United States General Accounting Office

GAO

Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives

May 1988

SPACE STATION

NASA Efforts to Establish a Design-To-Life-Cycle Cost Process

GAO/NSIAD-88-147

GAO
United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-227537

May 5, 1988

The Honorable Robert Roe
Chairman, Committee on Science,
Space, and Technology
House of Representatives

Dear Mr. Chairman:

This report is in response to your request that we review NASA's implementation of actions outlined in its December 1985 report to the Committee regarding space station operations cost management.

As arranged with your Office, we plan no further distribution of this report until 5 days after its issue date. At that time we will send copies of this report to the Chairmen, House and Senate Committees on Appropriations and Senate Committee on Commerce, Science, and Transportation; the Administrator, National Aeronautics and Space Administration; the Director, Office of Management and Budget; and other interested parties upon request.

Sincerely yours,

Frank C Conahan

Frank C. Conahan
Assistant Comptroller General

Executive Summary

Purpose

The National Aeronautics and Space Administration (NASA) is preparing to design and develop a permanently staffed space station. NASA currently plans to assemble the station in orbit between 1995 and 1998.

In April 1987 NASA estimated that design and development of a "Phase 1" space station will cost about $14.6 billion (1988 dollars). This estimate does not include the cost of operating the station over its 30-year life. NASA has estimated that space station operations could cost NASA's Office of the Space Station almost $1.4 billion (1987 dollars) annually.

In June 1987 the Chairman of the House Committee on Science, Space, and Technology asked GAO to review NASA's implementation of plans to control space station operations costs.

Background

In 1985 the Committee directed NASA to outline its plans to ensure that it did not overlook future operations costs during the space station's definition, design, and development phases. In its Report on Space Station Operations Cost Management, NASA responded that it would control operations costs by using a design-to-life-cycle cost approach. A program using such an approach establishes (1) the projected total life-cycle cost of a system as a design requirement equal in importance to performance and schedule concerns and (2) cost elements as management goals. The report indicated that elements of the design-to-life-cycle cost approach would be developed during the program's then-in-progress definition phase.

NASA indicated that by employing a design-to-life-cycle cost approach it would appropriately weigh future operations costs in design and development decisions and so obtain potentially substantial reductions in the station's total life-cycle cost. Specifically, NASA stated that it would

- evaluate impacts of alternate technical and programmatic approaches through a design-to-life-cycle cost criterion and a design review process that considered life-cycle costs,
- establish operations cost benchmarks and objectives,
- maintain management visibility over these objectives through regular reevaluation of cost projections and through a reporting system to track progress in meeting cost objectives,
- consider various operations cost control incentives that would be tied to the cost objectives, and
- improve operations costs estimates and develop an operations cost model.

Results in Brief

Although the definition phase was completed in January 1987, NASA is still developing major portions of the operations cost management system described in its 1985 report, including a cost management policy and cost benchmarks. NASA officials are establishing a programwide design-to-life-cycle cost policy and process later than had been planned and now plan to adopt a modified approach. Despite the lack of a formal process, NASA officials studied the life-cycle or operations cost impacts of key system options during the definition phase.

If the Committee wishes to review a full and current description of NASA's plans to ensure that operations costs are being considered during the space station's design and development, it will have to request such information from NASA after mid-1988, when NASA expects to complete its new policy and procedures. NASA plans to begin the bulk of the station's design and development after a 1989 design review.

Principal Findings

Life-Cycle Cost

NASA has renewed its efforts to establish a design-to-life-cycle cost policy after an inconclusive 1986 attempt to do so. NASA officials attributed the delay in establishing such a policy to the Space Station Program Office's 1987 reorganization and relocation and to disagreements over implementing a design-to-life-cycle cost policy. They told GAO that NASA studied key life-cycle cost impacts during the definition phase, although it did not require that all proposed design changes be so studied.

NASA is currently considering a draft directive to help establish a management system that would systematically consider and assess life-cycle cost impacts of design proposals. NASA officials informed GAO that the directive recognizes current development funding constraints. According to NASA, the directive focuses on stimulating life-cycle cost beneficial ideas that can be implemented within these constraints. NASA officials contrasted this modified design-to-life-cycle cost approach to what they characterized as the 1985 report's "ideal" approach.

Benchmarks and Reporting System

NASA did not establish operations cost benchmarks and objectives during the definition phase as planned but is still attempting to establish a set of goals to help guide development efforts. NASA officials informed GAO that the program will adopt resource allocation benchmarks by mid-

1988 to assist designers in controlling resource demands and associated costs. Although a March 1988 draft directive alludes to cost objectives, NASA officials were unclear as to how or when resource allocations would be translated into specific operations cost objectives or benchmarks.

NASA officials informed GAO that they still plan to establish a reporting system to track progress in meeting such objectives.

Incentives

Program officials expect that the program will use contract award fees as incentives to control operations or life-cycle costs. Use of such fees would require NASA to develop life-cycle cost or operations cost-related criteria on which to base contract awards. NASA also informed GAO that it used its selection process for design and development contractors to help motivate concern for life-cycle cost considerations. Although such considerations may have played some role in contract selection, GAO could not determine their importance relative to other criteria.

Cost Estimation

NASA has developed an operations concept and an operations cost estimating model to improve its operations cost estimating capability.

Recommendations

GAO's report describes the results of its review of efforts to implement measures outlined in NASA's 1985 report. GAO makes no recommendations.

Agency Comments

NASA stated that GAO's report fairly depicted NASA's formal approach to space station life-cycle costs. However, NASA also said that the report understated its actual concern with and attention to life-cycle costs. NASA further stated that the space station program had made substantial progress in operations cost management since 1985.

GAO believes that its report adequately depicts this progress. It notes that NASA is still developing major elements of the operations cost management system it promised in its 1985 report, including a life-cycle cost policy directive and operations cost benchmarks.

NASA's comments appear in full in appendix IV and are discussed on page 27.

Contents

Abbreviations

DTLCC	Design-to-Life-Cycle Cost
GAO	General Accounting Office
JPL	Jet Propulsion Laboratory
MESSOC	Model to Estimate Space Station Operations Costs
NASA	National Aeronautics and Space Administration
POP	Program Operating Plan
SDTM	System Design Trade-off Model
SSCB	Space Station Control Board

Introduction

On January 25, 1984, the President informed the Congress that he was directing the National Aeronautics and Space Administration (NASA) to develop a permanently staffed space station. After congressional approval, NASA established a space station configuration that incorporated major components to be developed by four NASA field centers and three international partners.[1]

The space station is intended to provide an affordable orbiting research facility that will permanently support a crew and attract a large group of users. NASA plans to begin in-orbit assembly of the space station (depicted in figure 1.1) in 1995 and to finish assembly in 1998.[2]

Program Phases and Organization

NASA has divided the space station program into concept, definition, design, development, and operations phases.[3] It completed the 21-month definition phase in January 1987 and announced the contractors for the design and development phases in December 1987.

NASA has established several major program milestones. For example, at the March 1986 system requirements review, NASA formally selected a concept which it believed would best meet mission requirements within cost, schedule, and technology constraints. The January 1987 systems design review milestone coincided with the end of the definition phase.

During the 1988 design phase preliminary requirements review, NASA plans to update project requirements to reflect changes resulting from design and development phase contract negotiations and other programmatic decisions. The agency also plans to define actions needed to proceed with detailed design at this point.

