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Space Station Engineering and Technology Development

Proceedings of the Panel on
Program Performance and
Onboard Mission Control
August 6-7, 1985

Ad hoc Committee on Space Station Engineering
and Technology Development

Aeronautics and Space Engineering Board

Commission on Engineering and Technical Systems

National Research Council

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Panel on Program Performance and Onboard Mission Control

Members

JOSEPH F. SHEA (Chairman), Senior Vice-President, Engineering,
Raytheon Company
LAWRENCE R. GREENWOOD, Vice-President, Strategic Operations,
Ball Aerospace Systems Division
JOHN V. HARRINGTON, Consultant
DONALD P. HEARTH, Director of Space Sciences and Technology,
University of Colorado
RICHARD W. HESSELBACHER, Manager, Division Advanced Development and
Information Systems, Space System Division, and President, Management
and Technical Services Company, General Electric Company
KENNETH F. HOLTBY, Senior Vice-President, The Boeing Company
ARTUR MAGER, Consultant
WALTER B. OLSTAD, Director, Strategic Planning, Lockheed-California
Company
JAMES T. ROSE, Director, Electrophoresis Operations in Space,
McDonnell-Douglas Astronautics Company
ALTON D. SLAY, Slay Enterprises, Inc.
CLARENCE A. SYVERTSON, Consultant
BYRON D. TAPLEY, Clare Cockrell Williams Chair of Engineering,
Department of Aerospace Engineering, University of Texas

Additional Participants

DAVID CRISWELL, CalSpace Institute
ALLEN S. HILL, Boeing Aerospace Company
CHARLES MATHEWS, Consultant
GEORGE B. MERRICK, Rockwell International
ROBERT MORRA, Martin Marietta Aerospace
ROBERT M. POWELL, Lockheed Missiles and Space Company
S. M. REDELSHEIMER, McDonnell Douglas Astronautics Company
REGINALD M. RHUE, The Johns Hopkins University Applied Physics
Laboratory
ARTHUR R. THOMSON, Cleveland State University

NASA Presentors and Participants

MARK ALSPAUG, NASA Johnson Space Center
DAVID BATES, NASA Johnson Space Center
MILT CONTELLA, NASA Johnson Space Center
BRYANT CRAMER, NASA Headquarters
AL HOLT, NASA Johnson Space Center
THOMAS KLOVES, NASA Johnson Space Center

ALLEN LOUVIERE, NASA Johnson Space Center
MARION PRINGLE, NASA Johnson Space Center
JOSEPH TALBOT, NASA Johnson Space Center
RICHARD THORSON, NASA Johnson Space Center

NASA Liaison Representatives

RICHARD F. CARLISLE, Deputy Director, Engineering Division, Space
Station Office
JAMES M. ROMERO, Assistant Director for Space Station Technology,
Office of Aeronautics and Space Technology

ASEB Staff

BERNARD MAGGIN, Project Manager
JULIE A. FERGUSON, Project Assistant

Ad hoc Committee on Space Station Engineering and Technology Development

Members

JOSEPH F. SHEA (Chairman), Senior Vice-President, Engineering,
Raytheon Company
LAWRENCE R. GREENWOOD, Vice-President, Strategic Operations,
Ball Aerospace Systems Division
JOHN V. HARRINGTON, Consultant
DONALD P. HEARTH, Director of Space Sciences and Technology,
University of Colorado
RICHARD W. HESSELBACHER, Manager, Division Advanced Development and
Information Systems, Space System Division, and President,
Management and Technical Services Company, General Electric Company
KENNETH F. HOLTBY, Senior Vice-President, The Boeing Company
ARTUR MAGER, Consultant
SIDNEY METZGER, Sidney Metzger and Associates, Engineering Consultants
WALTER B. OLSTAD, Director, Strategic Planning, Lockheed-California
Company
JAMES T. ROSE, Director, Electrophoresis Operations in Space,
McDonnell-Douglas Astronautics Company
ALTON D. SLAY, Slay Enterprises, Inc.
CLARENCE A. SYVERTSON, Consultant
BYRON D. TAPLEY, Clare Cockrell Williams Chair of Engineering,
Department of Aerospace Engineering, University of Texas
LAURENCE R. YOUNG, Professor of Aeronautics and Astronautics,
Massachusetts Institute of Technology

ASEB Staff

BERNARD MAGGIN, Project Manager
JULIE A. FERGUSON, Project Assistant

Aeronautics and Space Engineering Board

Members

JOSEPH F. SHEA (Chairman), Senior Vice-President, Engineering,
Raytheon Company
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Corporation
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Information Systems, Space System Division, and President,
Management and Technical Services Company, General Electric Company
KENNETH F. HOLTBY, Senior Vice-President, The Boeing Company
JAMES J. KRAMER, Manager, Advanced Technology Programs, General
Electric Company
PETER W. LIKINS, President, Lehigh University
DONALD J. LLOYD-JONES, Consultant
STEPHEN F. LUNDSTROM, Associate Professor in Electrical Engineering
(Research), Center for Integrated Systems, Stanford University
ARTUR MAGER, Consultant
STANLEY MARTIN, JR., Vice-President, V-22 Engineering, Bell
Helicopter Textron
JOHN F. McCARTHY, JR., Northrop Corporation
JOHN L. McLUCAS, Communications Satellite Corporation
IRWIN MENDELSON, President, Engineering Division, Pratt and Whitney
Aircraft Group
JAN ROSKAM, Ackers Distinguished Professor of Aerospace Engineering
and Director, Flight Research Laboratory, University of Kansas
ROGER D. SCHAUFLELE, Vice-President, Engineering, Douglas Aircraft
Company, McDonnell Douglas Corporation
RICHARD S. SHEVELL, Professor, Department of Aeronautics and
Astronautics, Stanford University
ROBERT E. SKELTON, Professor of Aeronautics Engineering,
Purdue University
ALTON D. SLAY, Slay Enterprises, Inc.
MORRIS A. STEINBERG, Vice-President, Science, Lockheed Corporation
LAURENCE R. YOUNG, Professor of Aeronautics and Astronautics,
Massachusetts Institute of Technology

Executive Staff

ROBERT H. KORKEGI, Executive Director
JOANN CLAYTON, Senior Professional Associate
A. J. EVANS, Senior Professional Associate
BERNARD MAGGIN, Senior Professional Associate
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Preface

In 1984, at the request of the National Aeronautics and Space Administration (NASA), the Aeronautics and Space Engineering Board (ASEB) undertook a study of NASA's space station program. The results of this study by the ASEB's ad hoc Committee on Space Station Engineering and Technology Development were published in February 1985. NASA found the study useful and asked the ASEB to continue examination of the evolving space station program through a series of more specific studies on:

- maintainability,
- research and technology in space,
- solar thermodynamics research and technology,
- program performance,
- onboard command and control, and
- research and technology road maps.

The subjects of maintainability, research and technology in space, and solar thermodynamics research and technology have already been the subjects of committee roundtable and workshop panel meetings. The subjects of space station program performance and onboard mission control, addressed in a roundtable forum by another committee panel are reported here in the form of meeting proceedings. It was the intent of this meeting to provide NASA with an insight into non-NASA experience that has the potential for improving space station system program performance from cost and mission operations considerations.

The panel consisted of selected members of the ASEB ad hoc space station committee and representatives from industry with special knowledge and experience in the areas of program performance and mission command and control. In the roundtable, individual panel members discussed their views on these matters and NASA representatives presented summaries of related space station program activity. The panel, in light of discussions with NASA representatives and further deliberations within the panel, developed summary statements of findings.

These proceedings contain synopses of the panel's discussion and NASA's presentations as well as the panel's observations for further consideration by NASA's space station program management. Several matters are addressed in these proceedings that warrant specific consideration by space station program management:

- Focusing on improving cost estimates to allow identification of cost drivers and to assist in program descoping, if descoping is required.
- Developing top-level directives that explicitly identify program philosophy, technical guidelines, and performance and cost constraints to provide a firm base for program definition, development, and support activity.
- Reviewing management lines of authority, responsibility, and staffing to assure single lines of direction and action; adequate staffing of critical functions, i.e., system operations; and best use of staff, i.e., interface management.
- Reserving bridge-type command and control operation for the space station and routine, daily, and long-term planning and operations support for the ground to allow appropriate use of the space crew.
- Making the program and contractor management fully aware of and sensitive to the matters of cost reduction and cost and schedule control to help hold program technical and cost factors within commitments.

JOSEPH F. SHEA
Chairman, Panel on Program Performance
and Onboard Mission Control

Acknowledgments

The panel appreciates the time, effort, and candor of the NASA representatives who provided information and engaged in open discussion during deliberations.

As with the other technical subjects reviewed in this series of roundtables and workshops on the evolving space station program, the panel recognizes that the program is in the concept development stage. Within a matter of not too many months, program management will have to firm up specifications and guidelines for the start of preliminary design. It is in this context that the panel makes its observations with a view to assisting NASA in accomplishing its difficult task.

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Introduction

BACKGROUND

In 1984 the ad hoc Committee on Space Station Engineering and Technology Development of the Aeronautics and Space Engineering Board (ASEB) conducted a review of the National Aeronautics and Space Administration's (NASA's) space station program planning. The review addressed the initial operating configuration (IOC) of the station. The committee's study was released in February 1985. NASA factored the results of the study into its Phase B (concept and preliminary design) request for proposals issued to industry in September 1984 and awarded in April 1985.

As a result of the committee's work, NASA asked the ASEB to reconstitute the ad hoc committee to address:

- onboard maintainability and repair,
- in-space research and technology program and facility plans,
- solar thermodynamic research and technology development program planning,
- program performance (cost estimating, management, and cost avoidance),
- onboard versus ground-based mission control, and
- technology development road maps from IOC to the growth station.

The objective of these new assignments is to provide NASA with advice on ways and means for improving the content, performance, and/or effectiveness of these elements of the space station program.

In response, the ASEB reconstituted the ad hoc committee. The committee established panels to address each subject. The participants of the panels come from the committee, industry, and universities, providing each panel with individuals experienced in the subject of special interest.

In view of NASA's interest in program definition and development, it was decided that the subjects of maintainability, program performance,

and onboard mission control would be addressed in roundtable forums focusing on concepts, system design, and organization.

It was decided that the subjects of research and technology in space, solar thermodynamic research and technology development, and technology development road maps would be addressed in workshops that focus on NASA program activity and plans.

To expedite the documentation and dissemination of the information, the deliberations of the panels are being reported as proceedings. The proceedings of the Panel on Maintainability were published in May 1985 and those of the Panel on In-Space Engineering Research and Technology Development, in August 1985. The proceedings of the Panel on Solar Thermodynamics Research and Technology Development are under final review. The proceedings of the Panel on Program Performance and Onboard Mission Control are presented in this report. No date has been set for the technology development road maps workshop.

THE PANEL ON PROGRAM PERFORMANCE AND ONBOARD MISSION CONTROL

The task statement for the Panel on Program Performance and Onboard Mission Control set forth that:

NASA will explain the background of the roundtable and present an overview of the program, but not the program approach [in any detail]. It is not intended for the panel to critique the program. . . . It is expected that a major benefit of the round table will come from the real time exchange of ideas among the panel and the NASA participants.

Possible discussion subjects for the meeting are:

- approaches to cost reduction and elimination through engineering design, development, production, test and evaluation, and operations
- management concepts for control of costs: design reviews, change control, and cost tracking
- contracting techniques to encourage the achievement and holding of low costs, schedules, and performance
- advantages and disadvantages of onboard versus ground-based space station command and control
- appropriate split of roles for the initial operating configuration and for the evolving (growth) station
- the relative roles of redundancy, automation, and remote expert advice
- design and development philosophy and implications

Specific points of interest are:

- non-NASA techniques for system design and documentation requirements and their potential cost impacts

- possible reductions in NASA programmatic procedures
- application of non-NASA standards
- alternate approaches to program reviews
- alternate approaches to configuration management
- alternate approaches to verification tests
- alternate approaches to cost estimating
- suggestions for alternative deliverable data

The proceedings reported herein cover the panel's meeting at the NASA Johnson Space Center on August 6-7, 1985. The meeting agenda is presented in Appendix A. The list of panel members and participants is presented on pages iii-iv.

