Chapter 13
THE FUTURE OF THE SPACE STATION PROGRAM

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AND WHAT ROUGH BEAST, ITS HOUR COME ROUND AT LAST, SLOUCHES TOWARDS BETHLEHEM TO BE BORN? —YEATS

Introduction

The Space Station program has become increasingly controversial since its inception in 1984. Two news reports illustrate the polarization of the issue in the summer of 1990. On July 9, the Wall Street Journal reported that Congress is threatening to cut off funds in December for NASA's proposed $37 billion space station because it's overweight, underpowered, hasn't proved it can perform important scientific experiments, and may require extra space shuttle flights for assembly in orbit.²

On August 20, Space Station News reported that sixty-four senators had sent a letter to Barbara Mikulski, head of the Senate appropriations subcommittee, urging full funding for the Space Station program and "understanding" with regard to its weight, power, and external maintenance problems.³ This is not the first year that problems in the Space Station program have reinforced the program's

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opposition and forced the program's supporters to step up their defense.

This chapter considers how the growing controversy over the Space Station program might be resolved, given a range of scenarios. The first section contends that achievement of the current program baseline is an unlikely scenario, and presents continued program instability and possible program termination as two more likely scenarios. The second section contends that "business as usual" — that is, the de facto policy which attempts to stabilize the program and to minimize the appearance of instability — probably leads either to a space station built down in increments or to program termination and possibly a restructuring of NASA. The third section considers how the present Station might be redesigned in order to salvage something from an investment that will approach $4 billion by the end of FY 1990.

This chapter does not attempt to predict the future of the Space Station program, nor does it recommend how the growing controversy should be resolved. It does attempt to evaluate testimony on the future of the program in the light of the program's history and underlying dynamics. The purpose is to provide a more realistic frame of reference that the public and public officials might use to make more informed decisions and to reassess the program as events unfold.

Scenarios

Achievement of the Baseline

Early each calendar year, with the beginning of Congressional hearings on authorizations and appropriations for the next fiscal year, NASA officials consistently testify that the Space Station program has been stabilized or soon will be. Stabilization is understood to mean the fixing of the program's design and capabilities, schedule of major milestones, and total development cost, as specified in the current program baseline. Just as consistently, the current baseline turns out to be an unrealistic scenario for the program's near-term future. So far at least, program stability is an annual expectation and an annual disappointment.

Consider a statement by Andrew J. Stofan, then Associate Administrator for Space Station, prepared for hearings early in 1988 on the FY 1989 authorizations:
Today, the cost of that [current baseline] configuration is identical to what it was when we came out of that review in January 1987. So we have now been a year with this configuration, and the cost has stayed stable for that period of time.... We have not changed the configuration or a system or a subsystem on that Space Station; it is exactly the same as it was.7

The implication that the program had stabilized was unwarranted: Within a month of Stofan's assurance, the development plan submitted to Congress showed major program milestones slipped by about one year. The covering letter from Administrator James C. Fletcher, dated April 7, 1988, notes that the plan "outlines a new program schedule. This schedule reflects the revised budget estimates for FY 1988 and FY 1989 and shows the first launch of a Space Station element to be early in 1995."8

Consider a statement the next year by James B. Odom, Stofan's successor as Associate Administrator for Space Station, which was prepared for hearings early in 1989 on the FY 1990 authorizations:

We are still on schedule for all major program milestones... Finally, I want to note that our estimate of total runout costs for the Freedom development effort remains at $13 billion in 1984 dollars. In summary, the program has stabilized. The configuration has been set since 1987, and our cost estimates and schedules remain the same.9

Within a few months, NASA initiated the Langley exercise to rephase the program under new leadership. This was motivated by an expected cut of $400 million from the FY 1990 request for the Space Station. But it was also motivated by the new leadership's risk assessment within the program, independent of the budget cut, according to testimony by Odom's successor, William B. Lenoir.10 Another motivation and a goal of the Langley exercise, according to the new Administrator, Admiral Richard H. Truly, was "to stabilize the program to the degree possible and carry it forward into the design phase."11

Finally, consider a statement by Lenoir, now Associate Administrator for Space Flight (which now includes Space Station and the Shuttle), prepared for hearings early in 1990 on the FY 1991 authorizations. The four points emphasized in the closing summary and conclusion of his statement are reproduced here (with emphasis added):

First, our objectives for Space Station Freedom have not changed. For our science program, Freedom offers a laboratory for research... and a platform for instruments.... For technology development, Freedom will be a unique national
facility—a testbed for evaluating technologies, procedures, and design approaches.... For our exploration program, Freedom's manned base represents the establishment of a permanently manned outpost in space and a stepping stone for the missions of the future.

Second, our progress to date on the Space Station has been substantial. The First Element Launch milestone is one year closer now than it was at our last budget hearing before this Subcommittee, and our design and development effort is moving forward accordingly on all fronts....

Third, some program adjustments have been required in the last year, but the basic integrity of the Space Station program is intact. The reduced funding for FY 1990 and the resulting need to minimize near-term program costs, technical risks, and schedule risks forced some changes in program plans, primarily involving the schedule for outyear assembly milestones and addition of planned capabilities. Despite these recent adjustments, however, the fundamental objectives of the Space Station program are unchanged, and the planned capabilities of the Space Station are maintained.

