NASA's Office of Space Science and Applications: Process, Priorities and Goals

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Process, Priorities, and Goals

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BACKGROUND PAPER

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Workshop on NASA's Office of Space Science and Applications: Process, Priorities and Goals

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NOTE: OTA appreciates the valuable assistance and thoughtful critiques provided by the workshop participants. The views expressed in this OTA background paper, however, are the sde responsibility of the Office of Technology Assessment. Participation in theworkshop does not imply endorsement of the background paper.

NASA's Office of Space Science and Applications: Process, Priorities and Goals

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INTRODUCTION

This Background Paper summarizes a one-day workshop convened to assess the effectiveness of the planning and priority-setting mechanisms used by NASA's Office of Space Science and Applications (OSSA) in carrying out its diverse scientific program. The workshop was requested by the House Committee on Science, Space, and Technology, and was structured to provide input to a study by the Committee's Task Force on the Health of U.S. Research. This examination of the NASA Space Science and Applications program is one of several case studies by the task force.[1]

Workshop participants included a representative group of practicing scientists, research administrators, and policy analysts who discussed how OSSA sets its goals, plans its programs, and evaluates progress toward achieving goals and objectives. They also discussed how OSSA responds to changes in the external environment that require modification to its ongoing programs and to its long-term strategic planning. In addition, the workshop deliberations provided insight into current issues of OSSA program management and of the difficulties facing NASA as it adjusts to an era of fiscal stringency following a significant five-year expansion of the OSSA budget.

In preparation for the workshop, OTA developed a detailed set of issues pertaining to OSSA's planning, priority-setting, and performance assessment procedures for purposes of focusing the workshop discussions. The issues were drafted to meet the general needs of the broader House Task Force study while reflecting the specific characteristics of OSSA's scientific program. These issues were discussed by telephone with all of the invited participants and modified to reflect suggestions for clarifications and additional topics

1 The Task Force is also examining, among others, fusion and mathematics research.

(App. A). The agenda for the workshop followed the broad groupings of the issues list.

Prior to the workshop, OTA invited each participant to write a short (3 -5 pages) response to selected issues. This brief summary of the workshop proceedings incorporates material from the discussions at the workshop, from the participants' issues papers, and from the background materials provided to OTA by the Office of Space Science and Applications. OTA has sought to make this summary useful for those who may not have detailed specialized knowledge of the programs, plans and organization of NASA's Office of Space Science and Applications. OTA prepared an initial draft of this paper, which was then sent to workshop participants and other knowledgeable individuals for review.

FINDINGS

Finding 1: The OSSA strategic planning process has proved effective in garnering improved funding for space science projects because it has successfully involved a broad cross section of the space science community in setting science priorities within the scientific disciplines. Yet, in its planning for future projects, OSSA often fails to be realistic about probable future budgets. OSSA also needs to find better mechanisms for containing cost and schedule growth after projects are underway.

OSSA committees, composed of discipline specialists, set scientific priorities for each discipline OSSA supports. OSSA has used the priority-setting process, in which proposed projects are closely scrutinized by teams of scientists, to build a strong constituency for its projects within the Administration and within Congress. As currently structured, the process is geared to steady increases in funding, but has difficulty responding to funding decreases. However, the Appropriations Committees' Conference Report for fiscal year 1992 limits NASA's 1993 funding allocations to increases of no more than 5 percent,[2] which is much less than the increases OSSA has recently experienced.[3] Hence, OSSA will have to adjust its planning and priority-setting processes accordingly.

OSSA could improve its priority-setting process by developing improved methods for establishing priorities across disciplinary boundaries. This will not be easy because it involves making judgments about the relative value of projects from widely different fields. A report from the Space Studies Board of the National Academy of Sciences on setting priorities in space research provides some guidance for such an effort.[4] OSSA may

2 "The conferees concur in the Senate language enumerating a series of principles designed to adjust NASA's expectations and strategic planning to leaner budget allocations in the coming years." Conference Report on the 1992 Appropriations for the Veteran's Administration, Housing and Urban Development, and Independent Agencies, House of Representatives Report 102-226 (to accompany H.R. 2519), Sept. 27, 1991, p.54. The Senate language directs that "the agency should assume no more than 5 percent actual growth in fiscal year 1993": Senate Report 102-107, July 11, 1991 (to accompany H.R. 2519), p. 130.

3 OSSA's budget has doubled in real terms since fiscal year 1982.

4 National Academy of Sciences Space Studies Board, Task Group on Priorities in Space Research, Phase 1, *Setting Priorities for Space Research: Opportunities and imperatives* (Washington, DC: National Academy Press, 1992).

have to develop mechanisms for canceling or drastically reprogramming projects that show signs of greatly overrunning their budgets, in order to maintain the scientific viability of other projects in its portfolio.

OSSA may also wish to examine the experience of industry in organizing strategic planning processes and in managing research and development assets. Although few industrial methods would be directly applicable to NASA's case, an examination of OSSA's processes by groups possessing expertise in "work process redesigns might prove beneficial in leading OSSA to new approaches for more effectively managing OSSA's considerable fiscal and intellectual assets.

Finding 2: The OSSA process could benefit from improved mechanisms to provide more systematic feedback to OSSA concerning the realism, flexibility, and success of previous plans.

Each strategic plan could formally include information regarding the key assumptions about resources available to OSSA and the amount of flexibility available if budgets do not meet expectations. However, improvements in OSSA's priority-setting process and in its management of the space science budget might still be undercut by instabilities caused by changes in the expected yearly NASA budgets, both within the Administration and within Congress.

Because the available budget is such a key factor in the successful conclusion of a project, Congress may wish to ask an independent institution to examine the historic impacts on OSSA's program of the annual fluctuations that result from changing congressional appropriations and from internal NASA rebudgeting. Such a study could also examine the consequences of launch delays, cost overruns, and under estimates for spacecraft systems development, and provide guidance for future OSSA planning.

5 **Methods used to analyze how a business practice is currently conducted, that also examine the charactistics of the customers for the output of the process, and determines which steps in the process add value or not.**

Finding 3: The lack of flight opportunities for science missions is a major impediment to maintaining high quality space science.

With the limited projected budget increases, more frequent access to space would require funding more smaller missions. The smaller missions could allow more frequent access to space for experimenters because they would not take as long as larger, more expensive missions to execute. They could also be much more effective in training graduate students because, among other things, they might allow a student to follow a project through from start to finish. Yet, in the yearly budget process, new starts for small missions tend to receive as close scrutiny as the large missions. Hence, NASA tends to expend nearly as much effort on them as on the larger ones. If Congress were to continue to encourage the proposal of smaller missions, NASA would find it easier to include a higher proportion of smaller missions in its mix of projects.[6]

Finding 4: Multidisciplinary projects, and those which serve both scientific and engineering goals, face especially difficult hurdles in the competition for funding within OSSA.