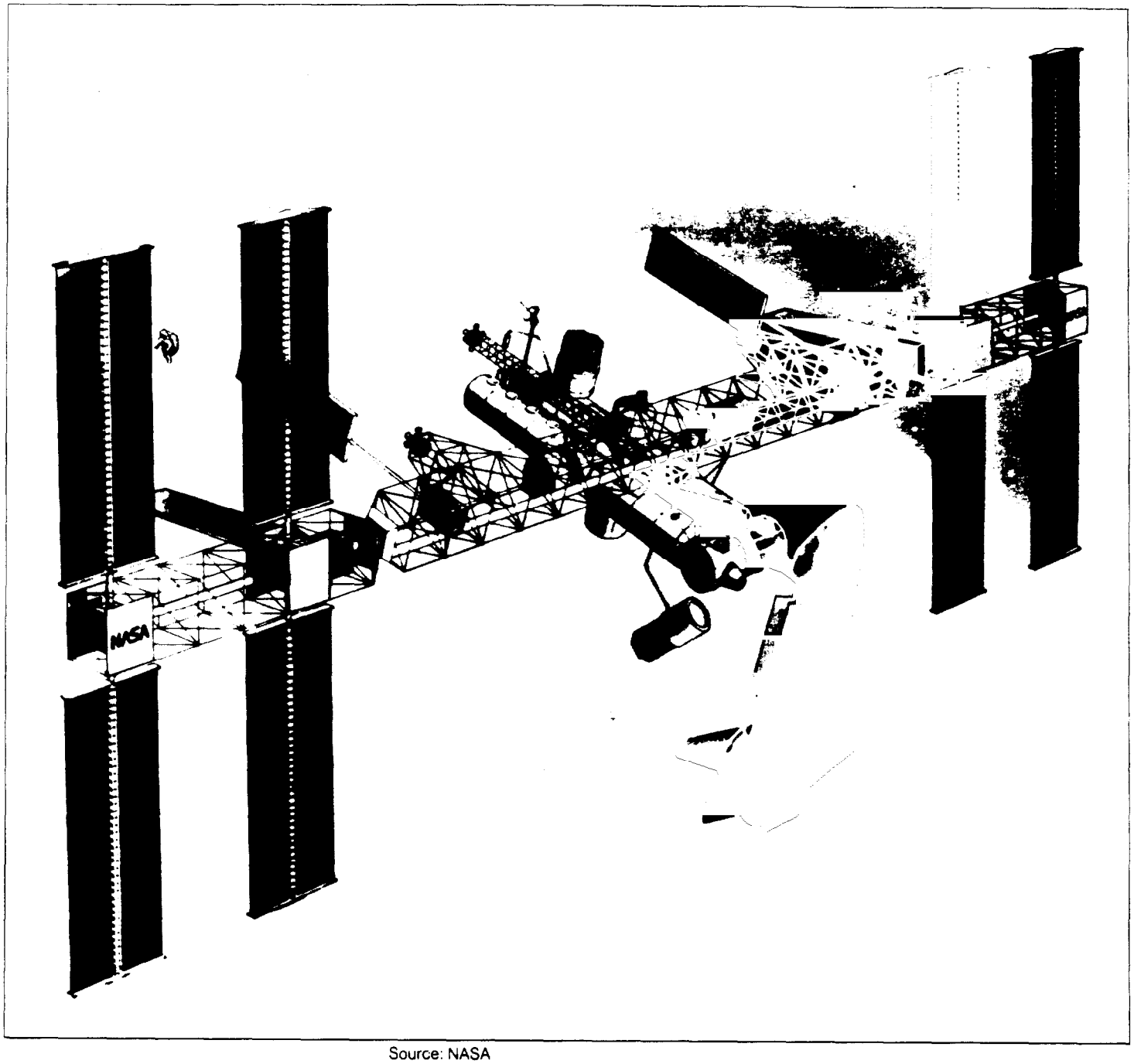
During the 1989 preliminary design review, NASA expects to review the basic design approach and to ensure its compatibility with program requirements. After reviewing engineering study results, preliminary test requirements, and schedules at this point, NASA intends to authorize fabrication of long-lead-time items and to proceed into detailed design.

[1]The international partners are Japan, the European Space Agency, and Canada.

[2]NASA's April 1988 Space Station Capital Development Plan indicates that all program milestones ar under review.

[3]NASA has renamed these phases since June 1986. What is now called the definition phase was then called the definition and preliminary design phase, and the design phase was called the detailed design phase.

Figure 1.1: The Space Station with a Space Shuttle Orbiter



Source: NASA

According to NASA, most of the actual design and development of the station will occur during the detailed design period.

NASA plans to establish the station's design during a series of critical design reviews in 1991 and 1992. NASA then intends to approve a set of engineering documents, authorize completion of station hardware and software, and complete plans for the station's launch, verification, and operation.

The program's management is divided into three levels. Level I is headed by NASA's Associate Administrator for the Office of the Space Station. Located at NASA's Washington, D.C., headquarters, Level I is responsible for policy and overall program management.

Level II, the Space Station Program Office in Reston, Virginia, oversees the program's direction and technical content and is headed by the Space Station Program Director, who is also the Associate Administrator's deputy for development. The Space Station Program Office was originally located at the Johnson Space Center in Houston, Texas. In December 1986, the Houston Program Office was dismantled and a new Program Office organization was established in Washington, D.C., to strengthen management of the upcoming design and development phase. Level II moved to Reston in late 1987 from its temporary Washington, D.C. facilities. NASA officials informed us that as of March 1988 Level II had not yet achieved the staffing levels of its Houston-based predecessor.

The Program Director also chairs the Space Station Control Board (SSCB), a nonvoting management forum made up of the heads of key NASA organizations responsible for space station program activities. The SSCB is responsible for formally adopting and controlling changes to the space station program's management and technical requirements, resources, and schedules. Space station organizations seeking to alter such program characteristics prepare change request documents for the SSCB's consideration.

Level III is made up of project organizations at various NASA field centers that manage the centers' assigned space station projects. The program's success depends on the integrated operation of major systems designed and developed at the Johnson Space Center in Houston; the Marshall Space Flight Center in Huntsville, Alabama; the Lewis Research Center in Cleveland, Ohio; and the Goddard Space Flight Center in Greenbelt,

Maryland. Each center is to manage one of four major design and development contractors.

Also involved is the Kennedy Space Center in Florida, which will be responsible for launch-related activities, processing space station payloads, and logistics during and after assembly. The Jet Propulsion Laboratory (JPL) in Pasadena, California, is involved in the space station program through its work on Level I and Level II projects and through staffing Level II's program requirements and assessment office.

Concern Over Operations Costs

In April 1987 NASA estimated that development of a "Phase 1" space station similar to the one depicted in figure 1.1 would cost about $14.6 billion (1988 dollars).[4] This estimate did not include the cost of operating the station over its 30-year life. NASA has estimated that mature space station operations[5] will cost the space station program almost $1.4 billion (1987 dollars) annually.[6]

NASA's definition of operations costs includes costs associated with preparations to support orbital operations during the development phase as well as recurring post-development phase operational costs. This definition includes the cost of initial crew and ground personnel training, initial spares and replenishment, operations support, facility maintenance and operations, training and trajectory planning for specific flights, launch site sustaining engineering, launch package integration, and space station overhaul and repair.

In NASA reports on space station operations cost management, NASA has stated that controlling total system costs for the long-duration space station program is its primary challenge and that space station operations will differ from operational experiences gathered during previous programs. Unlike those programs, space station operations will involve a

[4]NASA officials subsequently informed us that enlarging the space station depicted in figure 1.1 into an augmented "Phase 2" space station would add about $4.5 billion (1988 dollars) to this amount.

[5]In March 1988 NASA officials informed us that the mature operations period would be "a period of steady state operations beginning two or three years after the completion of assembly." Space station assembly is scheduled to be completed in 1998.

[6]The development and operations estimates exclude several significant NASA costs, such as launch costs, that will not be borne by the space station program. For more information, see our report Space Station: National Aeronautics and Space Administration's 1987 Cost Estimate (GAO/NSIAD-87-180FS, July 1987).

permanent human presence in space, long-term involvement with international partners, assembly in orbit, routine servicing and maintenance in orbit, and multi-year scheduling of activities and supporting logistics.[7]

NASA's ability to identify and control space station operations costs has been a source of congressional concern. In March 1985 the House Committee on Science and Technology found that NASA had not identified its management approach for controlling such costs. The Committee directed NASA to outline its approach "for achieving visibility of the status of operational cost parameters" and its plans to

- evaluate the effects of alternate technical approaches and programmatic changes on operations costs,
- develop appropriate benchmarks by which to measure operations cost projections during the program's definition, design, and development stages,
- ensure that management visibility to monitor achievement of cost objectives would be developed and maintained,
- provide adequate incentives to contractors and NASA units to ensure adequate appreciation of operations cost prediction and control, and
- predict and determine operations costs.