Finally, as you well know, full funding for FY 1991-1993 is necessary if we are to avoid additional disruptions in the Space Station development effort. The stability that is required can only be provided by multiyear funding.... Renewal of [the current] multiyear authorization and initiation of a multiyear appropriation are essential if we are to complete the baseline Space Station before the start of the twenty-first century.\(^\text{12}\)

Lenoir's statement is rather cautious in comparison to previous years, but otherwise typical in several respects. First, the general, long-term objectives used to justify the program are featured prominently up front. These objectives do not justify any particular program or budget; they are generally consistent with many different program baselines. Second, the appearance of instability is minimized through a selective review of the program's recent history. Lenoir draws attention to the stability of the FEL milestone, the basic integrity of the program, fundamental program objectives, and planned capabilities, despite recent adjustments. Those recent adjustments—the rephasing that resulted from the 1989 Langley exercise—were not considered minimal by the full House authorization committee four months earlier.\(^\text{13}\)

Third, program stability is considered both a feasible and the preferred scenario in this statement. Lenoir describes multi-year funding as a necessary condition for program stability, and program stability is required to complete the current baseline Station before the next century.

By mid-1990, within a few months of Lenoir's statement, a NASA internal assessment of the program acknowledged further instability. According to reports in the trade press, additional schedule slips and
content cuts would result from a $195 million cut by the House of Representatives from the program's request for FY 1991. But program officials had already begun to consider another rephasing exercise long before the budget cut because of "major hangups" within the program. These include "a shortage of volume, excess weight, and oversubscription of power requirements, as well as the ongoing maintenance problems and subsequent Extra-Vehicular Activity (EVA) requirements."14

In short, achievement of the current baseline program has not been a realistic scenario, nor is it likely to be realistic given NASA's own premises about the requirements for stability. First, NASA leaders have insisted that full funding of the annual request is necessary for program stability.15 Second, NASA leaders have acknowledged that some major changes, sufficient to destabilize the program, can be forced by internal reassessments that are independent of budget cuts.16 (To characterize such changes as part of the "normal" process of design is misleading because they have essentially the same destabilizing impact as budget cuts; the normal process accommodates changes through program reserves without destabilizing the program.) If one accepts these premises, then the current baseline will be a realistic scenario only if the program is fully funded and if all changes through design and development are accommodated by reserves. Neither condition is likely to be realized over the next several years, for reasons summarized in the instability scenarios below.

NASA leaders are apparently reluctant to face the logical implications of their own premises and chronic, severe constraints on the federal budget, even when pressed. In the October 31, 1989 hearings on proposed revisions in the program, Representative Harold Volkmer observed that "next year or the following year — somewhere along the line — we may have budget problems again." Then he asked Administrator Truly the obvious question: "Does that mean we do a rephasing of it each time?" Truly's struggle with the question is illuminating:

Again, I don't know how to guess. Certainly next year's fiscal constraints on the total budget are going to be severe, as they have been this year, but if we are on a program plan that we f and this is why I believe so strongly that, as I think this committee does, if we could get some stability in year-to-year funding so the program could plan on it, you wouldn't see disruptions. So I don't know how to answer since I don't know what the potential disruption would be. Certainly if it was major we would have to f we have to reassess it. We can't continue [sic] to provide capability on a schedule without money. It
is a three-legged stool. But I do believe that we are on a plan with what we achieved in the fiscal year 1990 budget to get an achievable budget level for the Station, and we have management in place now that has a tremendous amount of experience in managing very large, complex programs. We have done a lot of work with our international partners to make sure that they understood where we are, and we are continuing that work. So I feel good about where we are... But beyond that, I don't know how to answer your question.17

The Admiral begins and ends with the frank acknowledgement that he does not know how to answer, as if rephasing driven by funding shortfalls is a new problem for which there is no relevant experience. The difficulty in answering is attributed to not knowing "what the potential disruption would be." Truly substitutes a hopeful fantasy ("if we could get some stability in year-to-year funding") for the sobering fact that multi-year funding for the Station has been consistently rejected by Congress. He also finds reason for hope ("I feel good about where we are") in a highly selective assessment of the program's recent history. This is a manifestation of NASA's "success-oriented" culture.

A more realistic and balanced assessment would have recognized chronic funding shortfalls and recent changes driven by events within the program, considered them in the light of expected "severe" constraints on the federal budget and the "three-legged stool" ("We can't...provide capability on a schedule without money"), and drawn the logical conclusion: There is little uncertainty about whether the program will be further disrupted, even if there is some uncertainty about what, specifically, might force the disruptions.

