV and bibliography for each scientist at the Center and annual reports that summarize the work carried out at the Center.

- 1. What are the Center's principal space science related interests and areas of emphasis and specialization?
- 2. What are the Center's principal science-related advanced technology interests and areas of emphasis?
- 3. How is the Center's space science research group organized, and where does it fit in the organization compared to the Center's project management and advanced technology activities? How does the Center activity fit in the overall NASA structure?
- 4. To what extent are there joint efforts between the Center's space science organization and its advanced technology activities through shared RTOPs or other forms of collaboration in technology development?
- 5. What is the size of the civil service workforce in the Center's space science organization? How many of these are PhD level professionals?
- 6. How many and what level of on-site contractors support the in-house space science organization, and what are the principal contractor roles?
- 7. How many NRC RRAs, visiting faculty members, graduate students, or other similar professional collaborators are typically on-site in the Center's space science organization?

- 8. In what space science and flight projects does the Center have PIs and Co-Is?
- * 9. For what space science projects does the Center provide Project Scientists, Study Scientists, or similar science program management personnel? About what fraction of scientists' time is spent on these activities?
- * 10. To what extent and in what program areas do the Center science and advanced technology organizations support the Headquarters program offices in managing or administering the RTOP programs for outside grantees? What are your pass-through funds? How often have detailees from the Center been assigned to OSSA or OSTA?
- 11. What unique or special facilities, both computational and non-computational, are available for the Center's space scientists (either under their direct control or through other Center organizations)? Are these also used or available for use by outside scientists? What is the usage pattern? How is access decided?
- 12. To what extent do the Center's science and advanced technology organizations provide special support to the broader research community (e.g., through operation of observational facilities, computers, data management)?
- 13. How is awarding of discretionary funds handled within the Center?
- 14. How does the space science that is carried out at the Center complement space science at other Centers, Universities, and industry?

B. Goals, Objectives, and Measures of Quality and Success

- 1. What does the Center's space science organization consider as its overall goals and objectives and principal mission?
- 2. What is the Center's view of the role of science in the Center? What is the Center's view of the proper balance between individual basic research and NASA projects? What criteria does the Center use to decide what areas to go into in science?
- 3. Do recommendations from various NASA committees (e.g., SESAC and SAAC) and NRC (e.g., SSB and SAB) impact Center activities and in what ways?
- 4. Is science-driven technology being faced with a view towards involving the outside community (University, industry, international partners)? How do you decide what technology should be developed?
- 5. What are your principal strengths? How do you measure quality in your organization? How do you compare yourself to other organizations?
- 6. How do you get new blood in the system? How do you provide upward mobility for young scientists in your organization? How successful have you been in these areas? How do you achieve good morale? What are the awards and recognition?

- * 7. To what extent do Center space scientists serve as advisory committee members, journal editors, officers in scientific and technical professional organizations, etc?
- 8. What have been your biggest successes? The riskiest ventures you have undertaken? The most innovative projects? What hasn't worked? Why?
- 9. How is innovative, science-driven technology being developed?

C. Strategic Planning: Opportunities and Impediments

- 1. How do you do strategic planning? How is it linked to Headquarters and outside? How do the Center science and advanced technology organizations participate in Center and Agency strategic planning? (Three levels here: at the individual groups in the Center, at the Center overall, and in OSSA and OAST.)
 - 2. How do you decide the right size of organization within the Center? The right mix of projects?
 - 3. What would you like to be doing that you are not doing now?
 - 4. What are the major resource constraints? What future initiatives can't you pursue because of these?
 - 5. Are there also significant managerial and administrative obstacles, or other impediments to success?
- * Information requested prior to the site visit