The panel was briefed by NASA representatives; panel participants discussed their views on program performance and mission command and control; the panel engaged in general discussion; and then the panel organized into three subpanels. Two subpanels addressed the cost model and cost containment aspects of program performance; the third addressed mission command and control. The observations of the subpanels were reviewed with the full panel and NASA space station program representatives.

This proceedings report presents the results of this process in two parts. The first part deals with program performance, the second part with mission control. A final section presents the panel's summary observations. Comments and observations are presented without attribution.

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Panel Deliberations

INTRODUCTION

The chairman, Joseph Shea, and the NASA liaison representative from the Office of Space Station, Richard Carlisle, reviewed the background and objectives of the meeting, including the past activity of the ASEB's ad hoc Committee on Space Station Engineering and Technology Development.

The panel took up its two subjects, program performance and mission command and control, in separate roundtable discussions. Subpanels were formed to comment on and develop their observations on each subject. Mr. Carlisle's introductory comments and panel deliberations on the two subjects of the meeting are presented in this chapter. The following chapter summarizes the panel's observations.

Panel Objectives

Mr. Carlisle noted that through analyses, NASA has found a wide disparity between cost estimates for unmanned and manned space system hardware, software, and support. This disparity has caused concern about the ability to project costs for a new system, such as the space station. This concern has been amplified by wide differences in industry cost estimates for similar hardware elements. Specific comparisons of system manufacturer, Department of Defense, and NASA costs for similar subsystems show difference ratios of 1 to 10. This situation does not result in a comfortable feeling that the \$8 billion cost target for the initial operating configuration (IOC) space station will be realized.

As reported later by David Bates (p. 10), early cost estimates for the baseline program indicated costs higher than the \$8 billion target. Present IOC cost estimates indicate that holding to the \$8 billion cost target may not result in an acceptable program. Operations costs (ground and space) are of equal concern. If cost estimates cannot be relied on, it will be difficult to make meaningful trade-off analyses and system selections.

NASA has these basic questions: Why do NASA manned space systems cost more than unmanned space systems? Can costs be held down? Can costs be controlled?

Mr. Carlisle noted that he hoped the panel would discuss these and related matters openly to allow NASA representatives to gain from the panel's experience. Thoughts on methods of cost estimating are of special interest in view of the importance of cost estimates to program definition. He viewed this kind of discussion as more productive than a critique of what NASA is doing.

It is recognized that, ideally, cultural changes in the organization and/or management techniques may be indicated. However, to be realistic, the proposed changes have to be the type that can be accommodated by the agency.

The charge to the panel is to concentrate on space station engineering related to system analysis, design, operations, and program performance; therefore, there is a need to give attention to the differences between the projected space station program and earlier NASA programs.

PROGRAM PERFORMANCE

Panel Discussion

It is recognized that the space station is different from other manned space flight programs in that earlier missions (Mercury, Gemini, Apollo, Skylab, and Shuttle) were more specifically defined and did not have specific funding constraints. The space station mission has a cost target (IOC, \$8 billion), but the system is relatively undefined. Under these circumstances, it is difficult to estimate costs even if costs could be reasonably identified, which is not the case.

The panel's comments related to cost modeling and confidence and cost containment follow in the form of summary statements. These summary statements are followed by a synopsis of NASA costing activity and panel observations on program performance.

Cost Modeling and Confidence

With regard to cost modeling and confidence, basic questions were: What type of cost modeling might be appropriate? How might confidence in the estimates be improved? The panel's comments are summarized here.

Top Level Directives It was suggested that top-level program management, Level A, provide program guidance through a directive to set firm, top-level program philosophy, constraints, and cost targets and to instill design guides and cost consciousness in the program.

Establishing a Cost Base Definition of system capability and performance (top down) is key to delineating production and operations activities and to establishing a cost base. It may be necessary to bring a team (including contractors) together for this purpose because of the many interfaces and the need for good communications. The contractors selected should understand the process and its importance and have had experience with this type of estimating activity.

Cost Targets NASA needs to be explicit about IOC program costs. For example, NASA should note specifically that the amount is \$8 billion, not \$12 billion, or \$10 billion, not \$14 billion. There should be no uncertainty. Firm selection of a cost constraint should be done early to anchor the program. Leaving open the issues of program definition and costs reduces management focus and motivation for cost control. What is to be procured? What does the \$8 billion cover--design, development, IOC operations, NASA manpower?

Forcing Cost Analyses It is important to have cost targets to force cost analyses. Existing technology should be used to define the base system. Every subsystem cost beyond those of the base subsystems should be treated as an increment of cost that can be reduced.

Reduction of Program Content The representative baseline program costs assessed by NASA from in-house analyses are too high. An approach to reducing cost is to reduce program content and not necessarily to take an average cost reduction in all program segments.

Cost Estimate Improvement The program costs (contracted hardware and support) that have been developed were not derived in a consistent manner. NASA believes that the cost estimates will become more believable as the preliminary design phase of the program, the second part of Phase B, evolves.

Fitting Models to Hardware Good cost modeling is important if high-cost items are to be identified and costs reduced. Historical data can be used to build cost models, but the systems have to be similar in performance and content and in design, development, and testing if the cost models are to be relevant.

NASA Cost Estimating The panel needs a better understanding of NASA cost-estimating activity. (See page 10.)

Use of Common/Standard Hardware The space station is a new type of system for NASA because it will be designed for long life through repairability and maintainability. NASA experience, including cost estimating, does not include this class of hardware. For the space station, NASA should reexamine the matter of common/standard hardware (the same hardware used in more than one system) that it had once pursued as an approach to reduce program costs.

Cost Containment

With regard to cost containment, the basic question is: How can costs be contained or reduced once a program is defined and costs estimated? The subpanel's comments are summarized in the following paragraphs that deal with matters ranging from cost targets to interface documentation to the use of NASA in-house staff, contractor direction, and type of contracting.

Cost Targets Design-to-cost targets are needed early, down to at least the major subsystem level. Development of these cost targets will assist in cost trade analyses between design, development, test, and operations considering both IOC and growth. These cost targets need to be communicated to all levels of the program. However, it should be recognized that arbitrary cost constraints can adversely affect the project through the curtailment or elimination of required work.

Responding to Payload Requirements System design requirements are responsive to projected payload programs that have not and may not be funded. Therefore, requirements and costs may be overstated. The need to support overstated requirements may be conditioned by the belief that such responsiveness is required to retain a constituency. However, this, in part, may be the reason the science community is reluctant to support fully the space station. They may be concerned that costs will not be controlled and that large costs will have an adverse impact on funds available for science.

Design Constraints If cost is to be a serious program driver, design and development constraints must be mandated; one such constraint may be use of existing technology. An issue explored was: Is the space station program to be used to accelerate technology development or is the space station to use existing technology? Design specifications and cost considerations are affected by the selection of this constraint. It is the panel's view that, in general, available technology should be used to help hold costs and schedules.

Technology Development Both the use of technology not ready for application and changes in technology adversely affect schedules and costs. Early definition and development of critical technologies minimizes these adverse effects. Selective support and application of successful technology developments are important to enhancing space station performance and controlling costs.

Program Structure It is important to structure the program so that it can be reduced in size and/or scope through reduction and/or removal of program elements while retaining an acceptable, viable program. For example, incremental reductions in electric power generation for IOC and increased subsystem specification flexibility to allow adjustment of performance margins in response to system performance adjustments and/or cost constraints should be considered.

Two-Stage Design It may be possible to treat the design of the space station like that of a large commercial airplane. In the first time

through, focus on the design process, with concentration on design-to-function; in the second, concentrate on lowering costs.

Low Volume Production "Single"-item procurement causes high costs because costs cannot be reduced through knowledge gained through experience. There are ways around this: use of available and common hardware; accurate statements of requirements; and holding specifications to needs. Stringent safety requirements will increase costs. Safety and other design requirements should be reviewed for appropriateness.

Manufacturing/Test Options A way to contain costs is to have design teams explore more than one approach to manufacture and test and to look hard at simplification of interfaces.

Repairable/Maintainable Design DOD and NASA missions have been designed to provide essentially 100 percent operational capability even when a component fails. There is no general need for a "100 percent operational" design philosophy for a repairable and maintainable space station.

Interface Documentation and Control Good interface documentation and control (to minimize errors and reduce costs) is required in view of the number of contractors and NASA centers involved in the program. It would be desirable to define and organize this activity early with contractor input.

Computer-Aided Design and Manufacturing CAD-CAM can help control interfaces through easy access to common specification, design, and fabrication data bases. These techniques can also help assure a consistent tie between systems and structures, allow concurrent design and development activity, and assist in rapid, accurate change control.

Change Control A tight, quick change-control process can reduce costs. Although fast action is desirable, care should be taken in the system to avoid adverse change impacts and redundant change actions. Early setting of design specifications and change-control ground rules will help minimize rework and costs. Once specifications are set, they should be followed, with change implemented only due to a significant reason.

Out-of-Specification Flexibility Systems engineering decisions must be flexible enough to accommodate what is "out-of-specification but acceptable" to avoid rework costs.

Test Procedures To help minimize cost, articles should be obtained and tested early. Test requirements should not be imposed without a real need. Instead of repeating tests at higher levels of build-up, test and operational procedures should be established that build up and build on test activity, thereby minimizing inspection and check-out. It is better not to test to destruction. The same and/or similar evaluation equipment should be used through ground and flight operation.

Design and development changes can be expected in the "one-of-a-kind" space station program. Development test procedures can reduce equipment needs, changes, and adjustments. Consideration should be given to procedures such as subcritical testing and burn-in operation of equipment versus destructive testing, as well as to the use of built-in testing versus special test equipment.

Manned System Testing A review of acceptance testing (some one-third of manned system program costs) appears appropriate. NASA's manned systems have required greater levels of testing than have unmanned NASA and DOD systems.

Services and Support Space station costs appear to be 20 percent for hardware and 80 percent for other services and support. Unmanned spacecraft systems have an 80 percent/20 percent split. The "80 percent" space station activity needs to be examined for validity.

Standard/Common Parts High reliability and lower costs are enhanced through actions that provide parts control, standardization, and commonality.

Standards and Procedures Some standards, procedures, and operations (e.g., soldering specifications) may not represent the best state-of-the-art and can cause costs to rise. Standards and procedures should be reviewed for currency and applicability.

Ground and Space Control A hard, early look should be undertaken at on-ground support to hold down costs. It is recognized that the on-orbit control and management system will evolve through the period of build-up to IOC operation. In this period, it is anticipated that ground-based support will decrease and onboard mission command and control will become more self contained. It is also anticipated that the ground-support staffing will be reduced in time through automation of routine activity and special functions such as fault detection, isolation, and repair identification. These transitions need to be planned, recognizing that they will be based, to a degree, on operational experience.

Use of Crew Crew time in space, a valuable commodity, should be conserved. The crew should be used for mission work to the degree possible. The IOC should remain simple, and major diagnostics and planning for station rework, etc. should be done on the ground. It should be less costly to do mission control support work on the ground. An approach to maximizing crew time for payload work would be to restrict the crew to work required to keep the system operationally safe and useful between shuttle service (90-day) flights.

Use of In-house Staff NASA in-house staff could be used for in-line program support, as part of the design team, e.g., as the hardware and software test, acceptance, and/or integration team. This would put NASA in a strong technical position with respect to knowing the systems and would assist in reducing the contractor work force as the program matures.

Management Overview Non-hardware program costs can be high due to management overview and review. Compared to nongovernment civil programs, government management costs are two to three times as great, possibly greater. An analysis is needed of the kind, number, and content of reviews with action directed at reducing them.

Responsibilities of Managers In support of fast, knowledgeable decision making, NASA subsystem managers should be responsible for the technical, schedule, and cost aspects of their programs. These functions should not be separated as appears to be the general case.

Funding Stability Funding instability will cause cost escalation. An attempt should be made to eliminate unplanned fluctuations in actual budgets although such fluctuations are difficult to control.