What sustains presentation of the current baseline as the only scenario for the future of the Space Station program is political necessity. Continued instability jeopardizes the program's survival, as Chairman Roe observed in the October 31, 1989 hearings on proposed revisions in the program:

If the committee could only look forward to continued replanning, reshaping, broken commitments, changing management philosophies, and international embarrassment, I believe we should leave the Station behind us and begin anew with a more resilient plan for the future in space.18

Roe was still troubled about program instability eight months later when he requested an audit of program changes by the General Accounting Office: "The rephasing of the Space Station that occurred last fall...was of real concern to the Committee because it suggested
serious instability in the program." "Our hearings on the rephasing did not allay our concern." 19

Similarly, Subcommittee Chairman Nelson, a committed but concerned supporter of the Space Station program, reviewed the program's history of instability and drew the obvious conclusion:

So it is time to settle on one design, on one design schedule, and stick to it.... The constant changes are causing our international partners great concern and are making it increasingly difficult and expensive to move into the construction phase. 20

Administrator Truly, paraphrasing his prepared statement, agreed that "as I look at the history of this program...there is a real and true need to provide stability in this program for coming years." 21

Those supporters who contend the program can be stabilized because it must be stabilized to survive may be relying on faith at best and self-delusions at worst, but they are not relying on their own experience with the program. Selective inattention to their own experience apparently reinforces political necessity in sustaining achievement of the baseline as a scenario. 22

Instability Scenarios

The instability of the Space Station program is a symptom of an underlying problem, the lack of program resilience in an evolving environment. Resilience is the capacity of a program to perform as promised, despite disruptions external or internal to the program. Resilience is necessary because program performance depends upon funding and other critical factors that NASA cannot entirely control or adequately anticipate.

The Space Station program lacks resilience because it was conceived to be a large-scale, long-term program, interdependent with most other U.S. civilian space programs and with some space programs of other nations. Its large-scale and long-term mean that significant disruptions are relatively numerous, because more critical factors are subject to change over a longer period of time. Interdependence means that a disruption anywhere – in the program itself, in other space programs (e.g., the Shuttle), or in the fiscal and political environment – tends to force many changes and further disruptions elsewhere in the program. 23
Instability will be forced on the Space Station program by appropriations that continue to fall short of the annual request, by problems that continue to arise in development, and by surprises if not accidents that are likely to occur in operations on the ground and in orbit. There is no reason to believe that the program can avoid further disruption by events of these kinds. The specifics of the disruptive events are uncertain, but the specifics do not matter.

First, the near-term budget situation is not likely to improve. The Administration recently increased the projected federal deficit for FY 1991 to $168.8 billion. This exceeds the target set in the Gramm-Rudman-Hollings deficit reduction act by more than $100 billion. It implies automatic funding cuts late in the fall of 1990 of about 38% for non-defense discretionary programs, including civilian space.\textsuperscript{24} Current negotiations to bring the deficit under control are more likely to change the target than to achieve a major substantive agreement on expenditure and revenue decisions. In any case, the deficit is a chronic problem that is widely understood to require much more political courage and will than has been evident.\textsuperscript{25} Continued severe constraints on the federal budget are the only plausible projection.

NASA has fared extremely well in the competition heightened by severe constraints on the federal budget, but not well enough to fully fund the Space Station budget request or to secure multi-year appropriations. Chairman Traxler summed up the situation in debate on the FY 1991 House appropriations bill:

\begin{quote}
The fact is that the space station program is in deep trouble. And unless we fund this program and get it moving and insist that the problems are solved - we are going to continue to spend billions and never build a single piece of hardware....

Frankly, the fact is that we have probably tilted too much in favor of NASA. What we should have done is to add some extra money over and above what we provided for veterans medical care. But we stuck every last dollar into NASA that we could find....

And if anyone is not happy with that - stay tuned - because it's going to get a lot worse in the budget wars ahead.\textsuperscript{26}
\end{quote}

The House bill cut $195 million from the President's FY 1991 request for the Space Station. Whatever its size, the Space Station budget cut for FY 1991 is not merely a one-year inconvenience.

What can NASA do to increase the Space Station budget under these circumstances? All the obvious means have already been tried
without succeeding in stabilizing the program. However, further deterioration in program performance — cutbacks in capabilities, schedule slips, cost increases, and the like — could be used to bolster the argument that the program needs additional funding to avoid termination and to protect all those who share some responsibility for the program.

Second, problems in the development of the Space Station are increasingly likely to surface as the program continues. These problems will continue to be characterized by NASA officials as "normal." Nevertheless, responses to these problems will disrupt the program even if it achieves full funding. The following unresolved problems illustrate the potential for further disruption:

- Electrical power for scientific utilization of the current baseline may be insufficient (according to earlier NASA estimates) after "housekeeping" functions are provided for.28

- The excessive amount of EVA time required for maintenance during assembly will force substantial simplification of the current baseline or other changes.29

- The excess weight of current elements — roughly 150,000 pounds over the 512,000 pounds allocated in November, 1989 — is likely to force further reductions in capability and greater dependence on Shuttle.30

- Some Space Station assembly elements still do not meet the Shuttle's payload constraints.31

- The threat from medium-sized (between 1 and 10 cm) orbital debris is uncertain but acknowledged by NASA to be significant.32

- Interactions between plasma in space and direct-current power distribution could cause electrical arcing, adding to crew safety and maintenance problems.33

- Knowledge of the many physical and biological factors involved in protecting the crew from radiation is incomplete and uncertain.34
Attempts to find satisfactory solutions to such problems, whether successful or not, will take time and money and probably will compromise capabilities.