OSSA is responsible for microgravity research. It is also responsible for all of the research and medical applications to support human presence in space. Both areas of scientific research are multidisciplinary "laboratory sciences" and both depend upon, and provide information and other support for, the space shuttle and space station programs. Yet despite the fact that they serve both research and operational needs, these two disciplines have difficulty competing with more traditional disciplines such as astronomy and astrophysics, space physics, and planetary science. If NASA wishes to encourage these

6 **In directing that NASA submit a strategic plan to the Senate Commitee on Appropriations, the Committee directed that the plan "should emphasize a mix of small-, medium-, and large-sized missions": Senate Committee on Appropriations, Report 102-107 (to accompany H.R. 2519), July 11, 1991, p. 131.**

two multidisciplinary efforts, it will have to devote more effort to ensuring that they are adequately funded.

Finding 5: Congressional "earmarking" of funds for specific space science programs and projects undercuts scientists efforts to prioritize proposed space science projects, and adds to the skepticism scientists have developed regarding the authorization and appropriations processes within Congress.

Congressional earmarking for projects related to space science and space applications is part of recent trends[7] in federal funding of science and technology projects. Several workshop participants expressed dismay about the practice, which they see as counterproductive, since most earmarked projects have not undergone the intensive scrutiny of projects that are part of the OSSA priority-setting process.

7 See the general discussion of the results of earmarking for science projects in Eliot Marshall, "Pork: Washington's Growth Industry," *Science, vol.* 254, pp. 640-61, 1991.

WORKSHOP SUMMARY

Goal-Setting and Planning Process

OSSA has developed a well-structured process for generating its scientific program that extends across the whole range of technical disciplines for which the office is responsible (including astrophysics, earth sciences, planetary exploration, space physics, microgravity research and life sciences). The OSSA system for establishing goals and priorities has evolved over the life of NASA[8] and involves both external scientific advisory committees (e.g., the Space Studies Board (SSB) of the National Academy of Sciences (NAS)) and internal advisory committees organized under the Space Sciences and Applications Advisory Committee (SSAAC) of the NASA Advisory Council. OSSA has established internal advisory groups to resolve scientific and programmatic issues at the level of sub- disciplines of the major programs. OSSA also maintains working groups of scientists involved in particular space flight missions. The NAS/SSB generally establishes long-range strategies for the space science disciplines, while the internal advisory groups participate more closely with OSSA's near-term programmatic planning, including dealing with the details of OSSA's annual budget priorities and advising the Associate Administrator on the conduct of the ongoing program. The SSB also makes retrospective assessments of the performance of the major space science disciplines in relation to previously established goals and objectives for the program.[9]

The workshop discussed a wide range of issues related to OSSA planning and priority-setting. In general, the group agreed that the advisory committee process (both member selection and involvement with OSSA) is effective in representing the interests of

8 **For an account of the early days of selecting space science experiments at NASA, see John E. Naugle,** *First Among Equals: The Selection of NASA Space Science Experiments,* **The NASA History Series (Washington, D.C.: Government Printing Office 1991).**

9 The Space Studies Board has recently completed a set of four such assessments. (See p. 26).

those practicing most of the scientific disciplines. However, participants observed that advisory committees tend to include relatively few younger scientists, that scientists who are most successful in competing for flight opportunities and grants are those who get picked for participation, which lends a certain degree of conservatism to these groups. On the other hand, they also noted that the many OSSA science working groups provide opportunities for younger investigators to become involved in the process and to establish reputations at the subdisciplinary levels of the program.

The discussion returned repeatedly to the "diversity" of the OSSA scientific program in several contexts. One participant remarked that the breadth and diversity of OSSA's scientific mission is not unlike that of the National Science Foundation. Several participants also observed that the disciplines vary significantly in the maturity of the specific fields of study and in terms of the broader national scientific communities in which space science is embedded. To illustrate: OSSA is essentially the sole Federal supporter for planetary research, a field that has grown substantially since NASA came into existence.[10] It is also the sole supporter of microgravity research. In contrast, both NASA and the NSF have significant programs in astronomy and astrophysics. In even greater contrast, OSSA's life science program is minuscule relative to the overall national effort in biomedical research. This programmatic diversity and difference in emphasis can have significant implications for science and mission planning for the various space science disciplines.

Representatives of both the life science and microgravity programs expressed concerns that their fields were presented with particularly difficult planning, program, and funding issues because of the multi-faceted character of these programs, the relatively incomplete understanding of these programs by representatives of the "traditional" space

10 The ability to make observations in situ or from close proximity has revolutionized planetary research. As a result, the field is much larger and has a much different character than it had prior to 1957 when the Soviet Union launched the first spacecraft into orbit.

science disciplines, and the need to consider a range of engineering issues as well as basic scientific considerations. For example, the life sciences must support space shuttle operations and space station planning[11] in addition to carrying out basic and applied research in space. Microgravity research is not only directed to understanding how fluid and physical-chemical transport phenomena are influenced by the unique low-gravity environment of orbiting spacecraft, but also must provide assistance in developing technologies crucial to operating in space and for industrial applications. Life sciences and microgravity research are basically "laboratory" sciences that require quite different protocols for their execution than do the traditional "observational" sciences. The close coupling of these two disciplines with the operational needs of the space shuttle and space station programs adds additional complexity to their planning for scientific objectives.

OSSA faces many complex choices in seeking to develop an integrated space science program across its varied science disciplines. In general, scientists have been reluctant to attempt to set priorities, within much less across, fields of science. One participant with extensive experience in dealing with broad science policy issues commented that he had yet to encounter a set of systematic scientific criteria for setting priorities for programs across disciplinary boundaries, or for interdisciplinary research.[12] Yet participants recognized that each fiscal year OSSA must make priority and funding decisions that chose one area over another.[13]

The discussions noted the difference between "scientific" and "programmatic" priorities. That is, OSSA must include in its deliberations a much broader set of issues and concerns beyond scientific merit and must consider such factors as available funding,

11 It will also have to support space station operations in the future.

12 See National Academy of Sciences Space Studies Board, *Setting Priorities for Space Research: Opportunities and Imperatives,* op. cit.

13 One reviewer with experience in the private sector noted that strategic planning within a company is focused on the management of assets the company is likely to have at its disposal, whereas within OSSA, strategic planning is more focused on external marketing. OSSA uses its strategic planning process to determine how and when to present proposed missions to the Office of Management and Budget and to

mission costs, technology readiness, possible Congressional interest, and the need to maintain "vitality" across all of the supported disciplines. Even recognizing the difficulties, some participants expressed concern that scientific priorities are not given enough weight in OSSA's current priority-setting process for new missions. A reviewer later commented that OSSA places undue emphasis on giving each discipline its "turn" for a new start independent of the comparative merit of the proposed research.