The December 1985 NASA Report

In its December 1985 Report on Space Station Operations Cost Management, NASA informed the Committee that NASA was controlling operations costs through early implementation of design-to-life-cycle cost (DTLCC) controls. The report, signed by NASA's Acting Associate Administrator for the Office of the Space Station, states that NASA's operations cost management approach would include (1) policies to make operations costs visible and to encourage managers to weigh life-cycle costs in program decisions and (2) the ability to forecast operations costs and to integrate them into design decisions. With regard to the Committee's specific areas of interest, NASA stated that it would

- evaluate impacts of alternate technical and programmatic approaches through use of a DTLCC approach and a design review process requiring consideration of life-cycle costs,

[7]NASA's most extensive experience with operating long-duration, crew-carrying spacecraft was with the 84-day Skylab 4 mission in 1973 and 1974. The Mercury, Gemini, and Apollo programs focused on putting astronauts into space without special emphasis on operations costs. The longest such flight was less than 14 days. Space shuttle missions have been limited to 10 days. Unmanned missions did not demand extensive long-term logistics support.

- establish operations cost benchmarks after the systems requirements review (which occurred in March 1986),
- maintain visibility over cost objectives through regular reevaluation of cost projections and a reporting process to track progress in meeting objectives,
- consider various incentives (tied to the operations cost objectives) to control operations costs, and
- improve operations costs estimates and develop a space station operations cost model.

The most prominent theme of the report was its endorsement of the use of a DTLCC approach, beginning in the definition phase, to control future operations costs. According to NASA officials, NASA's DTLCC experience has been limited by the short operational duration of previous missions involving crews. We consulted the Department of Defense's approved guidance on DTLCC[8] and found that a DTLCC approach attempts to identify the optimum cost-effective solution to a given task within the limits of cost constraints and performance requirements. The approach establishes the sum of development, production, operations, and support costs as a design parameter equal in importance to performance and schedule parameters. Program managers should identify elements of program cost and establish them as design management goals. The Department of Defense directive on this topic[9] specifies that cost goals are to be allocated to suit the program's work breakdown structure[10] and to facilitate trade-off studies.

NASA's 1985 report describes the space station program's DTLCC approach in similar terms. It states that system life-cycle cost should be established as a parameter equal in importance to technical and schedule requirements throughout the design, development, and operational phases, and that life-cycle costs would include definition, design, development, and operations costs. NASA also indicated that it would use cost elements as management goals by stating that it would establish operations cost benchmarks.

NASA's rationale for endorsing a DTLCC approach was to ensure that the station's design and development phases gave adequate attention to

[8]The Joint Design-to-Cost Guide: Life Cycle Cost as a Design Parameter defines cost as including operations costs and uses the term design-to-cost instead of DTLCC.

[9]Department of Defense Directive 4245.3 (Design-to-Cost, April 6, 1983)

[10]A work breakdown structure is a product-oriented, family tree hierarchy containing the levels of work needed to achieve an objective.

future operations costs. In its 1985 report NASA stated that constraining development costs alone would encourage design decisions that would reduce development costs at the expense of increased operations costs. The difficulty in avoiding such an outcome is that NASA must cope with any design and development budget constraints in the near-term but will not incur mature operations costs until several years after the station has been designed and developed. NASA stated that it would ensure that it would appropriately weigh future operations costs in design decisions by defining program cost in terms of life-cycle cost.

The report states that the space station program's DTLCC decision making process would focus on minimizing total life-cycle costs. It also states that design phase consideration of life-cycle costs could substantially reduce total life-cycle costs and depicts the DTLCC approach as based on trading off development costs against the cost of operations facilities, equipment, staff, and procedures. To implement this approach, the report outlines a process through which NASA would prepare and evaluate operations cost estimates and develop operations cost objectives to help guide design decisions, and then track each program organization's progress in meeting these goals through a reporting process.

An important feature of the DTLCC process outlined in the report was the involvement of the SSCB, with its control over the program's management and technical requirements, resources, and schedules. According to the report, the DTLCC process would be used during the definition phase as a criterion by which to evaluate changes proposed to the SSCB. Design-to-cost analyses and cost reviews would be performed by program offices and boards involved in preparing recommendations for SSCB consideration.

The report concluded that the DTLCC process should

- establish life-cycle cost, technical requirements, and schedule as equal parameters throughout design, development, and operations;
- require that life-cycle cost be addressed during design, development, assembly, and long-term operations, with cost reduction emphasized in the early design phase;
- provide a procedure for integrating cost estimates and technical interactions, leading to cost-reducing decisions; and
- establish requirements and designs that balance potential budget constraints, life-cycle costs, schedule, performance, reliability, and other considerations.

Committee Reaction

The Committee reported in September 1986 that although the NASA report was "well intentioned," the Committee continued to be concerned about NASA's ability to anticipate and control operations costs. Noting that the space station's operations concept was less mature than the hardware development effort, the Committee directed NASA to "update" the 1985 report before beginning the design and development phases. In October 1987 NASA submitted a report entitled Space Station Operations Cost Management to the Committee. However, this report did not specifically address some of the DTLCC measures outlined in the 1985 report.

Objective, Scope, and Methodology

In June 1987 the Chairman of the House Committee on Science, Space, and Technology asked us to review NASA's plans for space station operations. As later agreed, the objective of our review was to determine the status of NASA's implementation of the cost control measures described in the December 1985 report. Using the 1985 report's statements concerning intended cost management actions as our criteria, we sought to identify (1) the degree to which NASA had implemented these actions, (2) the rationale for changes in its plans, and whether such changes had been conveyed in NASA's 1987 report, and (3) when possible, any potential differences in effect between the measures described in 1985 and NASA's subsequent plans.

We reviewed NASA's December 1985 report to identify planned operations cost management measures. To determine the extent to which these measures had been implemented, we met with NASA officials at the Space Station's Level I headquarters, the Level II Program Office, the Marshall Space Flight Center, the Kennedy Space Center, the Johnson Space Center, and JPL. We also reviewed a wide variety of documents, including the Program Cost Management Process Requirements document, requests for proposals, guidelines for preparing operations cost estimates, and the 1987 NASA report.

We did not attempt to assess the DTLCC system proposed in 1985 or NASA's currently envisioned approach, or to determine which approach would be better suited for managing the program's operations costs. We did not validate the computer models, cost estimates, work breakdown structure, operations concept, or cost ground rules discussed in this report. We also did not review in detail documents concerning certain definition phase decisions, including SSCB presentations and supporting studies to the SSCB, because NASA was unable to provide us with such documents in a timely manner. Program officials stated that they were unable to provide the documents sooner because of logistical problems

associated with the 1987 transfer of the Program Office from Houston to Reston.

We conducted our work between August and December 1987 in accordance with generally accepted government auditing standards.

NASA Is Still Developing a Modified DTLCC Policy and Substitutes for Cost Benchmarks

NASA is still developing a DTLCC approach to be adopted by the program as its official policy. The DTLCC approach being considered involves a significant modification to the DTLCC approach outlined in the 1985 report. NASA officials attributed the delayed development of a DTLCC approach and its modification to program reorganizations and budget constraints.

Although the space station program has not formally adopted a DTLCC process to ensure that all life-cycle cost impacts are identified and considered, NASA officials informed us that key operations cost impacts were studied during the definition phase. They also stated that they plan to establish a DTLCC system by mid-1988 that will meet the intent of the 1985 report while operating within constrained development budgets.

NASA did not establish operations cost benchmarks and objectives during the space station's program definition phase nor did it establish a reporting system to track progress against such objectives. NASA officials now plan to provide designers with allocations of space station resources. NASA's plans for translating such allocations into operations cost benchmarks are unclear, although NASA officials suggest that recent operations cost estimates may be adopted as overall cost targets. NASA officials also informed us that they still plan to establish a reporting system.

NASA to Modify DTLCC Approach and Adopt It Later Than Planned

In 1985 the Committee asked NASA to review its plans for evaluating alternate technical approaches and programmatic changes throughout the definition, design, and development phases to ensure that operations cost impacts were fully understood. NASA responded that it was adopting the life-cycle cost criterion to assess such impacts and that it was developing an initial DTLCC plan.