Contractor Direction It is important that NASA avoid telling people (contractors) "how-to-do." NASA should direct attention to "what-to-do" and allow contractors more freedom to pursue high performance at low cost.

Type of Contracting Several factors may create high costs: the type of contracting selected (unnecessarily restrictive and no incentives), the differences between planned and actual work, and planned and actual deliverables. System specifications need to be pragmatic and cost targets set to provide a framework for controlling and trading cost and product.

NASA Costing Activity

Following the roundtable discussion, David Bates of the NASA Johnson Space Center (JSC) Space Station Program Management Office, management Level B, presented a brief overview of the cost-estimating methodology used by Level B. The graphics he used are presented in Appendix B. After panel discussion of this overview, Allen Louviere of JSC commented on Level B's costing responsibilities.

Cost Estimating Methodology--David Bates, JSC (Briefing Graphics--Appendix B)

Both prime and non-prime contract cost elements are used to develop the total space station program cost estimates. The major program hardware elements (station, platforms, attached payload accommodations, and other costs called wrap--those costs not associated with the hardware but with program support activity) make up the prime costs. The non-prime costs include fee, reserve, and program definition activity.

It is estimated that of the 100 percent prime development costs, 60 percent pays for hardware and 40 percent pays for wraps. Non-prime program costs are estimated to be about 35 percent of the program's

development costs and include program reserves. NASA's manpower and related overhead costs are not included in the prime and non-prime costs.

Early cost estimates for the baseline program revealed costs higher than the \$8 billion target. Present IOC cost estimates indicate that holding to the \$8 billion cost target may not result in an acceptable program.

The early cost estimates for the reference space station configuration were refined through reexamination of assumptions, upgrading of cost models, use of contractor estimates, and inclusion of program elements originally overlooked. The soundness of the estimates are in question due to several factors: the broad variation in estimates from different sources for similar program elements; the difference in cost-estimating procedures and models used by the different work package teams; the use of weight and complexity factors as a simple way to modify existing models; a mix of data from manned and unmanned systems; and assumptions related to cost savings associated with the application of protoflighting and commonality. In addition, wraps and other cost factors are best guesses because of the open state of program definition.

Level B recognizes that the development of good cost estimates is hampered by additional factors: the number of system elements, interface uncertainties, lack of test and development plans, failure of the cost models to be truly applicable, and strategic over- or under-costing. Level B also recognizes that system weight is not a good cost function for many of the systems being costed even with the application of correction factors to adjust the models for complexity.

Comments and observations made during the overview briefing are noted here.

- NASA space station staffing (some 2,000 people) is significant, approaching a cost of \$840 million for the 7 years leading to IOC.
- Hardware versus support costs are targeted for 65/35, exclusive of NASA in-house manpower and overhead costs.
- To help hold costs to the \$8 billion target, it is assumed that the orbital maneuvering unit (OMU) will be funded by the Shuttle program and procured from that program by the space station program.
- Support costs for foreign systems have not been factored into the cost estimates.
- Level B is pursuing the development of independent cost estimates to provide a basis for evaluating contractor estimates.

- NASA's manned and unmanned system cost models have different cost trends with increasing weight, with the manned systems costing more per pound. The cause (or causes) of the differences is being examined, keeping in mind that parameters other than weight have to be considered.
- As a rule it is necessary to find systems as close as possible to the ones being costed and scale them if reasonable estimates are to be attained. Most of the models illustrated appear to be too far removed from the new systems being considered. Some systems are not necessarily weight related in the classical sense, i.e., software, electronic controls, and data systems.
- The Shuttle itself imposes costs due to packing and performance limits for both IOC and operations support. To reduce logistic costs, NASA should examine, if it is not already doing so, the ability to improve Shuttle load factors and performance.
- The ground control center will not be an initial area for reduced operations and, therefore, cost savings. But, in the longer term, it should be possible to simplify and reduce those operations and costs.

Costing Responsibilities--Allen Louviere, JSC

Allen Louviere, of the JSC Systems Engineering and Integration Office, discussed the office's program cost-estimating responsibilities. The office is sensitive to the problems of fully representing and costing the space station program and is covering matters other than major hardware: maintainability and redundancy, commonality and spares, growth and scaring (preparing for additions). Some cost matters have not been addressed adequately: on-orbit assembly; spare part requirements; launches (estimated at 12 to 15 for IOC); verification, fault detection, and checkout; interface and customer support requirements; and payload servicing. It is recognized that improvement in space transportation capability needs attention; it can beneficially affect design and support costs.

The office fully intends to address IOC versus operational versus growth costs to optimize life-cycle costs. The office is sensitive to the need to examine other cost models (military and NASA in-house) to improve the models used for space station costing and plans to examine military and in-house hardware and manufacturing specifications to simplify, standardize, reduce, and contain costs.

Panel Observations on Program Performance

The panel organized into two subpanels (Appendix C) to address the broad subject of program performance. One subpanel addressed cost modeling and confidence and the other cost containment. The subpanels made the following observations.

Cost Modeling and Confidence Subpanel

In general, the subpanel concluded that the present cost models, based almost exclusively on weight, are not acceptable. To make them useful for estimating costs will require considerable work and a careful look at and an understanding of the factors that affect costs. Weight is not a good single parameter for extrapolating costs. It is probable that no single factor will suffice. In the process of estimating costs a corollary action should be taken--exploring ways to reduce costs.

One reason NASA is not in a position to fix dollar targets for program elements is that program guidance has been so general. To help implement design-to-cost, the program should be explicitly defined before the second part of Phase B (preliminary design) gets under way.

Specific subpanel observations follow on cost modeling related to flaws, improvements, utility, and next steps.

Cost Model Flaws

- Present modeling, like most, has many flaws. It lacks consistency in assumptions, data bases, and application. The hardware systems used to structure the models do not always reflect the character of the systems under study.
- The selection of weight as the principal variable is often an oversimplification and not the correct variable.
- The wraps are not complete and are arrived at by rule-of-thumb, not on the basis of program content.
- Model limitations are not stated or understood regarding applicability, range of uncertainty, or level of credibility.
- Estimates of operating or life-cycle costs do not appear to have been made.

Model Improvement

- Detailed analyses or educated best guesses should be provided by experienced design and development groups where applicable data are not available to upgrade the space station cost models.
- The work breakdown structure should be set down and used as the framework for cost build-up. A range of costs should be provided for activities that are uncertain or not fully definable.

- U.S. Air Force models should be exercised but comparability with projected space station systems should be assured. Differences between manned and unmanned systems must be understood and characterized.
- Important parameters, other than weight, need to be examined and applied appropriately to adjust cost models.
- Models should be tested for reasonableness of cost estimates. In most instances this does not appear to have been done.
- A more in-depth base for establishing wrap costs needs to be developed and a costing philosophy identified. This action is also needed for operations and life-cycle costs.
- Whatever the cost-estimating system, its limitations and their implications to allow assessment of credibility need to be understood.

Current Model Utility

- The present models could be used for gross estimation of the order of cost for the baseline system, grossly scoping the "\$8 billion program" and grossly identifying large cost drivers. However, the models are too gross to use to descope a baseline system and/or to set subsystem cost targets.

Next Steps

- Effort should be directed to making the best cost estimates and not to developing the best cost-estimating technique.
- Cost assessments need to be built up from top-down statements of work using bottoms-up estimating.
- Such data should be used to refine in-house cost estimates. For comparison, other groups experienced in costing should make base program cost assessments.
- To reduce uncertainties, it is necessary to refine and calibrate the estimating system continuously.
- Cost targets need to be developed for program elements based on the steps noted above.
- Cost drivers at the subsystem level, subsystem by subsystem, need to be identified.

In summary, the subpanel believes that the present effort is directed at improvement of modeling and that it would be more prudent to direct effort and attention to making the best estimates and not to

developing the best methodology. It is believed that a good model for a unique system requires engineering attention, i.e., bottoms-up structuring from specifications to production to test and operations. The capability of assessing costs with reasonable confidence is needed at the time major configuration trades are made. Cost is a key and, to a degree, controlling parameter.

Cost Containment Subpanel

The cost containment subpanel was concerned that the space station program was not more explicitly defined in terms of performance and costs to provide a firm framework for the concept development part of the Phase B contracted activity and, more particularly, for the preliminary design part of Phase B. Another point of concern was the lack of clear, direct lines of management responsibility from program management levels C directly to B directly to A. A simple line of allegiance and command is needed to allow rapid and direct communication, decision making, and direction. This management scheme, in principle, is illustrated in Figure 1.

The subpanel's cost containment broad and specific observations, not prioritized, are listed here.

Broad Comments

Program Strategy NASA should establish and communicate a firm philosophical position on program strategy given the \$8 billion (or another specific target) budget. Is the program strategy one of technology push--advanced technology carried in the space station--or technology pull--advanced technology applied to the station? In the first case, the station is a ready means, using state-of-the-art technology, for working in space. In the latter case, the space station, itself, drives and uses advanced technology to provide the ability to work in space and can be expected to result in a more costly program in the near term.

Available Hardware NASA should use off-the-shelf available hardware if, as is assumed, costs are a real program constraint for the baseline space station. There should be a "no" to almost all technology alternatives, even "low-risk," for IOC. Exceptions to the "no" would have clear high benefits in the near term as well as the longer term.

Designed-in Payload Support In the interest of lower costs and flexibility, a harder position should be taken on limiting designed-in payload support capability. The space station should accommodate a broad spectrum of user requirements, especially for IOC, but should not be tailored to specific needs through built-in capability.

Growth and Operations The program office should select a configuration that constrains IOC costs (within the selected budget) but will accommodate growth, fully considering growth and operational

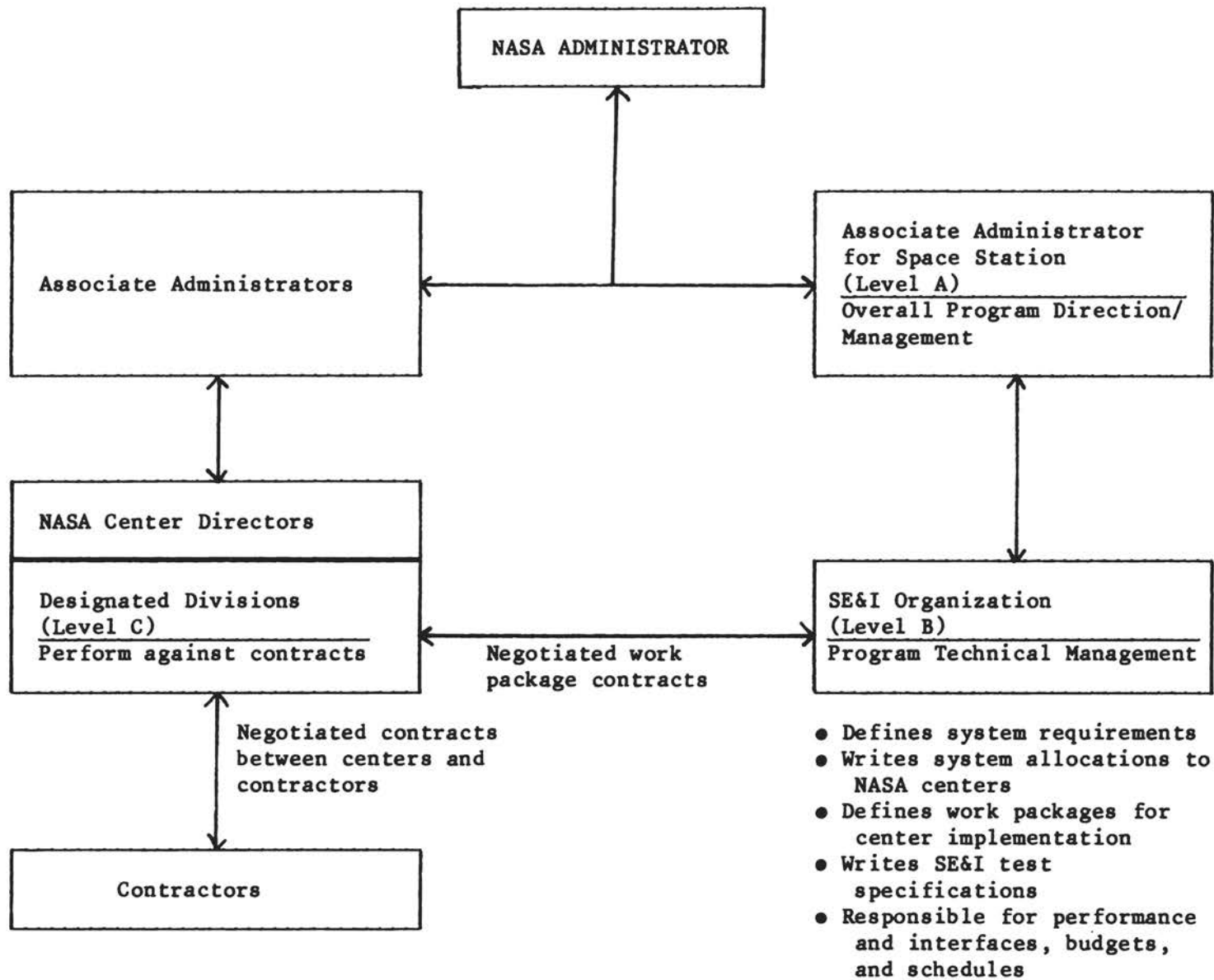


FIGURE 1 Management scheme.

costs. Configuration and cost decisions cannot be made without accounting for all of these cost factors.