Third, problems in operations are inevitable. The Shuttle is the Station's Achilles heel in this respect. Assembly of the Station can be disrupted by Shuttle-related events like those which have already occurred: An accident during launch preparations, the discovery of hydrogen leaks in the fuel system, or loss of another Shuttle. The Office of Technology Assessment estimates that the Shuttle is about 98% reliable. If so, we can expect to lose one Shuttle in approximately 34 flights. Using 1989 Shuttle manifest data, that means the probability of having all four orbiters available at the scheduled start of Space Station assembly was only 0.28; the probability of having them all available at the scheduled completion of assembly was only 0.12. Further, station assembly must proceed in the exact sequence planned, and yet Shuttle flights, historically, simply do not fly in the planned order.

Each successive flight in the dozens of flights required during Station assembly presents a difficult and exacting docking problem, because the partially-assembled Station will be somewhat different each time. Damage to or loss of any crucial part could set the program back years, because there are few spare parts. Moreover, mistakes and accidents are relatively likely because the Space Station, unlike most previous space systems, is never fully assembled and checked out on the ground. Uncertainty about the physics of the plasma problem can be generalized to other aspects of the program: The Station is too big to test in the environment it will work in. You've got to make the physics up as you go.

Such problems in funding, development, and operations interact: Responses to one problem tend to be constrained by, and to exacerbate, other problems. For example, obsolete underestimates of the threat of orbital debris were retained in April, 1989 because "changed debris environment [estimates] would result in design modifications that NASA could not afford." Similarly, a change request for a positively-grounded power system to address the plasma problem was killed by a quick cost estimate, about a half billion dollars. The plasma only became a problem because the program switched from alternating to direct current in response to earlier problems.
Adding Shuttle flights is one response to the payload-constraint and weight problems, but not a sufficient response. Moreover, adding Shuttle flights would increase the probability of losing a Shuttle and Station components during assembly, increase the amount of EVA time required, increase exposure to unknown radiation and debris hazards, and add significantly to operations costs.

Many interacting problems complicate management and integration, which were already complicated enough. An anonymous official working on the weight problem observed that "while the PDRs [preliminary designs reviews on individual systems] are going on, in the next door or two doors down they're scrubbing the [same] systems." The scrubbed version of a system forces changes in interdependent elements that assumed the previous baseline; and all changes from scrubbing must be coordinated through an unnecessarily complicated management structure involving several NASA centers in major roles. Proposed changes are especially disruptive because they are much more numerous and because they propagate many "what if?" exercises for interdependent elements, diverting time and effort from work on the baseline version.

In summary, the Space Station program will continue to be disrupted, and because the program lacks resilience a disruption anywhere tends to multiply problems elsewhere. Failure to respond to such problems adds to technical risk in the program. But responses put additional pressures on reserves of attention, time, and funds, and such reserves already have proven insufficient to stabilize the program. The result is continued instability, manifest in reduced program capabilities, delayed program milestones, and added program costs. NASA recently described how one problem, a budget cut, compounds other problems:

...the quick look assessment shows that a $150 million reduction in FY 1991 would increase total program costs by $100-250 million, would delete some content, would delay key operational milestones 6-9 months, and would delay planning for potential growth to meet future requirements by one year. In addition, the launch of the European and Japanese modules would be delayed 7-8 months under the current assembly sequence, with some accompanying cost increases.44

Termination Scenarios

Termination of the Space Station program has been raised as an alternative to program continuation for the last several years. NASA spokesmen typically select and emphasize the adverse consequences of
termination for others as well as for NASA itself. For example, in the 1989 authorization hearings, James Odom, Associate Administrator for Space Station, testified that:

A significant cut below where we are, I think, would be tantamount to killing the program. And I think that to do that would be almost irresponsible on our part, especially looking at the commitments that our international partners have made and the investment that our contractors and we have made up to this point in time.45

In contrast, threats of termination coming from Congressional critics typically select and emphasize problems within the Space Station program.46 Such statements are best interpreted as brinksmanship in the continuing controversy over the program. For NASA, the threat of termination is a tactic to pressure Congress to fund the Space Station program at a level NASA considers to be adequate. For Congressional critics, the threat of termination is a tactic to pressure NASA to improve program performance according to whatever criteria the critics insist upon, including program stabilization. The assumptions that Congress can provide funding adequate to support NASA's desired program and that NASA can stabilize the program are unexamined and probably unrealistic.

No can predict program termination or continuance with any confidence. The question for present purposes is whether termination of the Space Station will become more or less likely over the next several years, and under what circumstances? The answers depend upon the perspectives of those who would be most directly involved in a termination decision.

For NASA's leadership, it is doubtful that termination would be preferred over program continuance under any plausible circumstances, despite testimony that termination makes sense below some unspecified minimum level of funding. Continuance serves the institutional interest in maintaining employment and the shared vision of human exploration.47 Termination would be devastating in these terms, and would threaten NASA as we know it because NASA has centered the civilian space program on a station or the Station over the last two decades. From this perspective, the frustrations of managing and attempting to rejustify an unstable program appear to be rather minor.