A related issue concerns how OSSA priorities and strategic plans are (or ought to be) integrated into the broader strategic planning for NASA for the overall civilian space program, and for the national science and technology effort as a whole. One participant asked how closely coupled is priority setting for space science to priority setting for science funding as a whole? Do the funds allocated to science done in space accurately reflect the priority within the research enterprise overall?[14] Several participants observed that in principle it is highly desirable to raise such questions and to seek an integration of space science priorities first within NASA and second, within the whole of federally supported research. Because NASA has developed no overall strategic plan, the workshop felt that offering suggestions about how to accomplish such an integration would be premature.[15]

OSSA's Annual Strategic Plans

Since 1988, OSSA has published an annual Strategic Plan that covers the full range of science and applications programs for which the office has responsibility. The OSSA Strategic Plan is worthy of close inspection for several reasons. First, the plan is unusually

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Congress. Hence, the process tends not to be used to control the rate and size of the resources to different disciplines, as it would in industry. In other words, the mission planning activities within the disciplines determine the framework and priorities of the strategic planning process.

14 In fiscal year 1991, for example, NASA was the fourth largest Federal patron of basic research, after the National Institutes of Health, the National Science Foundation, and the Department of Energy.

15 Congress has asked NASA to submit a strategic plan to Congress concurrently with the fiscal year 1993 budget submission.

explicit about the criteria, or decision rules, that OSSA will use in establishing priorities in the actual budgetary implementation of the strategic directions defined in the planning process (Box A). At the initiation of the strategic planning process in 1988, OSSA's Associate Administrator made it clear to the division directors who represent the competing science disciplines that "...if it isn't in the plan it won't be in the budget."[16] The effect of this approach has been to reinforce the importance of lower-level strategic planning throughout the OSSA organization. Second, OSSA's strategic planning is tightly coupled with the programming and budgetary cycles that determine what projects are finally approved as the result of the external budget review process involving the NASA Administrator, the Office of Management and Budget, and the four Congressional Committees with cognizance over OSSA programs. The extent of this "coupling" to the ongoing decision processes of OSSA can be seen in Figure 1. Third, the OSSA Strategic Plan can be interpreted as an attempt to bring rational decisionmaking to the highly complex and disorderly resource allocation mechanisms of the Federal budgetary process. As one participant in the OTA workshop expressed it, "Based on the rarity of good strategic planning and management across government, industry and academia, my guess is that one is looking at the zenith of strategic planning in government."

16 On the other hand, the presence of a project in the OSSA plan does not necessarily guarantee that it will be funded.

Box A. -- Decision Rules for OSSA Programs (1989-[$]91 Strategic Plans)

L **Complete the ongoing program.** Completing the ongoing program always has the highest priority; resources allocated to those programs already underway will not be sacrificed or postponed in order to pursue new starts.

20 **Initiate a major or moderate mission each year.** Major missions preserve and enhance U.S. leadership in key areas of space science and applications, and we will pursue major missions whenever available resources allow us to do so. If an assessment of foreseeable expenditures for candidate missions, over both the near term and the lifetime of the program, indicates that our resources do not permit a major mission, we will seek to pursue a moderate mission.

3. **Initiate small missions in addition to major or moderate missions.** We endeavor to start a small mission or a small mission program every year, in conjunction with either a major or moderate mission.

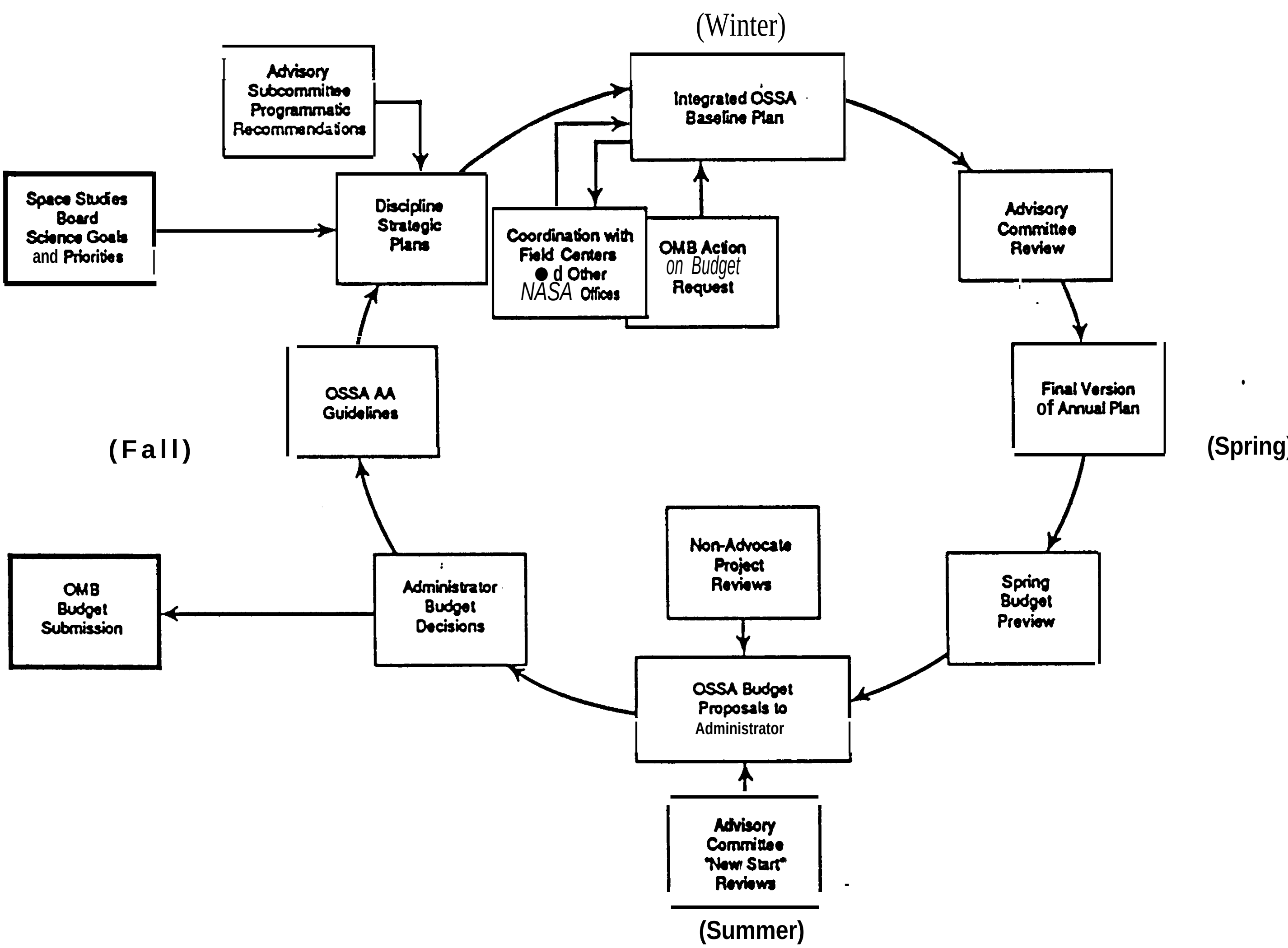
4. **Move aggressively, but sensibly, to build science instruments for Space Station Freedom.** S.S. Freedom initiatives are determined by the pace and balance of the scientific disciplines involved, relevance to and compatibility with Freedom Station capabilities and schedule, and technological maturity of the initiative. We will move forward systematically to provide a complete set of fully developed facilities and instrumentation for Space Station Freedom.