Cost a Constraint NASA should fix program design, cost, and strategy with costs as a real constraint; in addition, they should identify the concept and its capabilities to the user and funding communities. A constrained program could cause adverse user reaction, but a position needs to be taken to preserve long-term program integrity and support. High early program costs and/or schedule stretches may have a greater adverse impact on the program in the long term than a constrained IOC program. Administration and Congressional support could be reduced and/or withdrawn.

Program Guidance Definitive program guidance should be communicated to all active program participants. This is important whatever the final disposition of the matters addressed in the preceding paragraphs.

Single Chain of Command It is important that NASA minimize and focus organizational interfaces and responsibility through a single programmatic chain of command with top-down budget, technical, schedule, and performance management and control (Figure 1). Further, the project office (Level B) should obtain fixed-price and technical performance and schedule commitments from Level C. Level A must be the czar of the Level B and Level C effort.

Specific Comments

Wraps Review wraps for content and overlap. It is not clear that all major elements are accounted for or that some elements are not covered more than once between "prime" and "non-prime."

Expendables Reduce expendables to hold resupply requirements down. Judicious use of advanced technology will help.

Management Assignments Assign dollar targets for program elements down to the lowest possible levels of management. Assign to lower and upper levels of management integrated performance, schedule, and cost responsibilities.

Data Base Establish a common data base for the total program covering both technical and management matters. Communicate the data base to all program levels.

Minimize Documentation Tailor all documentation and oversight activity--specifications, practices, and reviews--to impose minimum requirements. This will require concerted, dedicated effort.

Change Control Define and establish change control procedures early. Make the system effective and its response fast. Define interfaces and performance boundaries as broadly as possible to minimize the need for change. This process (except for major changes that impact basic program performance, schedule and/or factors that

require Level A review and approval) should be overviewed and managed by the Level B systems engineering and integration group.

Use of NASA Personnel Use NASA personnel for in-line program activity; do more, watch less. For example, NASA personnel could work interface control, check-out, and test. This hands-on activity would keep NASA actively informed and integrated into the engineering development, assist in reducing contractor staff loads toward the end of development and test activity, and reduce program costs.

Commonality Reduce new work and duplication of activity through use of common parts and components. Use common specifications and make quantity buys, carefully monitoring production lines for performance and quality of articles produced.

Shuttle Optimization Optimize the performance and the loads for the Shuttle for space station application. This is a significant cost item for IOC, follow-on operations, and growth.

Engineering and Costs Involve engineering in the estimation and reduction of costs through early definition of design, development, and test activity; design to hold down costs; and analyses to help set cost targets and control and reduce costs.

MISSION COMMAND AND CONTROL

The Level B approach to mission command and control, ground and space-born, was reviewed for the panel by Richard Thorson of the JSC Space Station Office. The graphics used for his discussion are presented in Appendix D. A summary of his comments and related panel observations follow.

Overview--Richard Thorson, JSC (Briefing Graphics--Appendix D)

The people in mission control, often referred to as the "marching army," equate to a large cost item. A number of concepts for reduced ground-based support are being examined. No single approach has been selected. Of special concern is the user interface with space station mission control.

The level and depth of support required for mission command and control are being examined by the involved centers: JSC, station support; Goddard Space Flight Center, platform support; and Kennedy Space Center, logistics and prelaunch support.

The space station information system is projected to be a distributed system that will integrate required data at a command level. The system will serve all elements: ground support, station, platforms, and users. Information and system management interfaces are critical design areas.

The split of command and control functions between the ground and the space station is still to be resolved. Consideration is being given to allowing payload managers direct remote payload control and data retrieval. This requires careful consideration of such matters as space station operations, control, servicing, and safety. There are serious questions about the degree of freedom-of-access that users can have on a system of the nature of the space station.

With regard to platforms, there is no plan to allow direct access to data by payload managers. However, this is being examined. At present, the plan is to have all data transmitted through the space communications network to a central station on the ground.

Mission control will be treated in phases because requirements will change with space station build-up and with operational experience. But, interfaces need to be addressed and designed into the system to accommodate growth.

It is reasonably clear that mission planning and control will have to be handled on a daily as well as a long-term basis. The daily planning of operations may well be, in all probability will be, an onboard function.

Mission control studies include guidelines calling for low hardware development and operating costs. The contractors are to consider economic trades, use of existing facilities and equipment, and onboard autonomy. Identification and examination of needed ground support functions are in process. It is assumed that there will be a number of years of verification activity after IOC, that ground operations will move from verification to a reduced operations support mode, and that on-board command and control activity will grow.

Of particular concern is maintenance and operation of the space station itself and its payloads. Studies have not progressed to where decisions can be made on the appropriate split of command and control between the ground and the station. One area under study is onboard user payload verification.

It is probable, in the longer term, that the space station will have control over local traffic. The matters of launch, recovery, and platform movement can be expected to be the responsibility of ground control. It is also probable that maintenance and logistics planning and support will be a ground function iterated with the station command.

Spares and maintenance will be significant cost items. Some of these costs, even for IOC, are considered outside the original \$8 billion target program. Such IOC requirements will have to be factored into the program early. Providing spares later will be expensive in time and money. However, no clear identification of needs or costs have been made.

Because of the distributed nature of hardware responsibilities, including foreign participation, a centralized control of interfaces will be needed. Appropriate interlocks and/or interfaces will be required as will a unified system of command for mission planning and operations both daily and longer term. A bridge-type operation, as on a ship, is indicated. The bridge could be on the ground but more likely, especially for daily operations, it will be on the space station.

Mission command and control are possibly the most complex tasks of the whole space station effort. The tasks are receiving serious, in-depth attention by program management.

Mission command and control costs, both development and recurring, are under study. The costs associated with user activity are considered outside of the \$8 billion program and are expected to be funded by the users. The Jet Propulsion Laboratory is working to develop a model of user recurring activity. One concern is that near-term activity and costs will be pushed downstream to reduce early budget requirements. Such action could cause the near-term program to be underfunded and adversely affect out-year budgets, causing later problems.

Some issues important to the definition of mission command and control need to be resolved soon. One issue relates to the responsibility for the design and development of support and servicing equipment for payloads, including data handling. At present, it is assumed that such special needs will be the responsibility of the user, but what of general support, servicing requirements, and data handling on board and data transmission to the ground?

The space data transmission system, operating in the K-band, will handle 300 megabits of information. This capability will dictate the need for rapid data processing at the ground receiver site.

Subpanel on Mission Command and Control

After discussion, the subpanel (Appendix C) developed the following findings related to on-ground and in-space mission command and control.

Level of Attention The command and control responsibilities appear to be given appropriate, serious attention including balancing on-ground and in-space responsibilities and functions for station assembly, check-out, and growth.

Commonality Special attention must be given to connectors if as is indicated space station operations will be monitored by the crew and will be based on on-condition maintenance at the subsystem (card) rather than element level. This includes consideration of commonality and functional check-out to minimize kinds and numbers of parts and costs.

Crew Performance The crew's health should be monitored and attended to by a doctor on the station rather than through the use of monitoring devices worn by crew members and remote counsel. This will provide the best possible immediate care (with appropriate ground consultation if required) and help assure high levels of crew performance.

Commander's Role The commander must have ultimate authority over space station control and safety functions. He must also have intervention capability over all space station operational activities. This means that all critical operational data must be available to him and that he has the equivalent of a ship's bridge and associated responsibility and authority. There must be no ambiguity and clear lines of authority in management of the space station to assure safety of crew and preservation of the space station and its payloads, probably in this order of priority.

Traffic Control Operations in the space station and in the general vicinity of the station (about 20 miles) should be under the control of the station. Transport operations otherwise should be controlled from the ground. Although general command and control would be from the ground the crew on the station would be in the best position to judge and react to station and nearby traffic situations requiring prompt action.

Mission Planning Central planning and general scheduling of day-to-day functions should be managed from the ground. This would include general operations and routine housekeeping. It should be less expensive of space station crew and time to do routine planning and support work on the ground.

Operations Planning Operations is a difficult activity; for unmanned systems it generally represents about one-third of the program costs. The operations definition and development effort requires a manager responsible for, among other matters, the control center, protocols, space system control, communications, and data processing. It does not appear that Level B is staffed appropriately to handle the degree of design and development activity required. Consideration should be given to bringing a NASA center or a contractor into the activity to provide appropriate levels of technical and management support.

Operations Requirements Operational system planning should start with the development of a requirements baseline. The baseline should define such things as data rates and buffering as opposed to planning for broad mechanization. Emphasis on requirements and concepts appears to be missing. Building the system up from a more restrictive requirements basis versus a broad mechanization basis should be less costly and quicker.

User Operational Access User data streams appear to be complex. In view of the 300-megabit data handling capability, a data processing center attached to the ground station will be required. Is there a real need/requirement for real time interaction between distributed users and onboard payloads? If this is the case, the way this would

be accomplished was not evident. Because of safety and operational condition-matching requirements, it may not be reasonable to allow the user free access to experiments. This obviously will require case-by-case examination.

Data Archiving Archiving user data has been a significant problem. It can be expected to be a substantial growing issue for the space station program. The users should be responsible for archiving their own data. If space station operations and safety information is part of the data flow, consideration should be given to stripping and independently handling these data.

Automation The level and degree of automation will vary with time. A plan that defines the changing system and its implementation should be in development. The Shuttle could be used to develop automation capability. Automation is a large issue in itself. It should be applied where truly effective in reducing routine and/or performing difficult tasks for the crew. Criteria should be formulated to help direct the space station automation development.

Assembly Planning Assembly of the space station may be the most dangerous phase of the program. It will involve extra vehicular activity and control of individual and partially assembled elements of the station with the Shuttle present. A comprehensive assembly and check out plan is required for this activity.

The subpanel considered the listing of selected technology issues and implications shown in Table 1. The technical issues listed represent desirable space station features and to a degree are being addressed. Achievement of these features will require careful attention to matters such as fault-tolerant and standard network architecture, high-reliability parts, and standard hardware and software modules. Another important consideration will be built-in test capability at the major component and at the built-up system levels to simplify both ground and flight validation of function and to validate repair and maintenance work done in space.