The space station program considered but did not adopt a definition phase DTLCC policy document in 1985 and 1986. Instead, toward the end of the definition phase, the SSCB adopted a requirements document that provided for a significant modification to the DTLCC approach described in the 1985 report.

DTLCC Plan Not Yet Adopted

In 1985 the Space Station Program Office prepared a draft directive that would have established a definition phase effort to define designs that would minimize total life-cycle cost. NASA officials subsequently shifted

the focus of the draft directive from staying within a life-cycle cost goa to staying within a development cost goal. One revised version of the directive would have established a "secondary" goal of an "affordable life-cycle cost attractive to users." Another revision indicated that oper ations costs would be minimized, rather than required to stay within a set life-cycle cost target.

The space station program did not adopt any of the 1985 and 1986 dra DTLCC policy directives. It did not renew its efforts to draft such a direc tive until December 1987. NASA officials later acknowledged that the space station program had not adopted a DTLCC plan as soon as had bee originally planned. They informed us that they had set the draft directive aside because of disagreements related to the implementation of a DTLCC approach and disruptions stemming from Level II's 1986-1987 relocation and reorganization.

In November 1986 the SSCB adopted a Program Cost Management Process Requirements document. Although not a policy directive, the document included some aspects of NASA's intended cost control strategy. It specified that life-cycle and operations cost information will be require for future design and development decisions. The objectives of the cost management process, which applies to development and life-cycle costs are (1) establishing a coherent strategy to maximize space station productivity "within annual and total budget appropriations," (2) develop ing a system with known and affordable operations cost, and (3) achieving a capability to maintain crews aboard the station by 1994.

However, the document did not specify that life-cycle cost is to be considered a design parameter equal in importance to performance or schedule concerns. Moreover, it stated that the strategy used by the cos management process would be a "modified" design-to-cost approach, necessitated by (1) the research and development nature of the progra and (2) "multiple constraints," including "schedule, prescribed interna tional participation, specified performance, and annual/total cost limit tions to name a few."[11]

The document did not specify key officials' authorities and responsibili ties for controlling program cost. Although it briefly outlined the gener cost management roles of the SSCB and other program organizations, it

[11]The document lists the design-to-cost features to be retained but not those to be modified. The retained features are an initial benchmark for performance, annual and total cost, and schedule; the monitoring of progress against the benchmark; development of integrated solutions to problems; a formal benchmark adjustment procedure; and participant accountability.

left the roles of the Associate Administrator for the Space Station, the Program Director, the field offices, the Level III Project Directors, and the contractors to be determined at an unspecified later date. Similarly, the document left specific management commitments for implementing the process and standard program tools for conducting assessments to be determined at an unspecified date.

In commenting on the DTLCC approach's modification, NASA officials stated that because of unanticipated constraints on development phase funding they would transform the "ideal" DTLCC approach outlined in the 1985 report into a DTLCC approach that focuses on life-cycle cost optimal designs within those constraints. The officials stated that the constraints had limited NASA's ability to substitute increases in development phase expenditures for lower future operations costs and had made the ideal approach infeasible. A Level II operations official stated that the program is currently attempting to retain as much of the ideal DTLCC approach as possible within constrained near-term development budgets. NASA officials informed us that life-cycle cost would be employed as a design parameter, although apparently not as an equal to the performance and schedule design parameters.[12]

NASA has renewed efforts to formally define its DTLCC policy. In December 1987 NASA officials informed us that the space station program would establish an operations cost management process by mid-1988 and that Level II had begun defining a life-cycle cost impact analysis system in response to an anticipated Level I requirement. The Level I requirement, adopted in February 1988, calls upon Level II to (1) create and implement a plan for life-cycle cost analysis that will ensure that systematic analysis of impacts on program life-cycle costs becomes an integral and required step in configuration decisions and (2) maintain an independent capability to perform such analysis.

A March 1988 draft of such a DTLCC directive would, if adopted, direct Levels II and III to implement a process for "optimizing the balance among several competing [space station program] objectives." These objectives would include satisfying user needs, reducing total life-cycle cost, and complying with Level I's direction on annual development budgets and program schedules. The proposed DTLCC process would be used to achieve a station design that minimizes life-cycle cost while meeting

[12]NASA's 1987 report on space station operations cost management did not mention the adoption of a modified approach. Instead, it stated that NASA "will continue to assess whether operating costs or benefits of a particular improvement opportunity justify the necessary development costs."

performance and schedule requirements. Life-cycle cost impact assessments would be required for all proposed changes. A Level II cost management steering committee would assist the SSCB in evaluating life-cycle cost impacts of proposed changes and in identifying areas where design changes could reduce such costs. The draft directive would also establish the responsibilities of major program officials, require the use of cost objectives, and ensure that changes to annual funding constraints are assessed and linked to the cost objectives.

NASA officials have informed us that the DTLCC directive and a revised Program Cost Management Process Requirements Document will be formally adopted by mid-1988, after completion of negotiations on the design and development phase contracts. NASA officials also told us that a computerized model, the System Design Trade-off Model, may be adopted as a standard program tool to ensure that life-cycle costs are considered. (See app. I.)

Important aspects of the new DTLCC system have yet to be defined. The draft directive's provisions have not been formally adopted. Although the March 1988 draft stresses the use of cost objectives, NASA's plans for their establishment are still unclear. The specific manner in which the 1985 report's DTLCC concept is to be modified is unknown. Moreover, the draft directive states that specific procedures for incorporating DTLCC into the change request process would be left to the responsible organizations to develop. Level II officials told us that NASA has not established life-cycle cost-related thresholds establishing the circumstances under which Level III organizations would be required to submit a change request. Such thresholds would help define the degree of the SSCB's control over Level III.

The period of time to be used in estimating life-cycle cost impacts of particular systems is also unclear. The number of years assumed can affect the outcome of the DTLCC analysis. A Level II Systems Engineering and Integration official informed us in January 1988 that Level II would weigh a proposed change's cost impact over a 10-year period to avoid giving too much weight to operations costs. NASA's 1987 report suggests that the life-cycle costs of at least some systems will be analyzed using periods of less than the station's life of 30 or more years. A proposed revision to the change request form suggests that the period to be considered may be as short as 5 years.

Operations Costs Studies

NASA officials informed us that program officials studied the life-cycle cost impacts of key design decisions, although they acknowledged that a programwide requirement that all change requests address life-cycle costs had not been adopted. NASA officials told us that NASA did not require all change requests coming before the SSCB to address life-cycle or operations cost impacts and that those that did reflected operations costs issues in a variety of ways, depending on the preferences of the organization preparing the change request. NASA's October 1987 operations cost management report states that "change requests submitted to the SSCB must be accompanied by analyses of impacts to...system life-cycle costs" and that the SSCB "explicitly considers the operations cost implications of all proposed changes." We were told by a Level II operations official that these statements reflected the space station program's intentions for the design and development phases and did not represent actual SSCB requirements at the time the 1987 report was prepared.

In its 1987 operations cost management report NASA stated that the SSCB had reviewed proposed changes for their impact on operations costs as well as their impact on development costs and technical merit. The report stated that decisions concerning the space station's environmental and propulsion systems, orbital altitude, hardware and software commonality, software support environment, and use of commercial software would reduce lifetime operations costs "by several billion dollars." NASA officials subsequently informed us that NASA had conducted trade-off studies concerning design decisions viewed as having major potential impacts on operations costs and that life-cycle costs were a factor in all design trade studies, notwithstanding the absence of a DTLCC directive and a requirement that all change requests address life-cycle costs.

Our limited review of the studies that were provided to us in a timely manner indicates that operations costs were considered in evaluating some major design alternatives. For example, a 1985 contractor study of seven designs for the space station's environmental control and life support system projected that development and production of a closed system in which water would be recycled and reused would cost about $52 million more than an open system, in which all water would be resupplied periodically. However, operating the closed system over 90 days would cost about $52 million, whereas the comparable cost of the open system would be about $161 million. Selected SSCB minutes provided to us in March 1988 indicate that such operations cost data was considered in making certain definition phase decisions.