50 **Research base augmentations will be sought whenever they are warranted.** They are determined by the impact of b&h the external environment and other elements of the OSSA program on discipline stability, progress, and future needs. Provisions for meeting the long-term requirements for an adequate scientific work force and assuring access to the scientific data base from past missions are particularly critical.

SOURCE: National Aeronautics and Space Administration, Office of Space Science and Applications, *Strategic Plan 1991* (Washington, DC: National Aeronautics and Space Administration, 1991).

How did OTA workshop participants assess the annual OSSA strategic plans? One participant suggested that the appropriate criteria for making such an assessment should include: (1) the realism of the plan within the probable available funding and competing external priorities; (2) the flexibility of the plan to adjust to changes in the environment

Figure I.--Annual **Strategic Planning and Budgeting Cycle**



SOURCE: National Aeronautics and Space Administration external to OSSA (either within NASA or within other parts of the Federal Government); and (3) the effectiveness of the feedback mechanisms to assure that planning takes account of what has already happened. This workshop summary touches briefly on each of these considerations:

o ***Successes of the OSSA Strategic Plan*** -- How successful is the OSSA plan? Workshop participants expressed broad agreement that the plans had been instrumental in increasing the space science budget, which has doubled in real terms since FY1982. At the same time, they felt that large budgets do not alone assure an effective program of scientific research. In particular, workshop participants expressed concerns about the internal balance of the OSSA program with respect to "research and analysis" and "flight project" support, as well as the balance between large space flight projects and smaller missions. Some participants particularly decried the movement toward funding a higher percentage of large-scale, long-duration missions, with the concomitant shift in the role of science investigators from being directly involved in instrument design and experimentation toward data analysis and interpretation.[17] Others, however, viewed this trend as a consequence of increased maturity and knowledge in several space science fields. This shift was seen as particularly harmful in its effects on educating future space scientists who now have fewer opportunities for direct involvement in the design and fabrication of spacecraft instrumentation, and the development of experiments.[18] Furthermore, the larger, more complex spacecraft may favor scientists at NASA centers over those employed in academic institutions.

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17 This shift parallels a similar shift in the science community as a whole. See, for example, Herbert Friedman, "Big Science vs. Little Science: The Controversy Mounts," Cosmos, vol. 1, no. 1, 1991, pp. 8-14.

18 The shift to ever-larger projects, with the "'piling on' of research objectives, as well as researchers, in order to strengthen fiscal justification" was aiso noted in: Advisory Committee on the Future of the U.S. Space Program, *Report of the Advisory Committee on the Future of the U.S. Space Program* **(Washington, DC: U.S. Government Printing Office, December 1990), p. 26.**

Workshop participants differed in their interpretations of the realism of OSSA's strategic planning in terms of overall funding expectations. Some considered that OSSA's past funding expectations have been unrealistic and that the commitment to so many large-scale missions in recent years was highly risky given the overall outlook for the Federal budget and the relatively great impact that cost escalation of large projects would have on the OSSA budget. In addition, large projects often require large on-going budgets for operations.[19] Other participants took a more supportive view of OSSA's approach, suggesting in effect that instituting a more conservative plan would lead inevitably to fewer resources for OSSA. To paraphrase one participant, in the real world the predictable outcome of a "restrained" budget request is a "more-restrained" program.

Several participants challenged OSSA's current stance of giving highest priority to "completing the ongoing program," on grounds that those projects that vastly exceed their costs and schedules adversely affect the progress of other OSSA projects. In their view, such projects should be canceled to enforce cost-discipline on hardware contractors and project management teams. Other participants noted the impacts that these actions would have on the affected science teams and the practical political and other difficulties NASA would face in canceling ongoing large projects with large "sunk costs."[20] This discussion reflects the considerable frustration workshop participants face in dealing with delays caused by problems in other projects. No one had a clear solution to the dilemma cost overruns cause, but noted that cancellation must occur relatively early in the program if it is to be effective in reducing the adverse effects on other projects.

19 For example, operating the Hubble space telescope requires about $200 million per year.

20 In this regard, one reviewer noted the "conservative feedback pressure of contractors and their political support," which tends to keep funded programs in place regardless of cost overruns.

One participant indicated that he accepted the invitation to the workshop to carry a single message: "OSSA's planning queue is too long." To state simply his concerns, and those of other participants, the long planning queue sets up the potential for waste, not only of scarce financial resources, but also of scientists' time (in preparing and reviewing proposals). Dragging out projects interminably also lowers the morale of science investigators and extracts an opportunity cost by distracting them from seeking other career alternatives. This is especially debilitating if new missions have a low probability of being implemented. Participants offered no explicit suggestions of how OSSA should address this specific concern nor of the implicit problem of whether entire fields or subdiscipline in the program might have to be abandoned if the prospects for near-term missions become unfavorable.

o ***Flexibility and Feedback -- The*** recent shifts in the long-term funding assumptions for NASA and OSSA as a result of the Congressional decisions on the FY1992 budget present an opportunity to consider both the flexibility implicit in prior-year planning and budgeting for OSSA and the ability of OSSA's longer-term strategic planning to accommodate drastic changes in the external environment affecting the space science program. The material provided for the workshop participants by OSSA included briefing charts on the outcome of OSSA's August 1991 Woods Hole Planning Workshop, convened to reconsider the assumptions of the previous three strategic plans and to develop the basis for the 1992 Strategic Plan (App. B).[21]

The Woods Hole Workshop provided an opportunity for selected members of the scientific community to reassess the fundamental program and planning directions OSSA had been following during the first three years of strategic planning.[22] The

21 **The OTA Workshop Chairman and several other participants attended the Woods Hole meeting.**

22 The conference was billed as the 'First Triennial Review of OSSA Division Strategies and Proposed Mission Queues."

workshop also reexamined the structural elements of OSSA's "core" science program and updated the "decision rules" used to establish priorities across the OSSA program (Box B). Finally, the workshop made a first cut at developing a revised set of priorities and a new mission queue. This final objective resulted directly from reduced expectations for growth of the OSSA budget. As a result of congressional decisions as reflected in the fiscal year 1992 appropriation,[23] OSSA revised its long-term budgetary growth assumptions downward from the previous 10 percent real growth to 5 percent real growth beyond FY1992. The outcome of this process resulted in shifting the emphasis of the strategic plan in the near-term toward moderate and small missions and in reordering the long-term queue for more ambitious missions, now relabeled as "Flagship" missions (see App. B).