Supporters of the program in the Administration and Congress are also frustrated by the program's instability and poor performance,
which complicates the problem of selling the Space Station. Selling
the program, despite its poor performance, is sometimes the explicit
purpose of hearings according to chairmen of the Senate and House
authorization subcommittees, respectively:

Today, we will try and compile a record that will help us argue for [Space
Station] as a budget priority in the turbulent days ahead.48

...we want you to reassure us that [a slip in the schedule] is not the case...so
that we can go out and continue to sell to the Congress the appropriate amount
of money that is needed for this project which is so enormously important to
our country.49

NASA's commitment to First Element Launch in March, 1995 attempts
to address the concern over schedule slips, even if slips in other
milestones are unavoidable. So far at least, the frustrations of selling
a troubled program are more than compensated by other factors,
including tangible benefits for some constituencies and faith in the
program's many general, long-term justifications.

Skeptics and critics of the program tend to be frustrated by the lack
of good alternatives. From their perspective, program continuance is
a bad investment of public resources, but any attempt to terminate the
program would be a major political effort and risk, which, even if
successful, would disrupt the entire civilian space program. Moreover,
the public would demand to know who was responsible for terminating
a program which had already spent nearly $4 billion through FY 1990;
and everyone who shares some responsibility would be predisposed to
point the finger elsewhere. The resulting waves of recrimination could
touch everyone involved with the program in NASA, the
Administration, and Congress, and wreak major political damage on
some of them. With a few exceptions, members of Congress have been
unwilling to take initiatives toward killing the program.50

The net result has been a deadlock: NASA and Space Station
supporters have been unable to "build it right" and the opposition has
been unable to "not build it at all," and so the program continues. But
the perspectives behind the deadlock, and the outcome, are subject to
change as present trends unfold.

One trend is simply growing momentum. Some believe that the
Station program already has enough momentum to carry it "over the
hump" to assembly complete. Others believe the program will reach
that point with completion of the Critical Design Review, the
fabrication of hardware, or First Element Launch. Momentum means
that the stakes increase as a function of time: For supporters, each additional appropriation or milestone intensifies the motivation to continue and complete the Station; for opponents, each additional investment more effectively deters termination initiatives, because it becomes increasingly difficult to explain why more money was "wasted" on plans or hardware that will not be used.51

Continued program instability works in the opposite direction. Evidence of program instability leaked or reported to the press tends to stimulate and surface other reports of problems through a bandwagon effect.52 Such reports tend to undermine "soft" support based on nothing more tangible than faith in the program's justifications. As stepped-up selling efforts produce diminishing results, core supporters of the program become demoralized and eventually concerned that their visible support is becoming a personal political liability. Under these circumstances, it is prudent to keep one's head down and look for other causes to champion. Meanwhile, skeptics and critics are encouraged by the increasing results of their efforts and begin to sense a political opportunity. As such dynamics build up the potential for termination some minor event—a blink in the game of brinksmanship, perhaps—can trigger termination.

The probability of termination will increase from year to year, so long as instability and related problems in the program continue to occur and continue to be reported. Under these circumstances, the program's large-scale and momentum work to its disadvantage: It is perceived as a large and growing mistake, increasingly visible and therefore increasingly costly to support. Moreover, each year the program is stretched out makes it more vulnerable to scientific and technological obsolescence and to competition from any programs, American or foreign, with overlapping objectives.

Some NASA leaders have been especially concerned about slips in the schedule, one form of instability, as a threat to program continuance. Acting Administrator Myers testified that "there is certainly history that says if programs continue to slip, they finally get cancelled."53 During the 1989 Langley rephasing, Administrator Truly recalled his experience as an astronaut assigned to the manned orbiting laboratory (MOL), an ill-fated Air Force project of the 1960s. According to Space Station News:

That program cost $3 billion and slipped 3 times before it was cancelled, Truly recalled last week. "The space station is at that point. And I don't want to slip it." Said one contractor: "That experience with MOL really scarred him. This
[Langley exercise] comes right out of that - he believes you must get something into orbit.\textsuperscript{54}

In summary, it appears likely that (1) achievement of the current baseline for the Space Station program is as unrealistic as achievement of previous baselines; (2) the program will continue to be destabilized by funding shortfalls and by internal problems arising from program development and operations; and (3) the probability of program termination will increase so long as program instability continues to be reported. What can be done about the Space Station program?

\textbf{Business As Usual}

One policy alternative is business as usual, the \textit{de facto} policy of the Space Station program. This means continuing efforts by NASA and others to stabilize the current baseline design and basic performance criteria, especially capabilities, schedules, and total costs. This also means continuing efforts to avoid the appearance of instability when changes cannot be avoided, in order to reduce the threat of termination.

Business as usual is an unrealistic policy if stabilization of the current baseline is, in fact, the principal objective. As argued above, all previous efforts to stabilize the program have failed, and there is no reason to believe that such efforts will be any more successful over the next several years, even with full funding. Full funding is unlikely, and it will take additional time and money beyond the current baseline to find and coordinate changes in response to the major problems already identified. Thus the descoping of the Space Station to Block I in 1987, the rephasings in 1989 and 1990, and lesser changes in program content are very likely precursors to additional exercises to delete or defer work and to incur the higher costs resulting from such changes.

Under these circumstances, resulting political pressures to minimize the appearance of instability, and to exaggerate claims of stability, would compound the technical risks of business as usual. Lower-level officials would be reluctant to raise additional problems that might jeopardize the program; and higher-level officials would be reluctant to hear about additional problems that might call into question their credibility as well as the program's viability. Such internal problems of communication were major factors in the Challenger accident, according to subsequent investigations.\textsuperscript{55} The lesson is that problems left unattended do not disappear. Rather, they tend to show up later
in operations where the differences between appearance and reality are reconciled.