In November and December 1987, after the definition phase, program officials considered placing a lower priority on life-cycle costs to save development costs. The "Reduced Cost Option" study identified over $725 million in potential development cost savings. However, realizing these savings would have required NASA to transport an additional 50 tons of supplies to the station annually. The Space Station Program Director informed us that the high operations cost impact that would have resulted led program officials to reaffirm the original definition phase choices.

NASA Still Developing Resource and Cost Benchmarks

NASA did not establish operations cost benchmarks and objectives as indicated in the 1985 report. NASA officials do not rule out the possibility of establishing such benchmarks in the future and the March 1988 draft DTLCC directive provides for their use. However, NASA officials indicated that space station designers will first be allocated targets aimed at limiting each system's demand for the station's power, crew time, and other important resources.

Cost Benchmarks in the 1985 Report

In 1985 NASA responded to the Committee's concerns regarding "benchmarks by which to measure the operational cost projections during...the definition and design and development stages" by stating that it would

- establish a process for determining benchmark cost figures for operations parameters "as soon as possible after" the systems requirements review,
- set benchmarks for key operations cost parameters "shortly" after that review, and
- further define benchmarks after the systems design review.

Although the report does not clearly define benchmarks, its description of how NASA planned to establish and use them demonstrates that the benchmarks were intended to be key management elements in the space station DTLCC system.

The report states that "benchmark cost figures" would be determined for undefined "operations parameters" and that the benchmarks would be used as

> "performance standards and will be based on the reference hardware and operational configuration.... The sum of all established parameters will provide an initial estimate of total annual operations cost."

After establishing the benchmarks following the systems requirement review, the Program Manager was to have set operations cost objectives. These objectives were to have been similar, if not identical, to the benchmarks.[13] Level II was to have implemented, controlled, and tracked the cost objectives with Level I approval. The benchmarks and objectives were to have become part of the program's definition phase exploration of design and operations alternatives, enabling NASA to focus on the technical decisions and policies that would play a major role in determining operations costs. The report stated that NASA would establish benchmarks for each major design alternative studied and would adjust the cost objectives if it identified ways of operating the space station more efficiently and effectively.

The benchmarks and objectives were to have been refined after the systems design review for continued use during development. NASA would have established objectives at progressively lower levels of the program during the development phase as operations cost estimates were extended to the subsystem level.

Status of Cost Benchmarks

Although the systems requirement review was completed in March 1986 and the systems design review was completed the following January, NASA did not establish operations cost benchmarks. Current program documents make little reference to operations cost benchmarks. The November 1986 Program Cost Management Process Requirements Document includes some references to them, but it does not establish or further define either benchmarks or cost objectives.[14] The Level I Program Requirements Document (which sets requirements for Level II) and the October 1987 report on operations cost management do not refer to benchmarks in describing the cost management system.

Space station officials at all levels indicated neither benchmarks nor the process for their formulation had been established during the definition phase. Moreover, NASA officials generally could not clarify the broad description of benchmarks given in the 1985 report. Although some officials advocated the use of benchmarks, our discussions with Levels I and II officials indicated that not all program officials had accepted the

[13]The report noted that cost objectives would be "stated in terms of benchmarks," and the benchmarks themselves could be "accepted" as cost objectives.

[14]It provides for an initial benchmark for "yearly and total cost," system performance, and milestones, but does not specify how or when it is to be set. A chart indicates that an initial cost requirement is to be established by the beginning of the design and development phases. The document refers to, but does not describe, the establishment of a final benchmark for the development phase.

benchmark concept. Some officials believed that useful benchmarks could not have been established as early as the 1985 report had indicated. Level I officials suggested that the absence of an operations concept had frustrated the establishment of benchmarks. (See ch. 4.)

However, NASA does not appear to have ruled out the possibility of establishing such benchmarks. For example, the March 1988 draft DTLCC directive explicitly provides for the use of life-cycle cost objectives. Moreover, in December 1987, Level I operations officials informed us that NASA's latest operations cost estimate represented a significant step toward establishing benchmarks. One such official stated that the estimate's seven major categories and subcategories might be established as cost objectives in 1988. Table 2.1 shows the seven major categories and NASA's estimated operations cost for each.[15]

Table 2.1: Space Station Annual Mature Operations Costs

Dollars in millions

Category	1987 dollars
Flight hardware/software sustaining engineering	$ 36(
Integrated logistics support	23
User integration and support	6(
Support center operations	13
Prelaunch/postlanding operations	5
Information systems services operations	8
Management	16
Total	**$1,10**

The official also referred us to a NASA task force recommendation calling for establishment of an operations performance assessment approach that would require the unambiguous identification of costs associated with required performance measures. (See ch. 4.) NASA officials informed us that the task force recommendation is being studied for implementation. Officials also indicated that an initial annual cost benchmark may be established in mid-1988 but could not clearly describe how they would establish the total cost benchmark required by the Program Cost Management Process Requirements Document.

NASA officials noted that the October 1987 report on operation cost management identified space transportation, information systems, sustaining engineering, and integrated logistics as operations "cost drivers.

[15]These figures do not include a 25-percent reserve fund or provide for funds associated with space transportation, civil service personnel, or communication network service costs.

The 1987 report indicates that NASA will focus on these four factors as a means of controlling operations costs.

Resource Allocations and Cost Objectives

In late 1987 NASA officials began indicating that Levels I and II may establish target allocations of space station resources. Such resources include crew time, power, weight, and volume. NASA officials informed us that NASA had developed a resource allocation matrix that will provide each designer with target resource allowances to guide space station design. Level I officials informed us that use of the allocations to guide design could help ensure that mature operations costs do not exceed the $1.4 billion estimate. NASA officials also stated that they would establish key resource allocations by mid-1988 and that NASA would use computer models to tie the resource allocation targets to life-cycle cost targets, although they were uncertain as to how or when specific resource-cost linkages could be executed.

In commenting on our draft report, NASA stated that initial resource allocations would be completed in the "near-term." NASA also commented that

> "Where life-cycle cost can be associated with the systems that produce these resources, these will be issued to managers of these systems. In addition, the estimation of operations costs...will provide benchmarks against which the impacts of all types of programmatic changes can be assessed."

NASA Has Not Yet Established a Reporting Process

In response to the Committee's request that NASA describe its plans to "monitor achievement of cost objectives," NASA stated that it would employ a reporting process to track the progress of each responsible organization in meeting cost objectives, to explain problem areas, and to propose specific solutions. The report stated that NASA would base the reports on the cost objectives and the operations work breakdown structure.[16]

NASA officials told us that the program has not developed a reporting system as described in the 1985 report.[17] However, the March 1987 draft of the proposed DTLCC directive would require Level III offices to report

[16]NASA also stated that it would regularly evaluate operations cost projections. (See ch. 4.)

[17]The 1987 report states that NASA has adopted a performance measurement system for reporting planned and actual monthly expenditures. However, this system would not measure contractor performance against life-cycle or operations cost goals.

operations cost data and system resource consumption data to Level II on a monthly basis.

The 1985 report stated that reports on operations cost projections would be developed and used at specified program milestones, such as the systems requirements review, the systems design review, the preliminary design review, and the critical design review. A Level II space station official told us that NASA did not prepare a report on operations cost projections at the systems requirements review and that the operations cost section of the program's 1987 cost review served as the cost report for the January 1987 system design review. The other milestones cited in the 1985 report had not occurred at the time of our review.

Conclusions

NASA has yet to implement major portions of the operations cost management system described in its December 1985 report to the Congress, although it has made some recent progress in defining such a system and has studied operational cost impacts of some design decisions. NASA is also still working to establish substitutes for the benchmarks that were to have been established during the definition phase, and a reporting process to track progress against objectives.

NASA has recently renewed its efforts to adopt a directive that would establish the space station program's DTLCC policy and a centralized process to oversee future DTLCC analyses. NASA intends to modify the originally described DTLCC approach to focus on life-cycle cost optimizing designs that can be accommodated within constrained development phase budgets. NASA officials believe that these near-term budget constraints limit the program's ability to trade lower future operations costs for higher development costs.