23 **Senate Committee on Appropriations, Subcommittee on Veteran's Administration, Housing and Urban Development, and independent Agencies Committees, Appropriations, Report 102-107, July 11, 1991, p. 130.**

Box B. -- Decision Rules for OSSA Programs (Decision Rules Discussed At Woods Hole for 1992 Strategic Plan)

Recommended Decision Rules

In Priority Order:

- **Complete the Ongoing Program**
- **Provide Frequent Access to Space for Each Discipline Through New and Expanded Programs of "Small Innovative Missions"**
- **Initiate Mix of "intermediate/Modeiate Profile" Missions to Ensure a Continuous and Balanced Stream of Scientific Results**
- **Initiate "Flagship" Missions that Provide Scientific Leadership and have Broad Public Appeal**
- **Invest in the Future by Increasing the Research Base to Improve Program Vitality and by Developing Needed Future Technologies**
- **Build and Utilize Scientific Instrumentation for Space Station Freedom and Conduct a Spacelab Flight Program in a Manner Consistent with the Space Station Freedom Development Schedule**

SOURCE: National Aeronautics and Space Administration, Office of Space Science and Applications, "The Basis for the Plan." Briefing charts to explain the process and outcomes of the Space Science and Applications Advisory Committee Strategic Planning Workshop, Woods Hole, July 29- August 2, 1991.

The OTA Workshop's discussion of the outcome of the Woods Hole Workshop raised a number of issues concerning OSSA's planning and its responsiveness to the changed budgetary environment. One participant who had attended the Woods Hole meeting noted that it followed from a major shift in external conditions that required a careful reconsideration of OSSA's overall strategies. Participants in the OTA Workshop, however, disagreed whether such a basic reorientation of the program had in fact occurred. One commented that the revised mission queue --

while reordering and delaying the major missions - appeared fully as ambitious as the queue it replaced.[24] Several observers expressed concern over the reordering of the mission queue and over the means used to establish revised mission priorities within specific science disciplines. They stressed the point that the revised priorities were not based on an assessment of "scientific merit" but rather a general assessment of programmatic and other nonscientific concerns. Others countered that SSAAC was attempting to assess cross-disciplinary program priorities, necessitating a broader range of considerations beyond scientific merit. In the latter view, the "process" at Woods Hole had a successful conclusion.

However, one could argue about particular "outcomes." The only general conclusions one might readily draw from this discussion were: (1) that OSSA had initiated a process of consultation with the affected scientific communities in response to congressional cuts to the President's proposed budget; (2) that establishing priorities for backing off (e.g., budget, scope, and timetable) from the previous "growth-oriented" plan is inherently difficult, in part because of the expectations built up in previous successful planning efforts; (3) that maintaining "consensus" among OSSA's diverse community will be much more difficult in a constrained budgetary environment; and (4) that OSSA made a deliberate, yet not totally convincing, effort to scale back its assumptions regarding budget growth in formulating its new strategic plan.

Assessment of Process and Program Outcomes

Workshop participants generally agreed that OSSA has an effective process for involving its diverse communities in goal-setting, strategic planning and priority-setting

24 **Several participants also commented that the Woods Hole plan dropped the Orbiting Solar Laboratory, which had been on the priority list, and added a new mission - one to the planet** Pluto -- **which had not been part of the earlier OSSA planning efforts.**

within disparate scientific disciplines. There was a weaker consensus on whether the overall process is successful and, indeed, on how such success should be measured. To pick up on the point made in the previous section, the ***process*** may be successfull in terms of involving the space science community, but the ***outcomes*** in terms of program performance are much less successful. A recurring theme in many of the participants' discussion was the perceived past emphasis of OSSA planning on large complex flight projects[25] with the attendant potential problems of cost overruns, budgetary uncertainties, schedule delays, and consequent disruptions of other ongoing OSSA activities, including the conduct of scientific research.

Participants were especially outspoken about the "wasteful" effects of long delayed flight missions and of NASA'S inability to assure access to space on a predictable basis. The lack of flight opportunities leads to a serious loss of scientific productivity among researchers who find that their space experiments take a decade or more to accomplish.[26] In the university community, it also impedes the training of graduate students. These concerns have been pointed out in a number of previous studies.[27] Several participants also pointed out that as a result of the length of time it takes to complete most NASA science missions, timely followup of scientific results becomes extremely difficult. In addition, some of the technologies used in the spacecraft become obsolete before the spacecraft is able to fly. The delays in the Advanced X-Ray Astrophysics Facility (AXAF) and in the initiation of the Space Infra Red Telescope Facility (SIRTF) were cited as examples of failures to provide for timely followup to earlier space achievements.[28]

25 Most of the large projects now under development date from initial planning carried out in the 1970s.

26 Researchers may spend as much as a decade on a project only to have their mission cancelled. Participants cited the U.S. satellite for the International Solar Polar Mission (now renamed Ulysses) and the Orbiting Solar Laboratory as examples.

27 See, for example, NASA Advisory Council, *The Crisis in Space and Earth Science: A Time for a New Commitment* (Washington, D.C.: National Aeronautics and Space Administration, November 1986).

28 These delays are in large part the result of the size and complexity of these spacecraft. Europe and Japan are able to follow up now with Astro-A and Roengten satellites because they are much simpler spacecraft in less costly programs.

Although the discussion of the issue of large projects was never sharply focused, several participants suggested that this problem might be systemic in the current program approval process, which places such heavy emphasis on the justification and approval of "new starts." One participant commented that one of the most satisfying results of the recent OSSA strategic planning process was that it had avoided the earlier process of annual "shoot-outs" among new flight projects vying for approval as OSSA's highest priority for a new start. In effect the Associate Administrator and his staff themselves generated a Strategic Plan on the basis of the highest priority objectives that had risen to the top of each discipline through the advisory process. However, that same workshop participant also voiced concern that the "shoot-out" phenomenon returned at Woods Hole, as the result in part of the constrained future budgets under which the program now has to operate. Another participant suggested that the tendency toward very large flight projects derives-in part from the approval procedures of OMB and the Congress, which make it nearly as difficult to obtain approval of a small or moderate mission as to gain approval for what are now being called flagship opportunities. He described the situation as a "big mission trap." In review, a workshop participant noted that large missions maybe easier to sell within the Administration and in Congress because they engage a larger group of interests and so can mobilize greater political support.[29] The OTA workshop neither reached a strong consensus that this was a correct diagnosis of "the problem" nor made specific suggestions as to how those incentives that now encourage the initiation of large missions might be overcome.