Over a series of descoping and rephasing exercises, each of which adds to development and operational costs, business as usual could produce an operational space station. This progeny of the Space Station, several generations removed, would be less than currently promised and much less than was promised in 1984. It would also be plagued by intermittent operational problems, as the Shuttle still is, to the extent that internal problems are left unattended. The likelihood of this outcome depends upon the success of NASA's efforts to minimize the appearance of instability — among things, focusing attention on the general, long-term goals of the program, and encouraging the Administration, Congress, and the public to overlook the history of promises not fulfilled and problems not resolved. 56

Business as usual could also lead to termination of the Space Station — an outcome which, we have argued, becomes more likely as the series of descoping and rephasing exercises continues. Termination of this centerpiece of the civilian space program, could call into question the entire NASA structure and make restructuring difficult to avoid. Dale Myers testified to that effect when he was Acting Administrator of NASA in 1989:

I think NASA could be in a tailspin without the Space Station. I think the whole strategy of our program, all the long-range planning that I have been associated with since 1968, has involved the Space Station. And so, the idea of having a [civilian space] program without a Space Station is abhorrent to the highest degree, and I believe that if there were a major cut in the program, we would have to look at the total infrastructure of NASA again. It would take a different NASA to operate without a Space Station. 57

The many frustrations that have accumulated in and around the civilian space program in the post-Apollo era would be brought to bear on the issue of restructuring, making the outcome highly unpredictable — especially given the lack of prior planning for such a contingency.

On the other hand, termination of the Space Station would benefit NASA by freeing up enough resources to stabilize other projects in NASA's core program. 58

Redesigning for Resilience

Redesigning the Space Station program for resilience is a policy alternative to business as usual. This alternative attempts to improve
the return on the public's investment in the Space Station program, and to reduce the probability of termination and restructuring.

The basic idea is to reconceive the annual rephasing exercise as an opportunity to decouple elements of the Space Station program for competitive evaluation. (Decoupling for competitive evaluation reverses the processes of "scaling-up" and putting "all the eggs in one basket.") Those elements that cannot be justified in terms of a particular objective, schedule, and cost would be deleted or deferred. Those elements that survive competitive evaluation would be reconsidered for separate development and operation. They also would be prioritized for separate funding, and developed as warranted by the funds available. It should be possible to stabilize some parts of the program so that they can perform well according to their respective objectives, even if it is not possible to stabilize the program as a whole.

Something close to decoupling has already occurred as an unintended consequence of continuing struggle over the program. NASA has been unable to "build it right" and the opposition has been unable to "not build it at all," but together they have been able to "build it down" to meet annual budget constraints: Block II was decoupled from Block I and deferred indefinitely. Similarly, solar dynamic power, the new space suit, the OMV,19 the polar-orbiting platform,20 and other program elements were decoupled from Block I and deleted, deferred, or transferred from the program. However, this "build it down" process is extremely costly, as we have seen, and still has a long way to go before it produces a resilient program.

Redesigning for resilience could begin by anticipating the eventual outcome, the limiting case, of the "build it down" process: The program core that probably would survive in competition with other program objectives and elements, and would be small enough to minimize management and integration problems and to fit within realistic annual budget and total cost constraints. A small, decoupled core could be stabilized through simplification of management and integration under one center, and perhaps through multi-year appropriations if the number of dollars and years are small enough to make such appropriations reasonable. Such a core also might be "built up" efficiently, if not quickly, as program performance and the fiscal situation warrant. In other words, starting from the core, it might be possible to "buy it by the yard" — which is what NASA leaders promised when they promoted the initial concept of the Space Station.

One candidate for the core is a laboratory module, which, in an early 1989 Station baseline, could be man-tended for micro-gravity
research before addition of the full 75 kilowatts, a habitat module, and a permanent manned capability. In April, 1989, Chairman Bob Traxler of the House appropriations subcommittee asked about total Station cost "if we stopped the Block I assembly sequence at flight seven or eight — in other words, giving us man-tended capability." According to an insert in the hearing record, the information NASA later provided did not respond to Traxler's request. But Acting Administrator Myers did have an immediate response for Traxler:

We lose the whole strategy of NASA's future because the manned program is the key to assembly in space, to the operation of laboratory equipment, to the whole program as far as the future is concerned.

A permanent manned capability with the habitat module may be NASA's preference for the core, the last element it would give up under pressure to delete program content.

Later in the same hearings, Traxler pursued the matter with Associate Administrator Odom in a question about the assembly sequence:

During the man-tended phase of the Space Station - in other words, before the habitat [module] is added to the complex - station has sufficient power to run almost an unlimited number of experiments in the laboratory with an extended duration orbiter. However, once you add the habitat, which comes before you put up the balance of the 37.5 kilowatts of power, the availability to the user drops significantly. Is that correct?

Odom affirmed that was correct. Traxler went on to suggest an automatic hold on the habitat module if a delay were expected in getting the balance of power up, "because it doesn't make a lot of sense to add infrastructure and take away power from the user." Odom replied, "That is certainly an option, but if you want to get permanently manned capability as soon as possible, then obviously, the habitat is mandatory."