NASA's recent preparation of a draft DTLCC directive is a sign of progress. Its assessment of the near-term budget constraints' impact on the DTLCC approach it outlined in 1985 may be correct. Nonetheless, NASA's modified DTLCC approach would increase the risk that it may have difficulty in controlling the space station's future operations costs. NASA recognizes that emphasis on constraining development costs can stifle the motivation to exchange lower future operations costs for higher near-term costs.

The extent to which NASA can manage this risk will be substantially determined by the content and timing of its still uncompleted cost control policy and system. Its ability to focus effective management attention on design change impacts on future operations cost will remain an

open question until a DTLCC directive, resource allocations, cost objectives, and related procedures and documents are formally adopted and incorporated into the program. If the Committee wishes to review a full description of NASA's new operations cost management policy and procedures as it considers future space station funding, it will have to request such information from NASA after mid-1988 and before the 1989 preliminary design review that will precede the bulk of space station design and development work.

Agency Comments and Our Response

NASA stated that we had presented a reasonably fair summary of its formal approach to understanding and managing space station life-cycle costs and that we had properly distinguished between the adoption of a formal process and NASA's actual decisions. However, NASA added that the draft report did not fully present much of the program's life-cycle cost efforts and that our focus on NASA's progress in developing a formal life-cycle cost control system had understated NASA's concern with and attention to life-cycle costs, as evidenced by actual NASA life-cycle cost decisions. NASA also stated that the space station program had made substantial progress in operations cost management since 1985.

Many of the specific examples cited by NASA to support these comments were noted in our draft report. However, in some instances, we could not give greater emphasis to these examples because—as we noted in describing our review's objective, scope, and methodology—NASA had been unable to provide supporting documentation in a timely manner, due to logistical problems within NASA. At a subsequent meeting to discuss the draft report, NASA officials provided us with technical comments, additional documentation of past life-cycle cost-related decisions, and indications of recent progress toward defining a life-cycle cost management system. We incorporated this information in this report, as appropriate.

We believe that the potential value of a formal process to ensure that all decisions consistently consider life-cycle costs is evident, particularly given the complexity of the space station, the involvement of several NASA space centers around the nation, and the scope of design and development effort to come. NASA's renewed efforts to define a programwide life-cycle cost directive suggest that it appreciates the importance of a formal process to ensure that projected future operations costs are weighed appropriately with design and development costs.

NASA to Define Specific Incentive Criteria

In 1985 NASA stated that it would consider incentives tied to the cost objectives to help keep down operations costs. NASA officials now expect to use contract award fees as incentives to control operations or life-cycle costs. NASA will have to develop life-cycle cost or operations cost criteria on which to base awards.

NASA officials informed us that NASA's criteria for selecting design and development phase contractors may have helped motivate concern for life-cycle cost considerations. Although such considerations may have played such a role, we could not determine their importance relative to other selection criteria.

Consideration of Incentives

NASA stated in its 1985 report that it would examine contractor incentive programs as a basis for development and operations phase incentives. It also stated that it would consider internal management incentives that would be tied to the operations cost objectives.

Level I officials provided us with two JPL studies concerning incentives and award fees. A June 1987 study, based on work unrelated to the space station, considered incentive contracting and regulation, and described selected procurement contracting relationships and mathematical formulas for various award schemes. A December 1986 study reviewed life-cycle cost constraining incentives in requests for proposals. The study discussed contractual mechanisms that could be used to encourage space station contractors to consider life-cycle costs in making their design decisions and recommended various award fee structures for specific space station work packages. NASA officials told us that the paper was not widely disseminated and that it did not affect NASA's preparation of requests for proposals. However, the officials informed us in March 1988 that they would consider it in developing award fee criteria.

NASA Use of Contractor Selection as a Cost Control Incentive

The 1985 report stated that NASA was preparing a cost policy for all phases that would require that cost awareness and control be criteria in contractor selection and awards. However, program officials did not formally adopt a directive containing such a cost policy. The Program Cost Management Process Requirements document does not contain such a requirement. In December 1987 the Acting Director of Level I operations informed us that NASA's criteria for awarding design and development contracts nevertheless served as an incentive to contractors to keep

operations costs low. NASA officials told us that the space station program required contractors to submit life-cycle cost control plans and other life-cycle cost related data in their proposals, and that it considered these data in selecting the contractors. We could not determine the importance that NASA placed on life-cycle cost factors in the selection process because NASA did not assign an individual weight to this factor.

Plans for Incentives

NASA officials expect that operations or life-cycle costs will be reflected in some form in the award fee structure of the final contracts for the design and development phases, but specific criteria have yet to be defined.

Award Fees

NASA plans to negotiate cost-plus-award-fee contracts with the space station program's design and development contractors. Under such contracts, the government pays the contractor for an allowable cost, a base fee, and award fees. Unlike the base fee, which does not vary with performance, all or part of the award fees are based on the government's judgment of how well the contractor met specified award fee criteria.

Levels I and II officials stated that award fees will probably be used to motivate contractors to keep life-cycle or operations costs as low as possible. The award fee structure will be established during the first half of 1988, as part of contract negotiations. The Associate Administrator for the Office of the Space Station will chair a headquarters-level fee determination board to review center-developed award fee criteria.

The form that the award fee criteria will eventually take is still unclear. In December 1987 the Program Director and other Level II officials informed us that specific criteria had not been prepared. The Marshall Center's design and development request for proposals states that the overall award fee criteria will be achievement in technical, safety, reliability, quality assurance, and schedule areas; project management; and cost. The Acting Director of Level I operations told us that the contractor performance regarding life-cycle or operations costs would be judged as part of the technical performance area and could be in the form of performance measures, such as projected logistics and spares needs or power-generation efficiency. Award fee criteria can be renegotiated every 6 months.

Life-Cycle Cost Reserve

A November 1987 draft of Level I's Program Requirements Document identified the lack of incentives and funding sources for development phase expenditures aimed at reducing operations costs as a key obstacle to development phase consideration of operations cost implications. As adopted in February 1988, the document instructs Level II to consider using funding reserves to support changes in configuration or operations that lower life-cycle costs.

The document does not call for a specific life-cycle cost reserve. An earlier draft provided for a reserve equal to 10 percent of development expenditures for "funding development investments that yield life-cycle cost savings." Similarly, a June 1987 JPL-drafted space station design-to-cost plan proposed establishing a $1.2 billion reserve fund to support such efforts. According to a Level II official, NASA officials resisted the dedicated reserve fund because they believed it would encourage contractors or centers to initially withhold promising life-cycle cost-reducing concepts and subsequently request reserve funds to explore such ideas. Program officials were also reluctant to endorse such a reserve because of the perceived lack of resources.

NASA Continues to Develop Operations Cost Estimating Capability

In its 1985 report, NASA stated that it would develop an operations concept to improve operations cost estimates and an operations cost model, and would "regularly" evaluate operations costs projections. NASA has taken steps to fulfill these commitments.

Operations Concept

In 1985 NASA stated that it would continue developing a space station operations concept to better define cost estimating ground rules. In September 1986 the Associate Administrator created the Space Station Operations Task Force to recommend concepts for managing and conducting space station operations. The task force, chaired by NASA officials with experience in manned and unmanned programs, established panels concerning space operations and support systems, ground operations and support systems, user development and integration, and management integration. The task force briefed the NASA Administrator in May 1987 and completed its report in August 1987.

The task force report outlined an operations "framework" to ensure manageable and safe operations to promote productive and flexible user operations. According to the report, the framework was aimed primarily at achieving space station utilization goals, although operations costs were considered as well. The report also included 30 recommendations. In November 1987 the Associate Administrator announced that he had directed Levels I and II to implement the task force's proposed concept. The Associate Administrator noted that many of the recommendations had been accepted and the remaining recommendations were under review. One of the accepted recommendations requires preparing an operations cost estimate using the task force's operations framework, facility requirements, and center assignments. Another calls for annual operations cost estimates that account for each element in the task force's operational framework.