The workshop did not distinguish whether the problems of project delays and inefficiencies result from a failure of the planning process or from ineffective program

29 **Note, for example, the broad range of interests represented in the Hubble Space Telescope. See the discussion in Robert Smith, *The Space Telescope* (Baltimore, MD: Johns Hopkins University Press, 1989).**

management and the disruptions caused by instabilities and uncertainties in the annual budget process. Participants also expressed the view that Congressional "micromanagement" of NASA's science program and the resulting "fits and starts" were undesirable; they override or derail stable strategic planning efforts. One reviewer later suggested that both factors contributed to project delays, and pointed out that a lack of attention to technology development across the agency may make new spacecraft more risky and more expensive to develop than they should be.[30] The Woods Hole Planning Workshop placed highest priority over the next several years on completing the approved program, providing frequent access to space for each discipline through new and expanded programs of "small innovative missions," and initiating small and intermediate missions.

Issues, Concerns and Suggestions for Improvements

The workshop canvassed a wide range of issues and concerns about the effectiveness of the current OSSA program. The following paragraphs highlight a number of the recurring themes heard in the discussions.

o The ***OSSA Plan and the Federal Budget Process*** -- There was clearly a concern among many participants about a perceived "mismatch" or "disjuncture" between the carefully constructed strategic plans developed for the space science disciplines and the actual outcomes of the program. Some of these themes have been noted in earlier sections of this report. The Federal budgeting process is a major source of concern. On the one hand, scientists are encouraged to pursue a systematic process of developing rational plans for achieving scientific objectives and to seek better techniques for setting priorities across scientific disciplines. On the other hand, the current budgeting system

30 **The recent problems NASA has experienced in building the GOES-Next satellite for NOAA illustrates the negative effects of too little attention to technology development. NASA had "decided to forgo normal design definition studies and move directly from concept to hardware design and development": James R. Asker,** *Aviation Week and Space Technology,* **July 15, 1991, p. 23.**

does not provide the long-term funding stability required to carry out efficiently a program of scientific investigations that must necessarily extend over many years. The time-frames of OSSA projects may extend to a decade or more. One participant, reflecting his extensive experience on Capitol Hill, commented wryly that "...the budget process gets redone every year, but takes three years; each year it is done over; NASA is not unique." No one suggested that the situation on the budget would improve any time soon. In fact, the record deficit of fiscal year 1992 has underscored the likelihood that funding for the discretionary part of the Federal budget will remain highly constrained for years.

o ***Earmarking of funds*** -- A related issue is that of "earmarking" of funds for specific programs and projects in the appropriations process. Several participants observed that such practices run counter to Congress's own stated objectives of improving the effectiveness and efficiency of science programs. Earmarking also tends to foster cynicism and unhealthy rivalry within and among scientific disciplines, and suggests to scientists that their efforts to rank the importance of projects go unrecognized. One observer noted that scientists share in the responsibility for the increases in earmarking of science-related programs by exerting political pressure for their specific projects and activities.[31]

o ***Program Management*** -- Throughout the workshop, participants reflected on NASA's program management practices and their effects on the productivity and effectiveness of the scientific program. As noted previously, one area of great concern is related to "access to space" and the tendency for space flight missions to be stretched-out and delayed.[32] One participant observed that he had been involved in

31 For a broader perspective of earmarking, see the discussion in U.S. Congress, Office of Technology Assessment, OTA-SET-490, *Federally Funded Research: Decisions for a Decade* (Washington, D. C.: U.S. Government Printing Office, 1991) pp. 86-93.

32 This concern was also noted in the report prepared by the NASA Advisory Council: *The Crisis in Space and Earth Science: A Time for a New Commitment* (Washington, DC: National Aeronautics and Spare

the program since the 1960's and that he has now adopted the motto "fly before I die." The concern over stretch-outs is not only related to its effects on the science productivity of the directly-involved investigators. Of equal concern is what might be called the "domino effect" in which projects experiencing cost overruns (sometimes concurrently with budget cuts) cause the schedules of other projects to slip in order to maintain overall budget ceilings. Scientists are particularly indignant when such effects extend to reprogramming of funding for data analysis from past and on-going missions and for ground-based research, which are seen as particularly vulnerable to such disruptions and sensitive in terms of overall scientific productivity. Although not explicitly discussed at the workshop, one contributed paper from a university research administrator (who could not attend but sent comments for the workshop) described a "portfolio approach" to research management that might be used as one means of shielding the smaller non-project-related research from the disruptions caused by flight project overruns. With this approach, the emerging, interdisciplinary, or smaller projects would not have to compete directly with large-scale projects, but, instead would be provided for in a separate allocation that is set aside specifically for them either as a percentage of the total program or as a dollar level that cannot be raided to support large programs.[33]

o ***Technical and Program Risks*** -- Some participants expressed concerns that NASA's program management practices have become more conservative and risk-averse in recent years. The Challenger accident was cited to explain the shift, but some participants noted that a desire for "risk-free" approaches has also permeated OSSA's quality control procedures for projects that do not require "crew-rated" levels of quality

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Administration, November 1986).

33 See *Federally Funded Research: Decisions for a Decade,* op. cit., ch. *5,* for a broader discussion of this approach.

assurance. The implementation of such procedures were described as overly-bureaucratic, inflexible, and even counterproductive at times. One participant cited the example of a small satellite project in which individual electronic components were given detailed laboratory testing but could not be properly tested on a systems level because of schedule delays and increased costs incurred at the component level. One participant summed up the general concern very succinctly as follows: "we need to separate the desire for 'no risk' from the issue of whether present approaches can deliver it." The workshop offered few specific suggestions on what might be done to reverse a drift toward more conservative program management, since it is deeply embedded in the NASA organizational culture. NASA project managers see high professional risk in making serious technical errors but relatively little reward in saving time or money in the conduct of a complex and inherently risky project. Several participants offered the view that shifting toward the launch of smaller, more focused scientific projects should make project managers somewhat less risk-averse because there would be less riding on any one mission. One workshop member stressed that NASA's problems of program/project management are not unique; other Federal agencies with high technology programs experience similar problems of overpromising, underperformance, and turmoil resulting from the Federal budget process. Finally, it was observed that the recommendations of the "Hearth Report"[34] on NASA program/project management still apply and should be heeded.

o ***Coordination Improvements*** - Participants raised a number of issues concerning the need for improved coordination both within OSSA and in the outside organizations that interact with OSSA Within OSSA "interdisciplinary" research faces very difficult