**TABLE 1 Critical Technology Issues: Space Station
Command and Control**

Issue	Implication
Natural space environment	Fault-tolerant architecture Radiation hardened components
Long mission life	Fault-tolerant architecture High reliability parts Good built-in-test
Test	Good built-in-test capability Testability designed-in, not added Use of good design tools (Engineering CAD)
Reliability	Fault-tolerant architecture High reliability parts
Performance (initial and growth)	Modular distributed architecture Dedicated special function modules (e.g., image processing) Fiber optic internal communication network Standard network architecture (interface and protocols)
Growth and technology upgrade	Modular distributed architecture Standard network architecture (interface and protocols)
Low risk and cost	Standard hardware and software modules Standard network architecture (interface and protocols) Standard high order language Application generators used for software module development Use of good design tools (Engineering CAD)
Autonomy	Modular distributed architecture Fault-tolerant architecture

3

Summary Observations

INTRODUCTION

The panel on program performance and mission command and control believes that NASA is fully aware of the kinds of matters that need to be addressed to assess and control costs associated with space station design and development and mission command and control.

The panel believes that there are some program performance and mission command and control matters that with further attention could improve the success of the space station program. Selected topics discussed in the text of these proceedings, as they relate to program performance and mission command and control, are summarized in the following paragraphs.

PROGRAM PERFORMANCE

Management Directives

The matter of program performance focuses on program costs. The fact that NASA has chosen not to fix the IOC costs of the space station keeps the in-house and contracted activity relatively unfocused for too long a period of time. The panel believes that a Level A directive fixing program philosophy, providing design guidance, and setting cost targets would be very helpful in quickly driving activity toward practical performance and design choices and containing costs.

The freezing of mission performance capability to what can be done practically within budget and technical constraints is important. The users will be able to focus on what is possible and will adapt to realistic program constraints. Present planning is attempting to accommodate uncertain payload requirements from scientific and technical as well as funding considerations. Thus, there is slow closure on design specifics and cost estimates.

Technology Application

In the opinion of the panel, the program should use available technology to hold down costs. The program should be technically conservative unless associated performance and/or operational constraints are unacceptable. It is believed to be more important that the station serve as a facility to broaden our knowledge and use of space than to have the station itself serve as a driver of technology development.

Design and Performance Margins

In the area of systems engineering, costs can be reduced with attention to the following kinds of matters through provision for: broad design and system performance margins; adjustments to design and performance specifications during acceptance testing; tight interface control; and increased levels of redundancy. The adequacy of NASA in-house staff and the mix between in-house and contractor personnel should be reviewed. It may be necessary to increase support through the use of NASA center or contractor personnel.

Use of CAD and CAM

NASA is exploring the use of computer-aided design (CAD) and computer-aided manufacturing (CAM) not only to assist in design and manufacture, but also to establish a common data base among program elements and for interface control. This perspective is strongly endorsed by the panel. Special attention through these mechanisms should be given to establishing and controlling standard parts, systems, and modules for the program.

Management Culture

Past management practices are not necessarily appropriate for the space station program if performance, schedules, and costs are to be contained. Management changes may well require "cultural" changes within NASA.

These are some examples of change that should be considered: reducing reviews and reporting and related levels of documentation for design and fabrication; using screening tests to get high reliability parts; building spares concurrent with first articles; making only block changes; integrating testing and testing only to qualify not through destruction; using test articles for flight and/or spares; reducing the number of redundant checks; providing a system of rapid change control with short information loops; making articles work, not changing them for incremental improvement; using built-in tests as part of prelaunch checkout; using in-house staff for selected in-line design/development (possibly interface test and control) as a means of keeping staff technically in-the-program and helping to reduce

contractor support requirements; standardizing, simplifying, and tailoring specifications for consistency among center activities; and providing less "how-to-do" and more "what-to-do" directives to contractors.

NASA's system and subsystem managers should be made responsible for technical performance, schedules, and costs. This approach forces complete awareness of and responsibility for program needs, constraints, and performance.

Design-to-Cost

The approach to design-to-cost requires system definition and cost targets. It appears that this matter is not being pursued adequately. Life-cycle cost considerations are not evident. These costs need to be examined to allow sensible choices between IOC and growth. There is a need to be willing to trade system performance and schedules for cost.

To help contain program costs, it is important to enter preliminary design with a cost model and target costs. It is also important to enter into final design with cost margins so that trades and scope changes can be made.

Cost Modeling

Current cost estimating is not sufficiently refined to inspire or create confidence in the estimates. One concern is to understand the large differences between costs of manned and unmanned space flight systems. Although it may be of long-term value to improve the model, the desired improvements may not be adequate or come in time to be useful. It is believed that the effort might be best spent developing cost estimates from an engineering analysis of work to be done and time required plus procurement of hardware and equipment and supporting cost estimates. This bottoms-up approach would provide a sound base for follow-on space station cost modeling.

Contractor Sensitivity

An integral part of the process of cost awareness is contractor attitude, approach, and performance. The contractors need to have a strong incentive to deliver on schedule, within cost, and to performance and technical specifications. The contractors also need to know that there are penalties if commitments are not met. These matters need to be addressed in NASA's contracts.

MISSION COMMAND AND CONTROL

Onboard Control

The degree of onboard command and control should be dictated by best use of crew from crew safety and space station and payload system operational considerations. It is clear to the panel that the space station must have a commander operating from a "bridge," in the sense of a bridge on a ship, with ultimate authority for control and safety of the crew, station, and payloads.

The station should have control of activity in its vicinity, such as the Shuttle, and other transport vehicle approaches, dockings, and departures. Other activity should be ground controlled.

Ground Control

It appears reasonable to assume that most routine mission management work can be accomplished on the ground, leaving the crew to concentrate on the demanding on-site tasks.

Planning

The levels of planning for assembly and automation need to be increased. Assembly may well be the most exacting and dangerous part of the program. A comprehensive assembly and check-out plan is warranted to assure a thorough review and assessment of options and the final choice of plan and its implementation. Automation can be expected to evolve with specific needs and experience. However, definitive planning for the kinds and level of IOC automated activity is needed. Growth planning at present will in all probability be limited to general accommodations and interfaces.

Urgency

Because most of the matters addressed here affect the second part of the contracted Phase B effort (preliminary design), there is some urgency in developing a position on each. The more explicit the better.

Explicit direction for preliminary design will help focus the Phase B technical performance, design, schedule, and cost effort for Phases C and D guidance.

Staffing

The level of NASA staffing for the mission command and control function does not appear to be adequate for the importance and size of the task. Contractor or NASA center help to provide the level of technical and management support appropriate to the subject is indicated.

APPENDIX A

Meeting Agenda

SPACE STATION ENGINEERING AND TECHNOLOGY DEVELOPMENT
Panel on Program Performance and Onboard Mission ControlAGENDAAugust 6-7, 1985
NASA Johnson Space Center
Houston, TexasTuesday, August 6

Introduction	J. Shea, Chairman
NASA Comments --Concerns, Questions, Issues	R. Carlisle, NASA HQ
Related Comments	Panel
General Discussion	Panel
Organization of Subpanels Program Performance Onboard Mission Control	J. Shea TBD K. Holtby
Individual Subpanel Meetings Discussion Drafting of Position Statements	Subpanels

Wednesday, August 7

Individual Subpanel Meetings (cont.) Discussion Drafting of Position Statements	Subpanels
Review of Statements	Panel

COST METHODOLOGY PRESENTATION
TO ASEB

APPENDIX B

AUGUST 6, 1985
DAVID K. BATES

SPACE STATION PROGRAM MAJOR CONTENT

COMMON MODULE/ECLSS

MODULE OUTFITTING

LAB MODULES
LOG MODULES
HAB MODULES

SUBSYSTEMS

THERMAL
G N & C
D M S
C & T
POWER
APPLICATIONS SOFTWARE
PROPULSION

STRUCTURES

TRUSS ASSY
CONNECT & I/C OF MODULES
MECHANISMS
RESOURCE INTEGRATION
STS BERTHING
AIRLOCK

STATION SERVICES

EVA SYSTEMS

OMV ACCOMMODATIONS

CUSTOMER SERVICING

PLATFORMS

ATTACH PAYLOAD ACCOMMODATIONS

PRIME WRAP

PRIME TOTAL

NON PRIME

FEE

RESERVE

DEFINITION PROGRAM

SPACE STATION TOTAL

DEFINITIONS

DEVELOPMENT PROGRAM

TOTAL PRIME: TOTAL WORK PACKAGE PRIME CONTRACTORS COST WITHOUT FEE

PRIME HARDWARE/SOFTWARE: ALL HARDWARE AND ONLY APPLICATIONS SOFTWARE

PRIME WRAPS: PERCENTAGE OF TOTAL PRIME COST THAT PAYS FOR NON-HARDWARE ITEMS SUCH AS, PROGRAM MANAGEMENT, GSE, SYSTEMS TEST, INTEGRATION ASSEMBLY & CHECKOUT, AND SYSTEM LEVEL SE&I (AKA SYSTEMS WRAPS OR CONTRACTOR WRAPS)

60 - 40: 60% OF TOTAL PRIME COST BUYS HARDWARE/SOFTWARE; 40% OF TOTAL PRIME COST BUYS WRAPS

DEFINITIONS (CONT'D)

PROGRAM WRAPS: NON-PRIME COSTS, FEE, RESERVE THAT APPROXIMATE 35% OF TOTAL DEVELOPMENT PROGRAM COSTS

NON-PRIME COSTS: PROGRAM COSTS THAT PAY FOR NASA SE&I, OVERALL VERIFICATION INCLUDING MAJOR TEST ARTICLES, OPS CAPABILITY DEVELOPMENT INCLUDING MCC MODS, KSC FACILITY OUTFITTING AND SIMULATORS/TRAINING DEVELOPMENT, SOFTWARE SUPPORT ENVIRONMENT (SSE) AND NASA PROGRAM MANAGEMENT/SUPPORT (AKA PROGRAM SUPPORT AND INTEGRATION)