Although the task force report was issued after NASA had completed a major cost estimating effort, NASA ground rules for a subsequent mature operations cost estimate instructed participants to consider the task force's recommendations. Levels I and II officials told us that they will base a space station operations concept document on the task force report.

Operations Cost Model

NASA's 1985 report referred to a space station operations cost model that was identified in the 1987 report as the Model to Estimate Space Station

Operations Costs (MESSOC). MESSOC is under development and is scheduled to be integrated into the program by late 1988.

JPL designed MESSOC to estimate operating costs and outputs during the space station's mature operations phase. It is intended to identify effects of changes to the space station's configuration and to its operations, crew, and logistics policies on mature operations costs and on intermediate outputs (which involve space station user-available resources, such as crew time). JPL staff informed us that MESSOC users will be able to explore the costs and benefits of various programmatic changes. (See app. II for a list of selected user inputs.)

MESSOC will compute operations costs in 20 cost categories for each specific space station scenario created by a MESSOC user. (See app. III.) During our review, JPL informed us that they had completed algorithms—sets of logically sequenced mathematical equations—for 17 categories concerning operation of basic space station elements. The three remaining algorithms—concerning customer integration, customer logistics, and a communication and data-handling infrastructure—were still under development.

MESSOC draws on nine data bases, which include information on replacement parts, sustaining engineering requirements, mission characteristics, and training requirements. Some data bases are still under development. For example, NASA does not have complete data on replaceable items or for sustaining engineering. The Level II Operations and Utilization Director informed us that one MESSOC data base included assumptions of overly large and heavy replacement parts, resulting in overestimated logistics and transportation requirements.

The Acting Director of the Level I Operations Division informed us that MESSOC's developers had made certain assumptions regarding operations issues which were still being resolved by the space station program. He also informed us that MESSOC data bases and algorithms were undergoing constant change and improvement. A Level II official told us that during 1988 NASA will enter the three remaining algorithms into MESSOC and fill the data bases with initial data. He also stated that NASA plans to validate MESSOC and to incorporate it into the space station program by September 1988. Because MESSOC focuses on mature operations, NASA is planning a variant of MESSOC to focus on operations costs during the launch and assembly period.

Operations Cost Estimates

In its 1985 report, NASA stated that it would regularly evaluate operations costs projections.[18] NASA officials identified several cost estimating exercises containing mature annual operations costs. NASA also has prepared partial estimates of operations costs that will be incurred before mature operations.

The operations cost estimates are limited to costs to be borne by the space station program and do not include significant space station-related costs borne by other NASA organizations—such as the cost of shuttle missions to the station, construction of facilities, and certain personnel.

1986-1987 Cost Review

In August 1986 the Administrator directed the Office of the Space Station to revalidate or modify NASA's existing space station cost estimate. NASA guidelines for the resulting cost review directed participants to estimate operations costs for fiscal years 1988 through 1998 and for fiscal year 2000, which was assumed to be a year of annual recurring, or "steady state," operations.

In January 1987 the Program Office estimated operations costs for fiscal years 1987 through 1998 at $6.3 billion and fiscal year 2000 operations costs at $954 million to $1.3 billion (1988 dollars).[19] In a February 1987 briefing to the Office of Management and Budget, NASA did not present these estimates. It instead provided an operations cost estimate for fiscal years 1988 through 1992 of $908 million in then-year dollars, which include estimates of future inflation.

NASA's later fiscal year 1988 budget submission to the Office of Management and Budget included a $3.4 billion estimate (1988 dollars) for operations costs to be incurred during fiscal years 1987 through 1996. A NASA Comptroller's Office cost estimator informed us that this estimate was also based on cost review data.

NASA officials informed us that the cost review operations cost estimates were based to some degree on "grass-roots" data, but were developed

[18]The evaluations were to have been based on the cost objectives. NASA has not adopted operations cost objectives. (See ch. 2.)

[19]These figures were converted from 1984 dollars to 1988 dollars by multiplying the original estimates by a NASA conversion factor of 1.193.

largely with analogous and parametric cost techniques.[20] Although cost data received from the centers were also cross-checked with MESSOC projections, NASA officials informed us that the center data submissions were not as rigorously analyzed as the development cost submissions and contained some overlapping, incomplete, or inconsistent information.

Post-Cost Review Estimates

After the cost review, NASA attempted to develop a new operations cost estimate through its Program Operating Plan (POP) process, in which NASA centers submit cost data as part of its annual budget process. As part of a June 1987 POP exercise, the Space Station Program Director asked the centers to estimate operations costs for fiscal years 1988 to 1998 and mature operations costs for the year 2000. Levels I and II officials told us that they did not release the POP operations cost results because of problems with the POP submissions, including inconsistent consideration of the Space Station Operations Task Force recommendations.

Levels I and II officials informed us that during the summer and fall of 1987 they extensively reviewed and revised the data in the submissions to reflect the program's operations decisions and recommendations. A Level II official stated that the Level II review attempted to integrate the task force recommendations with the POP data and to revise some engineering and logistics data. In November 1987 NASA released a $1.375 billion (1987 dollars) cost estimate for annual mature operations.[21]

A NASA space station operations official indicated that including total NASA-wide costs could raise the annual mature operations cost figure to $2.5 billion to $2.7 billion. Other NASA officials later advised us that this figure was developed in late 1987 as a potential pricing basis for charging the international partners and other non-U.S. government users of the space station for common operations costs, space shuttle costs, and satellite support costs.

[20]Grass-roots cost estimating techniques are used for very specifically detailed designs. They depend on a detailed simulation of all operations and an exhaustive list of all required materials. Experts consider the grass-roots approach to be one of the most accurate cost methodologies. Analogous cost estimating techniques are used when a new system is similar to an existing system and experience can be used to estimate costs. Parametric cost models are based on a set of general parameters, such as weight and thrust. Cost data for older systems' parameters are used to predict a new system's cost.

[21]This figure includes a 25-percent reserve fund ($275 million). The other cost categories are shown in table 2.1 on page 24.

Plans for Future Estimates

In December 1987 Level II officials told us that the Space Station Program Office will annually revise its operations cost estimate, possibly through the POP process. Level II has also accepted a task force recommendation for establishing a process for annual operations cost estimates.

System Design Trade-off Model

The space station program is developing the System Design Trade-off Model (SDTM) to help provide program managers with a tool for developing optimal space station designs at the lowest life-cycle cost. SDTM may be used by the SSCB's life-cycle cost analysts. JPL officials believe that SDTM could help assist communication and decision making among all levels by providing a consistent tool for evaluating proposed design changes.

SDTM will use engineering and cost data bases and algorithms supplied by experts and by models such as MESSOC. It will organize and summarize such data, and identify the life-cycle cost impacts of proposed design changes, partly by automatically "resizing" space station systems and by calculating the resulting changes in "housekeeping" consumption rates.[22] For each proposed change in the space station's baseline, SDTM would produce estimates of optimal system sizes, housekeeping specifications, expected costs, and resource values. Initially envisioned to include a cross-consumption matrix of 30 space station elements and systems, SDTM has been scaled down to a demonstration version with a 18-element matrix.

Because it integrates space station engineering formulas, algorithms, and data bases with station parameters and costing models, SDTM's developers hope that it will quickly and consistently analyze the impact of design changes on performance and life-cycle costs. Therefore, SDTM is intended to act as an engineering and integration tool, enabling managers to select an overall optimal space station-level design, while providing information to help control lower-level element and system-level choices. A Level II official told us that SDTM will be a better tool for conducting design trade-off exercises than MESSOC, which instead focuses on the mature operations cost impact of policy changes on a set space station configuration.

NASA officials characterized SDTM as a descendant of models developed during the definition phase. Plans to develop SDTM were not completed until late 1987 and it is currently less mature than MESSOC. In late 1987 the model was revised to accommodate concerns that it would force designers to select the designs it identified as the most life-cycle cost efficient. Level II officials informed us that a steering group has been established to guide SDTM development.

[22]Housekeeping requirements are resources needed to keep the space station itself operational. Resources required to support user payloads are not included.