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34 **Donald P. Hearth, "Notes on Conclusions and Recommendations to Accompany Briefing Charts on NASA Project Management Study," NASA History Office, 1979; Donald P. Hearth, "Project Management in NASA: 1980 and Today." In Issues** *in* **NASA** *Program and Project Management,* **National Aeronautics and Space Administration, Spring 1991, pp. 5-10.**

hurdles when it crosses OSSA divisions (there is a tendency for one division to hope/expect that the other one will provide for the effort). The same is true for disciplinary research that does not fit within the traditional space science disciplines (e.g., the Gravity-Probe B project[35]). Also cited was a concern over the efficacy of coordination on technology development issues between OSSA and the Office of Aeronautics and Space Technology;[36] similar concerns were expressed with respect to the coordination (and potential for duplication) with the Office of Commercial Programs. Also mentioned were the difficulties in coordinating programs between OSSA and other Federal agencies (especially NOAA); it was noted that such problems have counterparts in the budget-examining divisions at OMB and in the various Committees of the Congress. The workshop made no concrete suggestions for overcoming these difficult and persistent issues affecting programs that cross organizational boundaries.

o ***The Life Sciences Program*** -- One reviewer suggested that placing most life sciences research in the Office of Exploration rather than in OSSA, as recommended by the Advisory Committee on the Future of the U.S. Space Program,[37] would remove it from competition with other space science projects and might improve its chances for funding. The Advisory Committee Report argues that because solving the practical issues of supporting human life in space will be crucial to successful long-term human spaceflight, it would fare better in the Office of Exploration. On the other hand, the Office of Exploration might not be well-equipped to treat the basic science aspects of the life sciences.

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35 For a description of this project, see Ann Gibbons, "Putting Einstein to the Test--in Space," ***Science*****, vol. 254, Nov. 15, 1991, pp. 239-41.**

36 One reviewer pointed out that OSSA was aware of the problem and had taken steps to improve coordination.

37 Advisory Committee on the Future of the U.S. Space Program, *Report of the Advisory Committee on the Future of the U.S. Space Program* **(Washington, DC: U.S. Government Printing Office, December 1990), p. 32.**

o **_Retrospective Evaluations_** -- One workshop member suggested that the planning process could be improved if OSSA encouraged formalized retrospective evaluations of the results of previous plans. More "hard data" for participating scientists on how well previous plans have fared would at a minimum provide a more informed basis for debates on the content and internal balance of future OSSA strategic plans. The use of such feedback mechanisms would inject more realism and flexibility in OSSA's strategic planning.[38] OSSA could contract with an independent institution for the collection and analysis of retrospective data and the preparation of a report.

Space Studies Board Assessments

Although they were not explicitly discussed at the OTA Workshop, we briefly note the contents of four "assessment" reports on space research activities prepared at the request of the Chairman of the Space Studies Board of the National Research Council. These reports are highly relevant to the work of the House Task Force on the Health of Research. The reports focus on solar and space physics, solar system exploration, space biology and medicine and satellite earth observations -- four major components of the OSSA program.[39] OSSA's Astrophysics program was not addressed in the series because it had recently been reviewed by the National Research Council's Astronomy and Astrophysics Survey Committee,[40] Microgravity research was also not reviewed because the Space Studies Board is currently developing a research strategy for this discipline.

38 *See Federally Funded Research: Decisions for a Decade,* op. cit., ch. *8,* for the general need to provide such data for federally funded research.

39 National Academy of Sciences Space Studies Board, *Assessment of Programs in Solar and Space Physics 1991; Assessment of Solar System Exploration Programs 1991; Assessment of Programs in Space Biology and Medicine 1991; and Assessment of Satellite Earth Observation Programs 1991* (Washington, DC: National Academy Press, 1991).

40 National Research Council, *The Decade of Discovery in Astronomy and Astrophysics* (Washington, DC: National Academy Press, 1991).

These reports, completed during 1991, were undertaken in order to assess the current status of each of the major space research disciplines and to "review the responses of the National Aeronautics and Space Administration and other relevant Federal agencies to the Board's past recommendations." The reports provide additional information for the assessment of OSSA's priority setting process. Other government-sponsored research programs might benefit from similar independent assessments at periodic intervals. The very existence of such reports says a great deal about the seriousness with which the space research community addresses the major issues of goal-setting, strategic planning and program effectiveness.

Summing Up

The procedures and institutional arrangements that OSSA uses to set goals, review progress, and establish scientific and programmatic priorities are in many ways exemplary; other agencies could benefit from emulating them. It is particularly notable how deeply the OSSA \internal advisory committees are involved in the ongoing management deliberations on agency programs and budgets. OSSA has also been highly sensitive to recent changes in what NASA might expect in terms of budget support, as reflected in the Woods Hole planning workshop of this past summer.

Good planning and priority systems within OSSA are, however, no guarantee of ultimate program success. The existing planning process has been based on what some workshop participants term "success-oriented planning," i.e., planning that assumes the ability to complete projects at a faster rate than likely, given previous experience. Planning must anticipate the uncertainties of future OSSA budgets, available launch opportunities, and expected stretch-outs of large projects.[41] Thus, OSSA's priority-setting process has not

41 See Eliot Marshall, 'X-Ray Astronomy: The Unkindest Cut," *Science, vol.* **254, pp. 508-510, for an account of some of the uncertainties space scientists experience in completing a large project.**

guaranteed overall success within NASA. At the same time that the process has been successful in garnering increased funding for OSSA's programs, it has raised expectations among project scientists that cannot be fulfilled. Participants in the OTA workshop were generally concerned about the future health of OSSA The missions now in the queue as a result of the Woods Hole workshop require greater growth in the OSSA budget than workshop participants felt was feasible given the extraordinary pressures on the discretionary portion of the Federal budget.[42]

The recent stresses from the budget, and the high expectations of OSSA's diverse science communities based on previous OSSA strategic planning and funding successes, will continue to present a major challenge to OSSA's managerial and intellectual resources. Future efforts should consider how to make the planning process more resilient, and how to enable it to take sufficient account of the variety of pressures on NASA's budget and other internal and external priorities.[43]

Several members of the workshop, as well as outside reviewers, also commented on the fact that good planning ultimately depends on the assumption of follow-through on the budget after Congress approves a new start. Budget stability is a very important component of the process. One reviewer pointed out that the annual budget fluctuations that occur in response to changing congressional appropriations or to internal NASA rebudgeting are likely to have a major effect on the efficacy of OSSA's planning. The reviewer suggested that a detailed study of these effects over the last decade of OSSA plans could provide valuable insights for the Task Force.

Because this workshop was convened to assess the OSSA planning process, it gave very little attention to international efforts in space science. Yet what other countries have

42 Yet several reviewers noted that it was difficult to make significant changes in the outcomes of the process because of the entrenched interests within the scientific disciplines, which tend to be well-organized and which have a relatively sophisticated understanding of the federal political process.