FEE: PRIME CONTRACTOR PROFIT CARRIED AT 8% OF PRIME COST

RESERVE: UNENCUMBERED FUNDS CARRIED AT 8% AT LEVEL A AND 10% AT LEVEL B/C COMPOUNDED AT 18.8% OF TOTAL PROGRAM COSTS

CHRONOLOGY OF ESTIMATES

CONCEPT DEVELOPMENT GROUP - CDG

MAY - SEPTEMBER 1983

SKUNK WORKS

JULY 1984

LEVEL B REVALIDATION OF SKUNK WORKS

FEB - JUNE 1985

CONTRACTOR DR-09 SUBMITS

JUNE 3, 1985

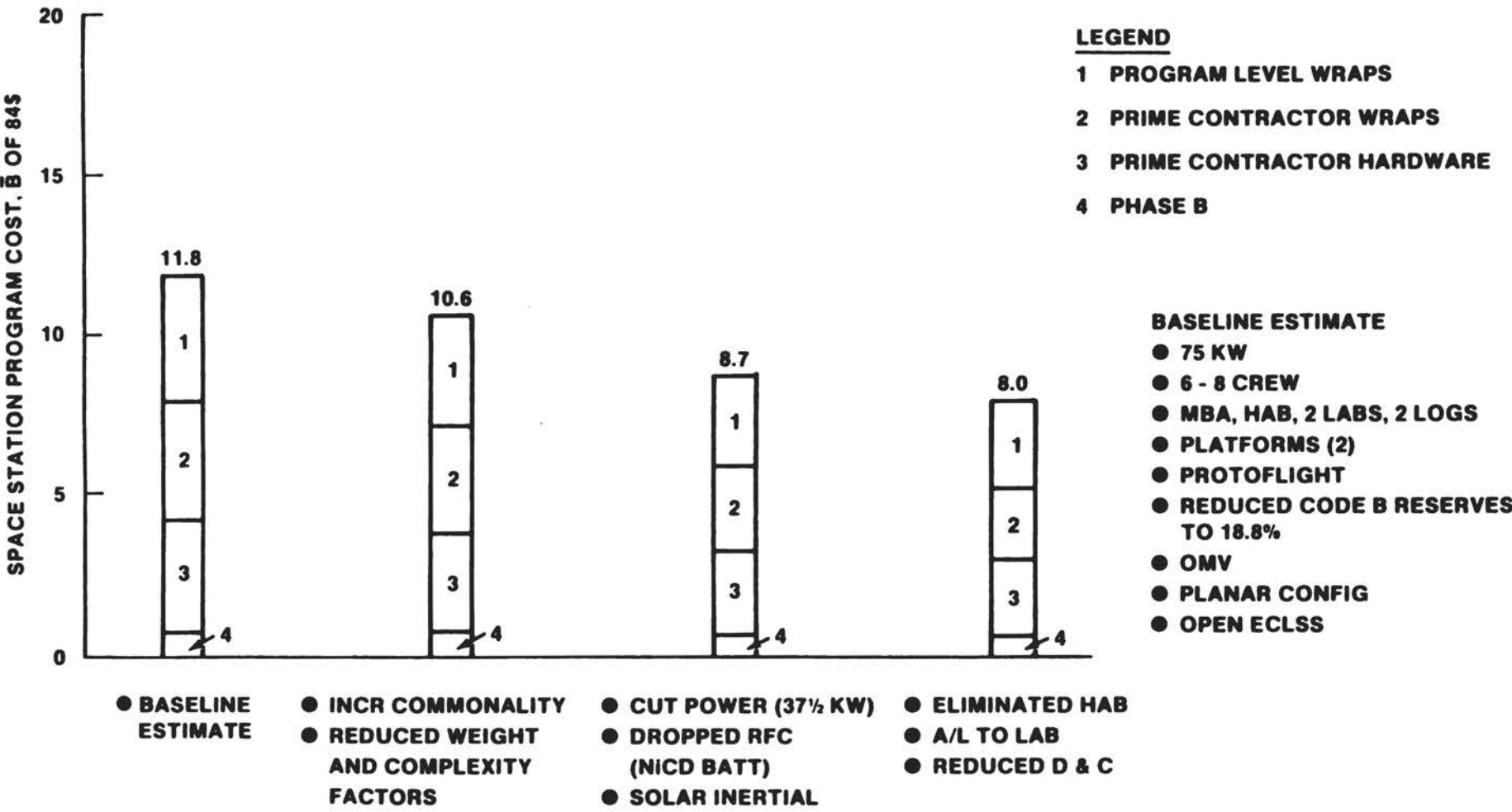
LEVEL C SUBMIT

JUNE 28, 1985

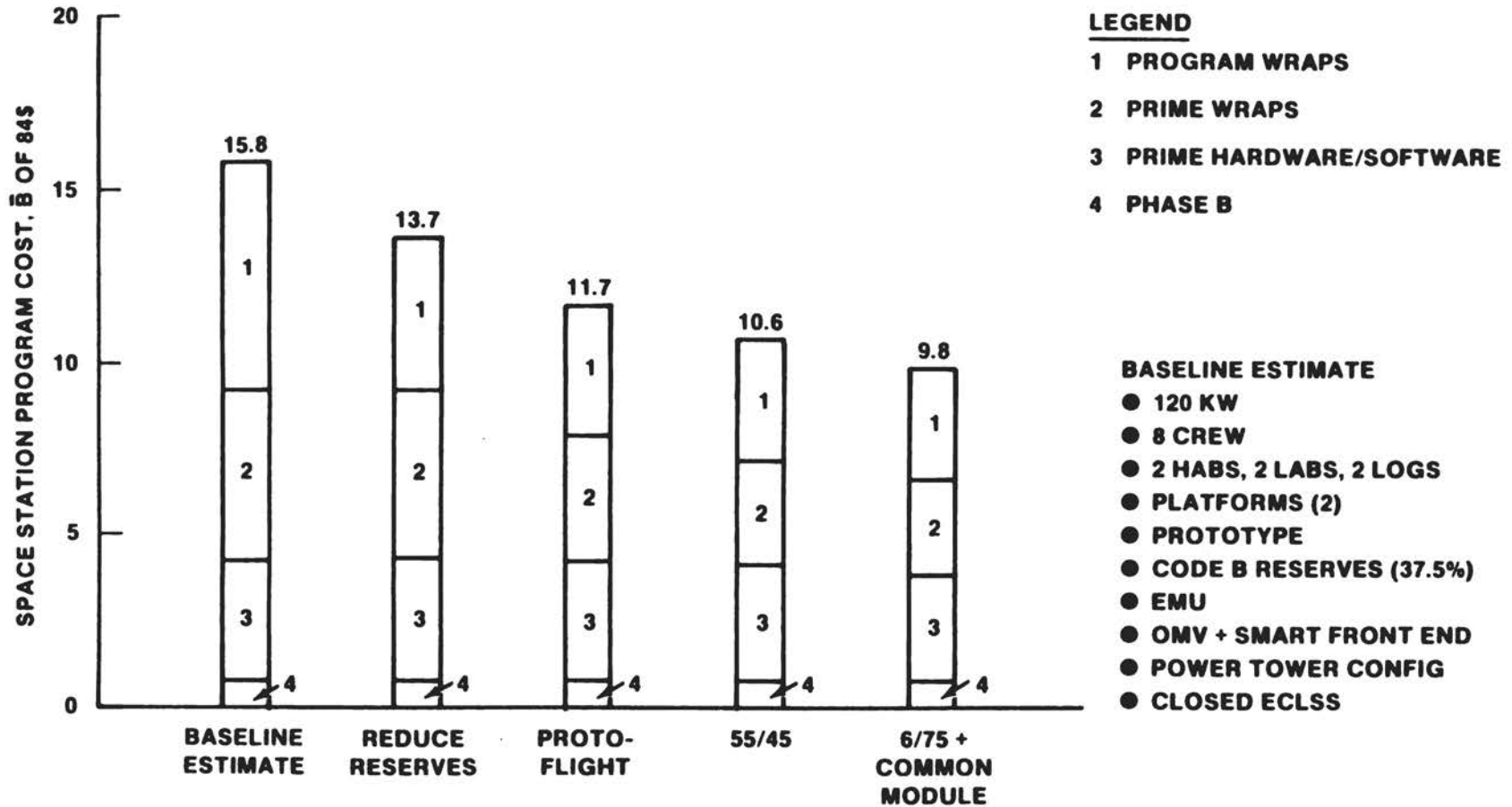
LEVEL B RECOMMENDATION

JULY 25, 1985

CDG Summary of Actions Taken to Reduce Program Costs



Skunk Works Summary of Actions Taken to Reduce Program Costs



- 0 USED BEST TOOLS & PEOPLE AVAILABLE
 - o CAREFULLY TUNED MODELING
 - o DETAILED ENGINEERING EVALUATION OF WEIGHTS, COMPLEXITY FACTORS AT BOTH LEVEL B & C INDEPENDENTLY
- 0 USED BEST DATA AVAILABLE
 - o MANNED AND UNMANNED DATA BASES
 - o DR-09 DROPS FROM ALL PHASE B CONTRACTORS
 - o TRACEABILITY MAINTAINED FROM PREVIOUS ESTIMATES
 - o SCRUTINIZED FOR OVERLAPS, DOUBLE BOOKKEEPS AND THE LIKE
- 0 TOOK ADVANTAGE OF ALL MAJOR COST AVOIDANCE AVENUES
 - o PROTOFLIGHTING
 - o COMMONALITY
 - o NON-CONSERVATIVE SYSTEM WRAPS
 - o NON-PRIME STS SYNERGISM (E.G. MCC)
 - o CAPABILITY PHASING OUTSIDE IOC
 - o TENDENCY TO UNDERSTATE IMPLICIT RESERVES

0 LEVEL B REVALIDATION

- o STARTED FROM SKUNK WORKS ESTIMATES OF REFERENCE CONFIGURATION
- o LEVEL B SE&I (TAIMS) REVIEWED SKUNK WORKS ESTIMATE SYSTEM BY SYSTEM
- o CER'S, WEIGHTS, CONTENT, COMPLEXITY FACTORS RE-EXAMINED
- o MSFC PRC MODEL FOR HARDWARE, RCA PRICE FOR SOFTWARE
- o SOME "I FORGOTS" (E.G. APPLICATIONS SOFTWARE, SOFTWARE SUPPORT ENVIRONMENT)
- o SOME UNDERSCOPIING (E.G. ATTACHED PAYLOADS)

0 CONTRACTOR DR-09 SUBMITS

- o SUBMITS FROM EACH PHASE B WORK PACKAGE CONTRACTOR
- o ESTIMATE BASED ON REFERENCE CONFIGURATION
- o PRICED EACH END ITEM WITHOUT ALLOWANCE FOR COMMONALITY
- o WIDE RANGE OF ESTIMATES BY SUBSYSTEM (E.G. TRUSS \$8-150M)
- o USE OF IN-HOUSE MODELS - MAJOR VARIANCE IN DATA BASES
- o SEVERAL CONTRACTORS HAVE DONE RE-ESTIMATE BASED ON LEVEL C EVALUATIONS OF ORIGINAL SUBMIT
- o STATION TOTALS BUILT UP FROM 100% RAW CONTRACTOR ESTIMATES FOR COMPARISON PURPOSES

METHODOLOGY (CONT'D)

0 LEVEL C SUBMIT

- o WP-1 MSFC - DEVELOPED OWN ESTIMATE USING MSFC PRC MODEL, LEVEL C DEVELOPED WEIGHTS AND COMPLEXITY FACTORS, AND EQUIPMENT LIST
- o WP-2 JSC - REVIEWED ROCKWELL, MDAC, AND IN-HOUSE (REVALIDATION) ESTIMATES, USED A COMBINATION BASED ON MANAGEMENT ASSESSMENT OF RISK BY SUBSYSTEM
- o WP-3 GSFC - USED GSFC UNMANNED MODEL FOR HARDWARE WITH INITIALIZATION FROM CONTRACTOR DR-09 DATA - PRIME WRAP ESTIMATE BASED ON MSFC PRC MODEL (WRAPPED WITH MANNED CER'S)
- o WP-4 LERC - USED ADJUSTED MEAN OF 5 ESTIMATES; CONTRACTOR ESTIMATES, LERC PRICE, PRC, AND SKUNK WORKS. ADDED SIGNIFICANT DOLLAR COST FOR TESTING AT CONTRACTOR
- o NON-PRIME - USED BOTTOMS UP ESTIMATE BY LEVEL B SURVEY OF LEVEL C NON-PRIME COSTS

METHODOLOGY (CONT'D)

0 LEVEL B RECOMMENDATION

- o LEVEL B/C ESTABLISHED SCRUB GROUND RULES IMMEDIATELY AFTER MAGNITUDE OF LEVEL C SUBMITS AND NON-PRIME ESTIMATES KNOWN - JULY 2
- o LEVEL B AND LEVEL C INDEPENDENTLY APPLIED GROUND RULES TO SUBMITS - JULY 9
- o RECLAMA SESSION HELD TO CONVERGE POSITIONS - JULY 18
- o RESULTS FORM BASIS FOR LEVEL B SUBMIT TODAY

FACTORS AFFECTING SSP TOTAL COST ESTIMATES EARLY IN PHASE B

- 0 AMBIGUITIES VIS-A-VIS ROLES, RESPONSIBILITIES; E.G., LINE OF DEMARCATION BETWEEN COMMON MODULE/LAB & HAB MODULE OUTFITTING, ETC. (OVERSTATE)
- 0 USE OF HISTORICAL COST MODELS AS PREDICTOR OF FUTURE COSTS. (DRAGS HISTORY, FAILS TO ACCOUNT FOR MOST RECENT - AT THE MARGIN - PRODUCTIVITY IMPROVEMENTS, E.G., CAD/CAE/CAM, NCM, ETC., AS WELL AS FUTURE PRODUCTIVITY ENHANCEMENTS, AND/OR REQUIREMENTS RELAXATION.) (OVERSTATE)
- 0 USE OF HISTORICAL COST MODELS (COVERT RESERVE AND CONTINGENCIES) COUPLED WITH OVERT RESERVE--RESULT IS USING "COMING OUT" ESTIMATES AS "GOING IN" ESTIMATES, VIZ. "DOUBLE DING." (OVERSTATE)
- 0 ENVIRONMENT WHICH IS CONDUCTIVE TO (ENCOURAGES) INFLATED ESTIMATES, E.G., ZERO-SUM GAME. (OVERSTATE)
- 0 ENVIRONMENT WHICH ENCOURAGES CONCURRENT (ALL ELEMENTS START TOGETHER) PHASE C/D. (OVERSTATE)
- 0 NON-ATTAINMENT OF AMBITIOUS "START-UP" PROCUREMENTS, STAFFING PLANS, ETC., COUPLED WITH OVERT (EXPLICIT) RESERVE TO ACCOUNT FOR RESULTANT SCHEDULE EXTENSION. (OVERSTATE)
- 0 OSIF'S (UNDERSTATE) }
0 BUY-IN'S (UNDERSTATE) } TO THE EXTENT THEY EXCEED HISTORICAL EXPERIENCE