Selected MESSOC User Inputs

Crew variables	Logistic variables
Crew by number and type	Logistic resupply cycle
Work hours per day	Maintenance criticality code
Work days per week	Level of repair option
Tour length	Depot-level spares depth
External vehicular activity observation time	Pipeline spares safety level
Training curriculum	Minimum ground spares stockage
External vehicular activity time	Test time during checkout
Tours per year	Schedule replacement or servicing time
Operational variables	**Cost variables**
Station altitude	First year of station operations
Shuttle flights by destination	Learning curve slopes
Expendable launch vehicle flights by type	Time horizon for accumulating costs
Payload and servicing mission sets	Launch vehicle cost per flight
Orbital maneuvering vehicle	Composite wage rates
Orbital transfer vehicle sorties	
Tracking and Data Relay Satellite System links	
Number and size of engineering support centers	

MESSOC Cost Categories

1. Element Support Center maintenance and support
2. Training operations
3. Flight design and planning
4. Flight implementation
5. Work package sustaining engineering
6. Software Support Environment and Technical Management Information System support
7. Maintenance documentation, data bases, procedures, and analyses
8. Inventory management
9. Ground transportation, handling, and storage
10. Ground support equipment maintenance and support
11. Intermediate/depot-level repairs
12. Flight equipment spares
13. Element processing/reprocessing
14. Consumables
15. National Space Transportation System/expendable launch vehicle services
16. Integration management and institutional support
17. Flight crew pay and allowances
18. Customer integration operations
19. Customer logistics and payload maintenance
20. Communications/data handling infrastructure

Comments From NASA

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of NPN

MAR 2 8 1988

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International
Affairs Division
U. S. General Accounting Office
Washington, DC 20548

Dear Mr. Conahan:

We appreciate the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled, "Efforts to Control Future Operations Costs Through a Design-to-Life-Cycle Cost System," dated February 26, 1988.

NASA feels that the GAO has presented a reasonably fair summary of our formal approach to understanding and managing Space Station Program life-cycle costs. However, much that the program has done in this area is not fully presented in the report. A number of these activities are addressed in the enclosed comments.

Sincerely,

M. Peralta
Associate Administrator
for Management

Enclosure

NASA Comments on GAO Draft Report:

"SPACE STATION: Efforts to Control Future Operations Costs Through a Design-to-Life-Cycle Cost System"
Dated February 26, 1988

The draft report appears to be an adequate review of the status of NASA's progress in adopting a formal approach to controlling operations costs. The report properly distinguishes between the adoption of a formal process and actual NASA decisions that reflected life-cycle cost considerations. Since the report concentrates on the former and NASA has made major decisions concerned with life-cycle costs, the report understates NASA's concern with, and attention to, life-cycle costs. We briefly summarize below NASA's progress in both formal process and major decisions. We have arranged these in the format of the GAO report.

Life-Cycle Cost -- NASA's Space Station design is rooted in satisfying user requirements and achieving affordable life-cycle costs. At the beginning of the program definition phase, program managers identified the key configuration decision areas where operations costs would be a major factor. These areas were specifically addressed during the definition phase and resulted in the series of design decisions which were described in the December 1985 and October 1987 reports requested of NASA by the Congress. During calendar year 1987, these decisions were reexamined and reconfirmed. Considerable life-cycle cost savings were thus achieved by the Space Station Program.

Life-cycle cost continues to be a commitment of Space Station Program management as NASA enters the development phase. This commitment was demonstrated recently by the Program Director and all levels of NASA management by retaining the life-cycle cost-effective systems in the baseline, as opposed to changing to systems with lower initial development costs but which increase life-cycle costs. The Space Station top-level Program Requirements Document requires that the program perform systematic analysis of life-cycle cost impacts as an integral part of configuration decisions; that Level II maintain an independent life-cycle cost analysis capability; and that a modeling capability exist to provide rigorous life-cycle cost analysis.

A forthcoming directive on design-to-life-cycle cost (DTLCC) describes the respective responsibilities of Levels II and III organizations in a rigorous approach to life-cycle cost management. This directive is designed to implement the intent outlined in the December 1985 report to Congress on "Space

Station Operations Cost Management." The December 1985 report outlined an ideal process in which NASA could trade off the investment cost of developing the Space Station with operations costs. The implementing directive recognizes today's more constrained environment, focusing on stimulating life-cycle cost-beneficial design ideas that can be implemented within the program's development phase funding envelope.

Benchmarks and Reporting System -- The key to life-cycle cost management is to understand the design areas that drive operations costs, and to establish monitoring and control methods that provide design incentives which constrain or lower those costs. A major effort in these design management activities is to appropriately allocate scarce resources. Some resources will be required to maintain the Space Station in an operational and usable state; but, clearly, the objective is to provide a cost-effective level of these resources to users. The Program will consider life-cycle cost as a major aspect of its efforts to design the Space Station to satisfy both demands for these resources.

To help in accomplishing both these goals, the program has established a resource allocation matrix to track the use and availability of Space Station resources as design alternatives are examined. For example, mass-to-orbit and Space Station crew time are two highly valued resources. The October 1987 report identified transportation and hardware spares costs as two of four key operations cost drivers. These on-orbit resources and operations cost drivers are directly related, and the program is quantifying these relationships, and their ties to life-cycle costs, through models and other analysis tools. Through judicious assignment of target numbers in the resource allocation matrix, the program will balance user and life-cycle cost requirements. Designers will be required to live within these resource allocations, and, through them, will be able to see the impacts of design changes to their systems on both themselves and any other affected systems.

Resource allocations and other technical requirements are managed through a rigorous change control process. Key requirements are controlled by the Space Station Control Board (SSCB), chaired by the Program Director. Variances from these allocations must be reported, and requests for changes must be approved in this forum. The independent Level II life-cycle cost analysis capability mentioned above will function in support of the SSCB, enabling the Program Director, in making design decisions, to weigh the life-cycle cost impacts along with performance impacts on safety, user and other requirements. Where life-cycle costs can be associated with the systems that produce these resources, these will be issued to managers of these systems. In addition, the estimation of operations costs, as described below, will provide benchmarks against which the impacts of all types of programmatic changes can be assessed.

Incentives -- Along with such management controls, the program is also examining the use of award fee structures to provide contractors with effective incentives for life-cycle cost control. The purpose of such an incentive structure is to generate new design trade-offs, such as the search for optimal ORU definitions (orbital replacement units are components at a level that can be readily dealt with by Space Station crew) to lower costly logistics resupply requirements.

Operations Cost Estimation -- Along with Space Station design efforts, NASA has progressed substantially in planning for Space Station operations. The October 1987 report to Congress described the work of the Space Station Operations Task Force in developing an operation concept. This work has been adopted by the Space Station Program, and forms the basis for operations planning activities through the development phase. In addition, the Space Station Program assessed operations costs in 1985, 1986, and 1987, and plans to do so yearly. Each has been more detailed than the prior estimates, and the operations cost assessment of 1987 took into account the recommendations of the Operations Task Force. The program has continued the development of its operations cost modeling capability, and a model to estimate mature operations costs will be completed and validated this year.

Summary -- The Space Station program has made substantial progress in operations cost management since 1985. The issuance of the DTLCC directive and subordinate documentation, delayed by the major changes in the program management structure in 1986 and 1987, will provide the formal structure for these ongoing activities. While development phase funding constraints limit the range of options available to the program for operations cost reduction, many productive steps can be taken; most are now are underway. Near-term steps to be taken include: determination of contract award fee structures; completion of initial resource allocations and design evaluation models, which tie the resource allocations to operations cost estimates; and performance of specific technical and cost studies in logistics and other key areas.

Several extensive configuration analyses, which included operations cost impacts, have been conducted since the initiation of the Space Station program. Both development and operations cost estimates have played a large role in choosing a configuration and the capabilities that best balance these costs with user requirements. Operations concept development and operations cost estimation techniques are more mature at the beginning of the development phase of the Space Station than those of any previous space program beginning its

development phase. Thus, with the lessons and products of these efforts in hand, NASA is ready to begin development of a Space Station that is both productive and life-cycle cost affordable.

Andrew J. Stofan
Associate Administrator
for Space Station

Date: 3/25/88

*U.S. G.P.O. 1988-201-749:80123

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