The FY 1991 appropriations bill recently passed by the House of Representatives appears to protect the power supply for users of a man-tended U.S. laboratory module. It stipulates that at least 30 kilowatts must be available to users of the Station, and that full power of 75 kilowatts must be provided before any international modules are added to the Station.

Elimination of the Space Station truss would facilitate if not force decoupling of the modules for separate evaluation. This is not out of
the question. A NASA task team recently recommended that the agency consider "the total elimination of the truss and its replacement with pressurized modules in which, and on which, all station elements would be mounted." This was proposed as a means of reducing the EVA time required for external maintenance. Elimination of the truss would also focus attention on finding the core.

Redesigning for resilience might also include smaller space stations as an alternative to finding the core of the present Space Station. Representative Bill Green, the ranking minority member of the House appropriations subcommittee, contended that "The time has come for us to consider scrapping NASA's plan and replacing it with an updated version of our former space station — Skylab." Green went on to mention another alternative without recommending it:

Several years ago, we nearly approved a smaller version of Skylab if many of you will remember the Industrial Space Facility - the ISF. This program, which I personally thought to be a wonderful idea - and a test bed for the Station, was scrapped when it became perceived as a threat to the Space Station — another victim of political shortsightedness.

Redesigning for resilience entails short-run instability as the program is taken apart in order to achieve stability later on a smaller scale. For Space Station supporters who believe that the program can be stabilized before termination, redesigning for resilience is an inferior alternative to business as usual. For supporters who believe that business as usual means eventual termination and perhaps restructuring, redesigning for resilience may merit consideration.

However, NASA controls the technical expertise necessary to design and assess in sufficient detail the alternatives to business as usual. OMB and Congress are effectively limited to requesting alternatives and responding to whatever NASA provides. (The ISF is a partial exception.) Consequently, NASA is in the driver's seat: NASA can stonewall or avoid responding to requests for alternatives to business as usual, leaving OMB and Congress with a choice between the present Space Station as it is built down incrementally, or no space station at all.

Summary and Conclusion

The scenarios and policy alternatives considered here provide a frame of reference for thinking through the future of the Space Station
program as events unfold. The key is to look beyond claims that the program will soon be stabilized to the evidence and logic that bears on those claims. The rationality and political feasibility of forthcoming decisions on the program depend most critically on the question of stabilization.

We contend that the present Space Station program cannot be stabilized over the next several years, despite the best efforts of NASA, the Administration, and Congress. The underlying problem is that the program lacks the resilience necessary to perform as promised in a turbulent situation that NASA cannot anticipate or control. The problem can be traced to the 1984 concept of the program — large-scale, long-term, and tightly coupled with other programs — which subordinated program performance to other considerations.

If so, there are no good alternatives for resolving the Space Station issue. Business as usual, the attempt to stabilize the program and to cultivate the appearance of program stability, leads either to a risky space station — less capable, later, and more costly than the present one — or to program termination and possibly the restructuring of NASA. Redesigning for resilience could salvage something more quickly and at less cost from the present program, or replace it with a smaller space station program. But all those outcomes that appear to be feasible are also failures with respect to the capabilities, schedules, and costs that were promised in 1984 and are promised in the current baseline.

The larger issue is whether, or under what circumstances, NASA will recognize the need for resilience, and design it into future programs and into civilian space policy as a whole. The alternative is to replicate the mistakes of the Space Station program throughout the civilian space program. This is a particularly disturbing possibility while the Earth Observing System enters development and the unformed Space Exploration Initiative continues to incubate.

Notes

1. The authors gratefully acknowledge the comments of many authors of chapters in this volume, particularly the comments of Albert D. Wheelon, and the support of the Alfred P. Sloan Foundation.


5. A secondary theme in the testimony is that content deleted from budget requests -- such as Block II or solar dynamic power -- has been deferred, not permanently deleted. Thus program capabilities are alleged to be retained.

6. Of course stabilization allows for normal changes and refinements within the envelop defined by fixed design capabilities, schedule, cost.


8. See NASA, Office of Space Station, *Space Station Capital Development Plan Fiscal Year 1989* (April, 1988), which was submitted to the House Committee on Science, Space and Technology and the Senate Committee on Commerce, Science and Transportation.


10. See his testimony in *Proposed Space Station Freedom Program Revisions*, Hearings before the Committee on Science, Space, and Technology, U.S. House of Representatives (October 31, 1989), p. 20. See also NASA's response to a question submitted in advance of the hearings, p. 78: "In the course of our review, some station subsystems, the technical and schedule risk were found to be sufficiently high to merit a reassessment even if the program had received its full funding."


13. Chairman Roe of the House authorization committee characterized the rephased Station as "a radical departure from the design and schedule that this committee has given its unwavering support to." See *Proposed Space Station Freedom Program Revisions*, op. cit., p. 3.


15. Sometimes NASA spokesmen imply, erroneously, that full funding or funding stability is a sufficient condition for program stability. See, for example, prepared testimony in *Proposed Space Station Freedom Program Revisions*, op. cit., p. 93: "It is critical that some stability be introduced into Space Station funding in order to avoid program disruptions and future deferrals or deletions."