- 0 HIGHER-THAN-NOMINAL INTEGRATION (TECHNICAL AND PROGRAMMATIC) REQUIRED BY SSP, MANAGEMENT ENVIRONMENT, INCLUDING COMPLEX INTERFACES, INTERNATIONAL COORDINATION/INTEGRATION, ETC. (UNDERSTATE)
- 0 CONSTRAINED ANNUAL FUNDING, BOTH EXPECTED AND UNEXPECTED. (UNDERSTATE)
- 0 PROTOFLIGHTING IMPACT ON SCHEDULE FLOW. (UNDERSTATE)

PRELIMINARY DATA

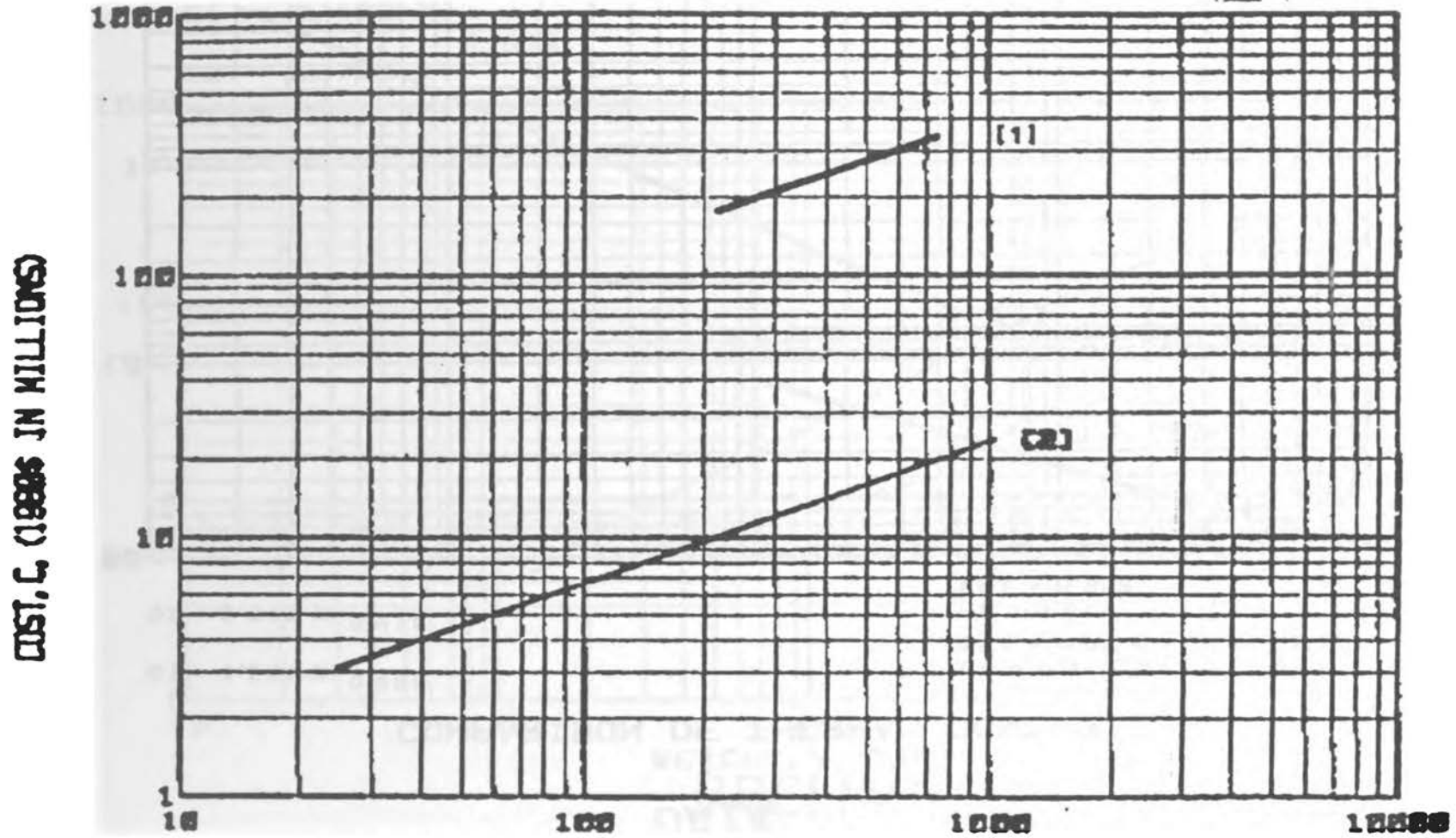
COMPARISON OF ATTITUDE CONTROL

$$C1 = 12.460 W^{0.600}$$

$$C2 = 0.533 W^{0.548}$$

CC - NOT CALCULATED
SEA - NOT CALCULATED

CC = 0.871
SEA = 0.407



COST, C. (1980s IN MILLIONS)

WEIGHT, W. (LBS)
PRELIMINARY DATA

PRELIMINARY DATA

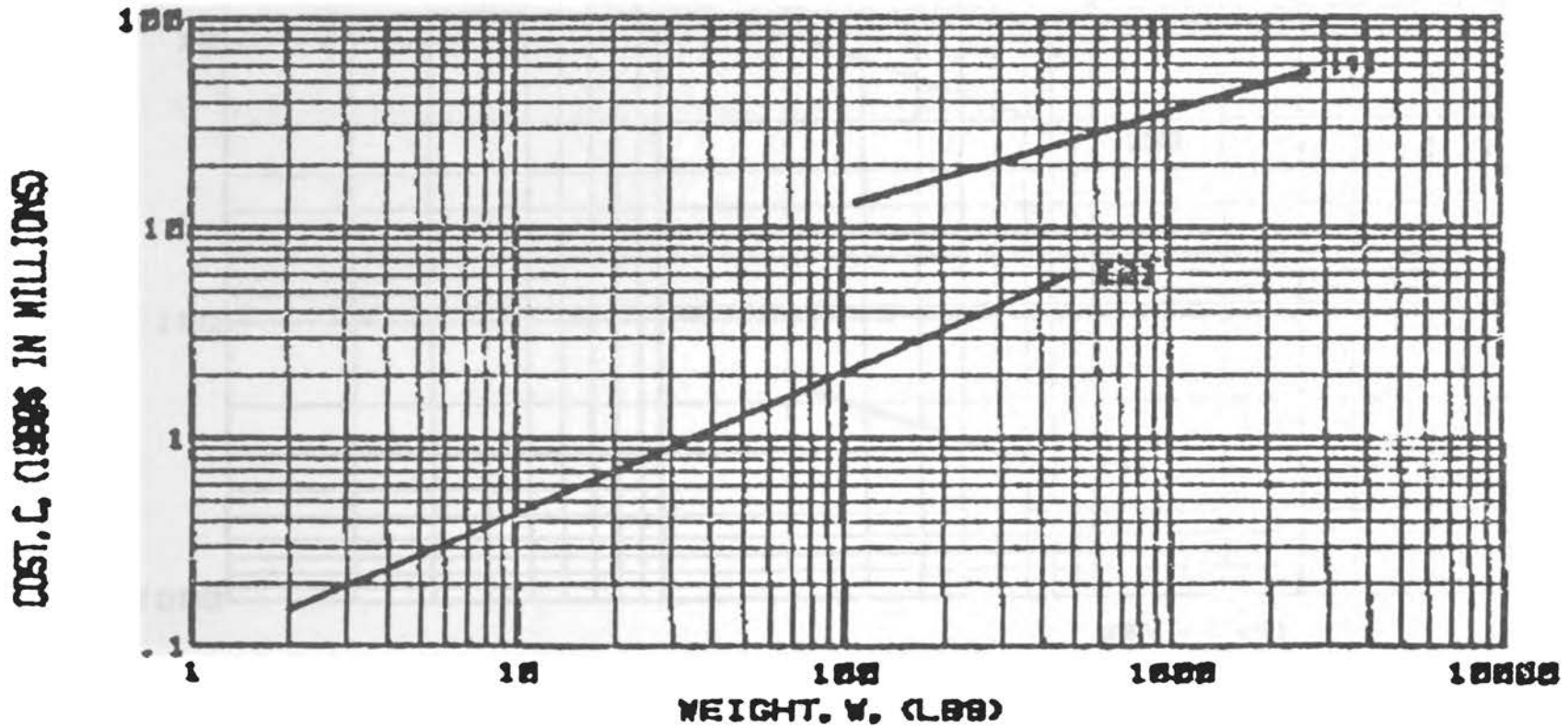
COMPARISON OF THERMAL CONTROL

01 - 1.351 W 0.500

02 - 0.083 W 0.670

CC - NOT CALCULATED
SEA - NOT CALCULATED

CC - 0.911
SEA - 0.509



COST, C. (MILLIONS)

WEIGHT, W. (LBS)
PRELIMINARY
DATA

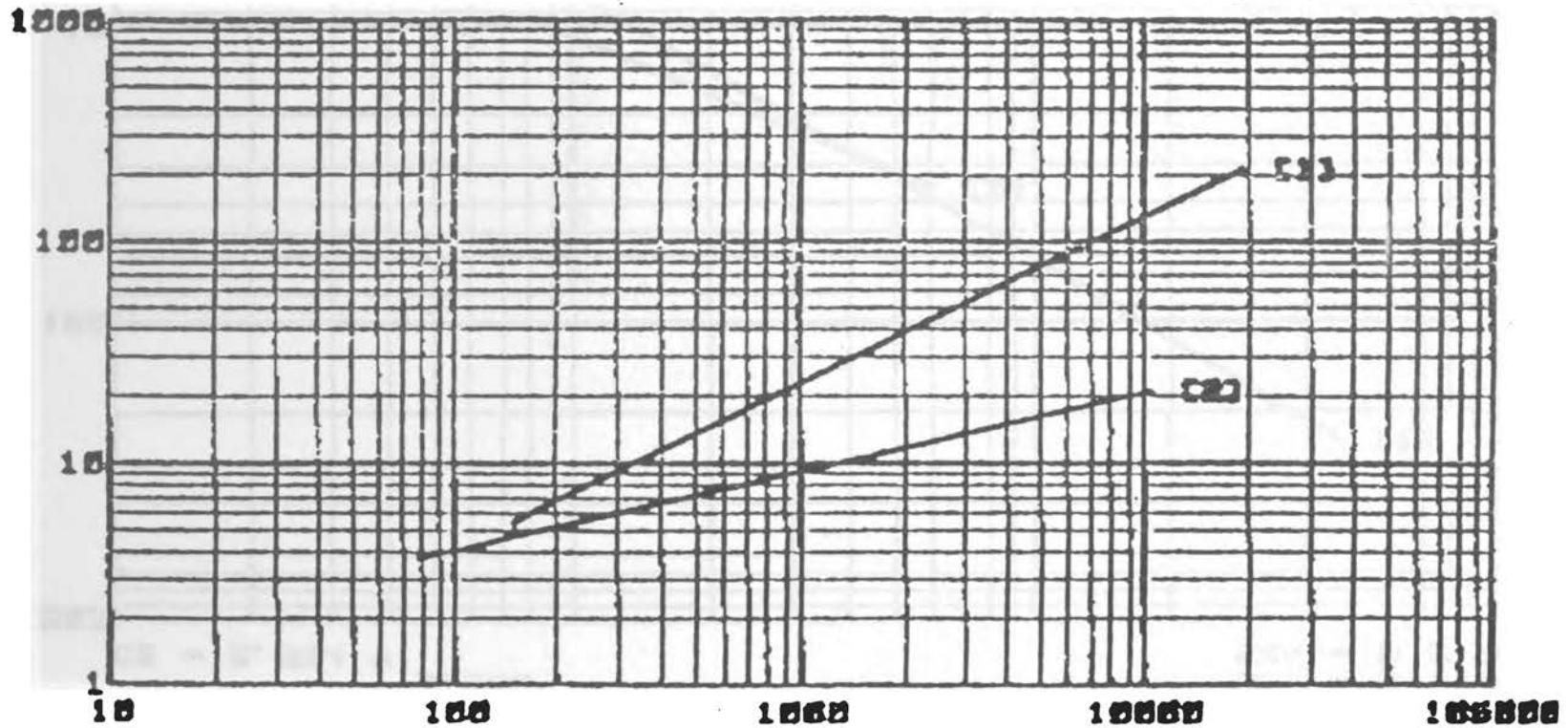
PRELIMINARY DATA

COMPARISON OF SECONDARY STRUCTURE

C1 - 0.122 W 0.753
 C2 - 0.700 W 0.854

CC - 0.984
 SEA - 0.977
 CC - 0.982
 SEA - 0.978

COST, C, (1980\$ IN MILLIONS)