43 One participant, commenting later, wondered whether space scientists really had the will to change the system, given that they have largely benefitted from the process as it stands.

already accomplished in space science and their future plans affect the U.S. planning process, if only indirectly. In particular, political considerations, inherent in many international cooperative projects, may skew the science priorities and either cause a project to be continued despite a relatively low scientific ranking, or to be canceled even though it ranks high scientifically. Constrained budgets for space science have led to an increasing interest in greater international cooperation on a variety of space science projects. How foreign space science projects and cooperative projects affect OSSA planning should therefore be given full attention.

Appendix A. -- Assessment Issues
Workshop on NASA's Office of Space Science and Applications: Process, Priorities and Goals

OTA developed the following set of broad issues in order to help workshop participants focus on process, plans, outcomes, and possible improvements. Although the issues are broadly stated, the discussion of them necessarily focused on specific examples.

Goal-Setting and Planning Process

The Task Force is particularly interested in how OSSA establishes its long-term goals and objectives, and the process by which OSSA assesses the current state of knowledge (and technology) with respect to future space missions and the potential contributions of these activities to the advancement of knowledge. It is also interested in how the results of the process are circulated among the communities and how frequently the assessments are made.

1. How are participants in the planning process selected? Are they representative of the scientific and technical disciplines involved? Is the process an open one in the sense that young investigators and emerging fields of science are provided an opportunity to compete for resources and priority with established activities and investigators?

2. To what extent are long-term goals and objectives driven by basic scientific issues and the state of knowledge in particular fields and disciplines? To what extent do extra-scientific issues and considerations affect the overall scope and direction of the program?

3. How do the above considerations vary across the diverse scientific disciplines that comprise the space science program (e.g., astrophysics, planetary exploration, space physics, earth science, microgravity)? Do all disciplines within OSSA have a structured planning process and published long-term scientific strategies? (Cite examples of particularly good or weak areas.)

4. How are cross-disciplinary priorities and issues addressed in establishing the overall direction of the space science program? How effectively do emerging disciplines and smaller scientific communities (e.g., microgravity, life sciences) compete with more established traditional space science activities (e.g., planetary, astrophysics, space physics)?

5. How effectively are results (and failures) of previous space missions and investigations factored into the overall scientific and project planning for the program? Are "lessons learned" applied in practice?

6. Does the planning process for space research take adequate account of scientific and technical progress in other fields (e.g., space astrophysics vs. ground-based astronomy)?

Annual OSSA Strategic Plan

Since 1966, OSSA has published an annual Strategic Plan that covers the full range of science and applications programs for which the office has responsibility. The Committee is interested in the views of the scientific community outside NASA toward this process:

7. How successful is the OSSA strategic plan? How successful has it been in gaining support for OSSA programs from the funding entities (OMB and the Congress) and the broader public interested in the space program?

8. Does the strategic plan grapple with the real issues facing the space science program? How successful has it been in dealing with the difficult tradeoffs forced by budget constraints and the competing claims of OSSA's diverse science disciplines?

9. Does the plan provide outside observers with adequate insight into the basis for the agency's decisions on program priorities and funding allocations? Is the process reported in the plan perceived by OSSA's scientific constituencies as being fair and even-handed?

10. Is the priority-setting process (especially the set of decision rules, pp. 16 and 21 of the 1991 plan) perceived as being rational and appropriate to the selection of project new starts? For establishing " the funding balance between ongoing efforts and new initiatives? Between "big science" and "little science"?

11. Does the OSSA plan reflect an appropriate awareness of the external concerns and interests of the Congress and the Administration, including the broader national agenda? Is the OSSA planning process resilient in responding to changes in the external environment (e.g., the recent major shift in long-term funding assumptions resulting from the budget agreement and Congressional funding guidelines to NASA)?

Program Outcomes

12. How well has OSSA succeeded in actually meeting the goals and objectives set for its programs by the scientific community and by Administration and Congressional policies? What are appropriate measures for success?

13. By what means does the broader scientific community assess the effectiveness of OSSA programs? Do these assessments become factored into the decision-making process on future planning and budgets? Is there there adequate "feedback" mechanisms?

14. Is the OSSA program as it currently exists appropriately "balanced" across disciplines and types of activities involved in the program?

15. Will major shifts in the OSSA program planning process be required to meet the constraints of more stringent funding guidelines now being addressed for NASA?

Suggestions for Improvements

16. What changes might improve the effectiveness of the planning and program implementation processes used by NASA in its management of the space science program?

17. Are there substantive changes in program directions that would lead to more effective utilization of available resources for the conduct of the OSSA program?

Appendix B.--Results of the Woodshole Strategic Planning Workshop,
July 29- **August 2,1991**

Table l.--Recommended Integrated Queue for Intermediate/Moderate Profile and Flagship Missions

1994	Thermos here Ionosphere Mesosphere Energetic and Dynamics (TIMED)- ***Intermediate***
1995	High Energy Solar Physics (HESP) - ***Intermediate;*** Space Infrared Telescope Facility (SIRTIF) - ***Flagship***
1996	Pluto Flyby or Neptune Orbiter (PF/NO) - ***Flagship*** Inner-Magnetosphere Imager (IMI) - ***Intermediate***
1997	Mars Environmental Suxvey (MESUR) - ***Moderately Paced;*** Grand Tour Cluster (GTC) - ***Intermediate***
1998	Orbiting Solar Laboratory (OSL) -Flagship Sub-Millimeter Intermediate Mission SMIM) - ***Intermediate***

SOURCE: National Aeronautics and Space Adminstration, 1991

Table 2.--Recommended Implementation Process

- *o* Initiate the following year-by-year sequence identified in the queue. Do not move to next year until all missions in current year are approved.
- *o* For year with more than one mission opportunity, missions are listed in priority order
- *o* The readiness assessment of the Non-Advocacy Review Board should be a key element in the process of readying missions of new starts at least by the year noted. All missions must be rigorously cost-controlled so that they do not exceed boundaries of original structural element.

SOURCE: National Aeronautics and Space Administration, 1991.

Table 3.--Core Science Program -- New Activity

Research & Technology Enhancements	Small Missions: Frequent Access to Space	Intemediate Missions: Continuity & Balance / Flagship Missions Leadership In Space		Utilization of Space Station
94 TOPS-O-	94 Explorer Augmentation	1994	TIMED	Life Sci Centrifuge
95 SOFIA		" 1995	HESP SIRTF	
R&A Enhancements	96 Discovery	1998	PF or NO M	
		1997	MESUR GTC	
	[98 Lunar Scout] [98 Integral]	1998	OSL SMIM	

Pending Further Discussion by SSAAC In November 1991

SOURCE: National Aeronautics and Space Adminstration, 1991 .