16. See notes 9 and 13 above and *Proposed Space Station Freedom Program Revisions*, op. cit., p. 78, for the most relevant testimony. These specific changes included switches to DC power distribution and hydrazine propulsion modules, and deferral or deletion of the new space suit and the closed loop environmental control life support system.


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22. Selective inattention is not unusual. In non-technical terms, selective inattention means "you just miss all sorts of things which would cause you embarrassment...to notice. It is the means by which you stay as you are, in spite of the efforts of worthy psychiatrists, clergymen, and others to help you mend your ways. You don't hear, you don't see, you don't feel, you don't observe, you don't think, you don't this, you don't that, all by the very suave manipulation of the contents of consciousness by anxiety..." From Harry Stack Sullivan, The Fusion of Psychiatry and Social Science (New York: W. W. Norton, 1964), pp. 216-217.

23. For more on the lack of resilience as the underlying problem in the Space Station program, see Brunner and Byerly, op. cit.


27. These include, in addition to requests for multi-year appropriations, transfers of some Space Station program costs to other NASA programs and to other departments (particularly DOD), and attempts to develop some program elements with commercial funds, as well as attempts to lobby and mobilize support for higher appropriations through letters from aerospace contractors, the circulation of figures on the amount and geographical distribution of program funds and employment, and even TV specials.

28. According to a recent report by Bob Davis, op. cit., p. A6, "the operation of the station itself will require so much power that so far it has only 10 to 15 kilowatts available for experiments -- less than the 30 considered adequate for the labs."


30. See "Station Weight Becomes Number One Concern," *Space Station News* (July 9, 1990), pp. 1-5. See also *Defense Daily* (July 10, 1990), pp. 42-43 and (July 11, 1990), p. 54.

31. This volumetric problem is discussed in connection with the weight problem, for which additional Shuttles are a possible solution. See the sources cited in the previous footnote. See also, the National Research Council, *Space Station Engineering Design Issues* (Washington, D.C.: National Academy Press, 1989), in which a committee reports, p. 49, that "the 50-ft photovoltaic radiator will not fit in the Shuttle payload bay for the first flight."


35. A bridge crane accidentally flexed Discovery's right payload door. *Aviation Week & Space Technology* (July 9, 1990), p. 11.
38. This is a conclusion of the Space Station Advisory Committee, as quoted in *Space Station News* (June 11, 1990), p. 8. Later that month, the optical problem of the Hubble Space Telescope was traced to the failure to test the mirrors in combination on the ground. See Warren E. Leary, "Hubble Telescope Loses Large Part of Optical Ability," *New York Times* (June 28, 1990), p. A1.
40. The GAO report on orbital debris, *op. cit.*, p. 18, which went on to report that "A senior NASA engineer voiced his opinion that NASA is wasting time, money, and resources by developing the station to meet understated design requirements."
41. Leonard Davis, *op. cit.*
42. "Station Weight Becomes Number One Concern," *Space Station News* (July 9, 1990), p. 4.
43. In an interview in *Space Station News* (August 20, 1990), p. 7, former NASA Administrator James Beggs acknowledged it was a mistake not to put a single center in charge of the Space Station program. That was done for what he described as "political reasons."
46. For an example, see Bob Davis, *op. cit.*
47. The seminal statement of the vision is Wernher von Braun, "Crossing the Last Frontier," *Collier's* (March 22, 1952), pp. 24f.
48. Senator Gore, *Hearings before his Subcommittee on Science, Technology, and Space* (March 16, 1989), p. 1. To the witnesses, he said (p. 2) that "each of you must work harder to make the case for the space station program as a budget priority, as a foreign policy priority, and as a technological leadership priority."
50. Representative Charles Schumer introduced amendments to transfer funds from the Space Station program in 1988 and 1989. Floor action on the latter occasion, the twentieth anniversary of the first moon landing, can be found in the *Congressional Record* (July 20, 1989), pp. H3960-H3961, H3979-H3993. Floor action on a similar amendment introduced by Senator Daniel Patrick Moynihan can be found in the *Congressional Record* (July 12, 1988), pp. S9366-S9377. More recently, in a July 25, 1990 address to the National Press Club, Representative Bill Green advocated termination of the Space Station in favor of an advanced Skylab.
52. Notice, for example, how the conjunction of the Hubble's optical problem, the Shuttle's hydrogen leak, and the Station's EVA and weight problem was generalized into concern about deeper problems in NASA. In that frame of reference, even the delay of an Atlas launch is network news.


55. See the Report to the President by the Presidential Commission on the Space Shuttle Challenger Accident (June 6, 1986), p. 200. Richard P. Feynman, a member of the Commission, concluded that "because of the exaggeration at the top being inconsistent with the reality at the bottom, communication got slowed up and ultimately jammed." From What Do You Care What Other People Think? (New York: W. W. Norton, 1989), p. 215.

56. Until recently, the Savings & Loan crisis illustrates the potential of the Administration, the Congress, and the public to overlook promises not fulfilled and problems not resolved.


62. Ibid., p. 47.

63. Ibid., p. 59.

64. Ibid.

65. As reported in Space Station News (July 9, 1990), pp. 6-7.


68. Ibid., p. 6.