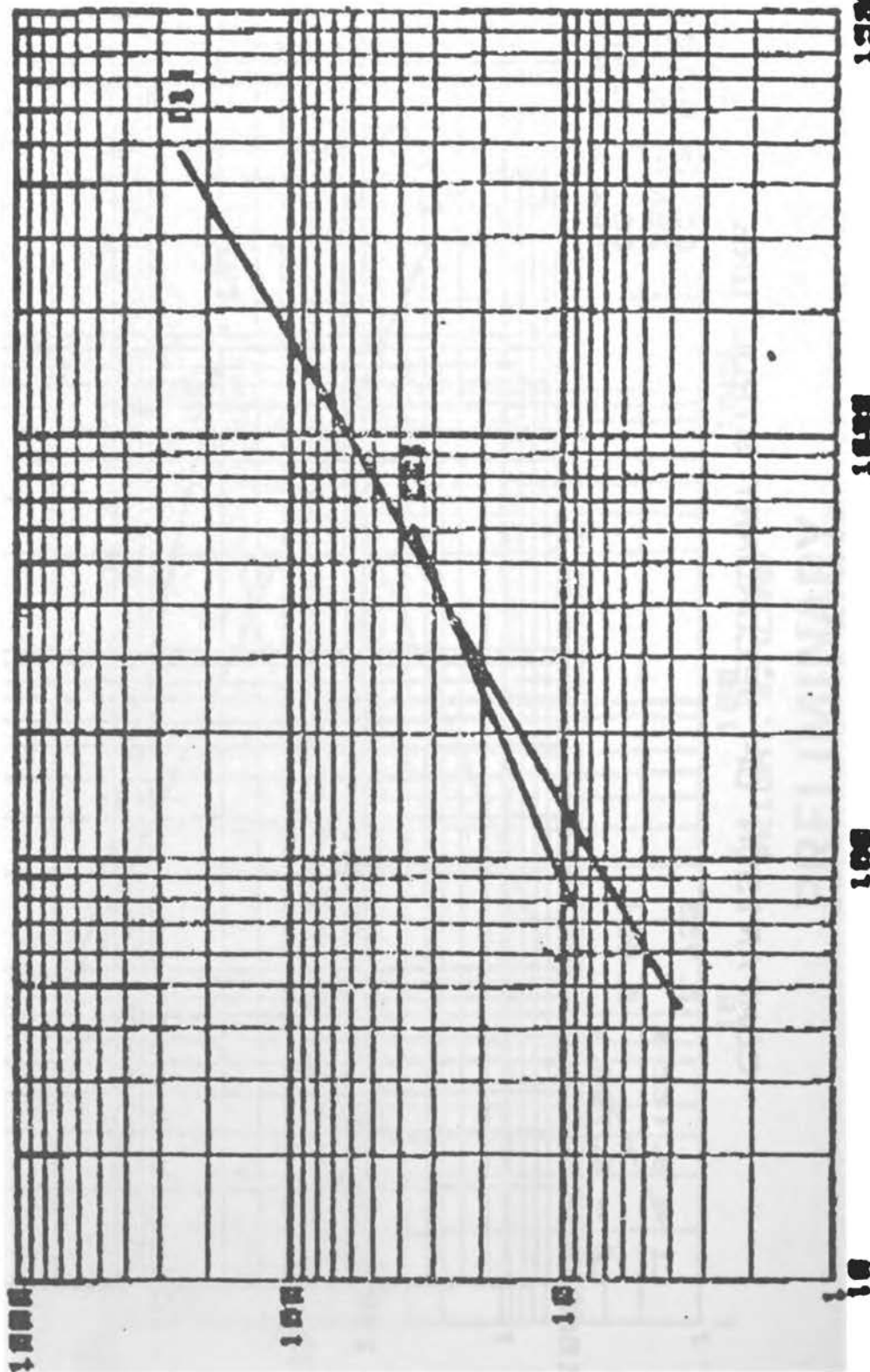
WEIGHT, W, (LBS)
PRELIMINARY
 DATA

PRELIMINARY DATA

COMPARISON OF COMMAND & DATA HANDLING

C1 - A. 128 Y A. 008
 C2 - A. 004 Y A. 005

CC = A. 008
 CCA = A. 008
 CC = A. 008
 CCA = A. 008



DST, C (1986 IN MILLIONS)

PRELIMINARY DATA

APPENDIX C

Subpanel Membership

Subpanel on Cost Modeling

W. Olstad, Chairman
D. Criswell
G. Merrick
S. Redelsheimer
R. Rhue
A. Slay
C. Syvertson
B. Tapley

Subpanel on Cost Containment

R. Hesselbacher, Chairman
L. Greenwood
A. Hill
K. Holtby
A. Mager
R. Morra
R. Powell
A. Thomson

Subpanel on Mission Command and Control

K. Holtby, Chairman
D. Criswell
L. Greenwood
A. Hill
A. Mager
G. Merrick
R. Morra
R. Powell
S. Redelsheimer
R. Rhue
A. Slay
C. Syvertson
A. Thomson

MISSION COMMAND AND CONTROL PRESENTATION

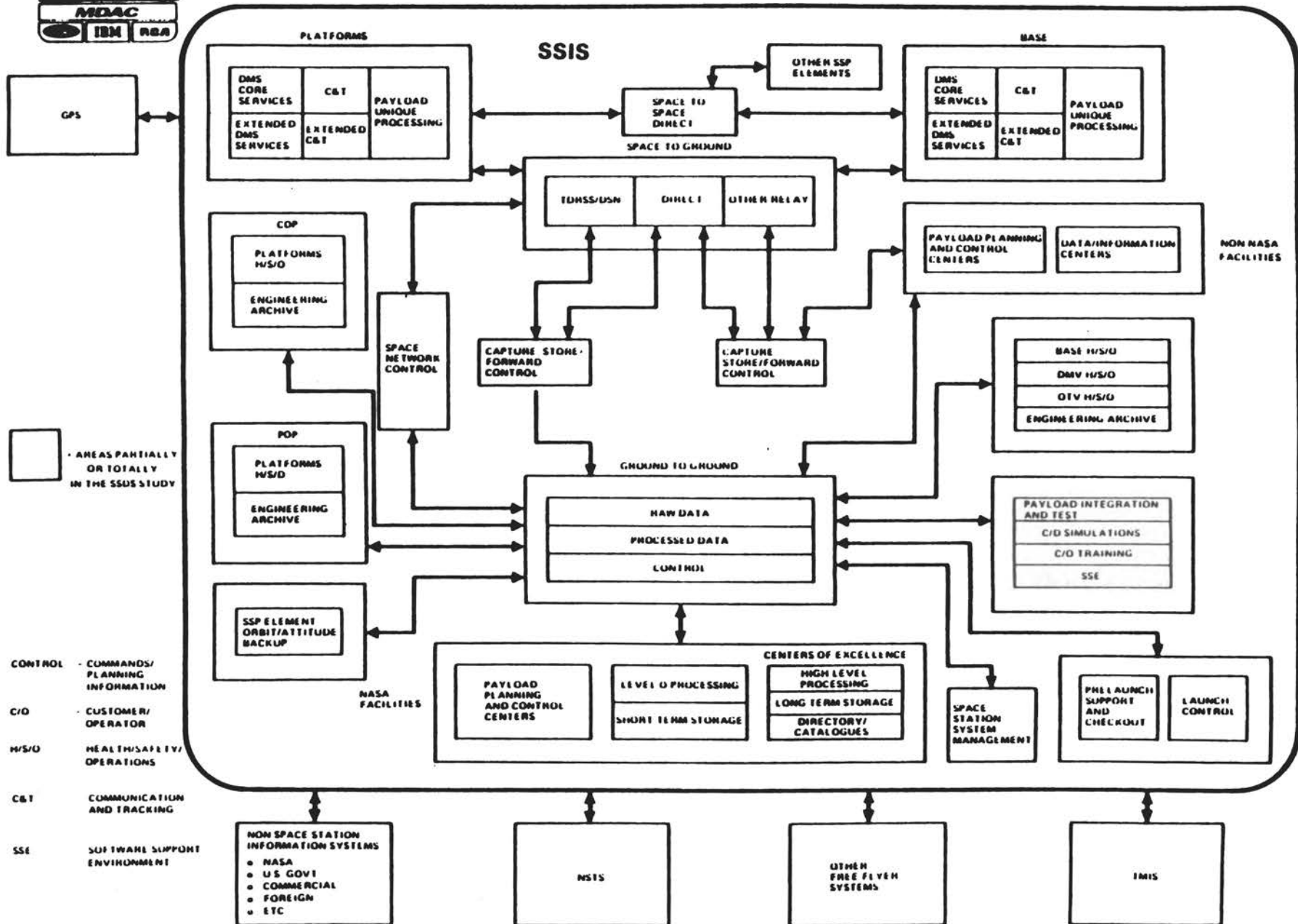
AUGUST 7, 1985
RICHARD THORSON

SPACE STATION GROUND OPERATIONS SUPPORT FUNCTION

- o GROUND SUPPORT CONCEPT UNDER DEVELOPMENT/DEFINITION
 - o LEVEL A OPS CONCEPT
 - o STRAWMAN CONCEPT IN LIMITED REVIEW
 - o INCORPORATES USER AND SUPPORT MANAGEMENT FUNCTIONS
 - o DELEGATES HISTORICAL SUPPORT FUNCTION TO ACCOMPLISHMENT OF USER MISSIONS
 - o OPS LINE ORGANIZATIONS CURRENTLY DEFINING DEPTH OF SUPPORT FUNCTION
 - o JSC LINE OPERATIONS (STATION SUPPORT FUNCTIONS)
 - o GSFC LINE OPERATIONS (PLATFORM SUPPORT FUNCTIONS)
 - o KSC LINE OPERATIONS (LOGISTICS AND PRELAUNCH)
- o SSIS
 - o DEFINING STATION, PLATFORMS, AND USER INFORMATION MANAGEMENT INTERFACES (S,T,E)



SSIS FUNCTIONAL BLOCK DIAGRAM



- o GROUND RULES AND GUIDELINES
 - o DETERMINE CENTRALIZED VS. DISTRIBUTED FUNCTIONS BASED ON:
 - o ECONOMICS
 - o FUNCTION
 - o USER REQUIREMENTS
 - o UTILIZE EXISTING FACILITIES WHERE FEASIBLE AND COST EFFECTIVE
 - o UTILIZE PART TASK TRAINERS, MOCK-UPS, TEST BEDS ETC. VS. HIGH FIDELITY SMS-TYPE SIMULATORS
 - o MAXIMIZE USE OF ON-BOARD SYSTEMS AND CREW (AUTONOMY)
 - o SYSTEMS MANAGEMENT (STATUS, MAINTENANCE AND LOGISTICS SUPPORT)
 - o TRAINING - OJT AS APPROPRIATE INCLUDING AUTOMATED TRAINING AIDS
 - o CHECKOUT
 - o LRU'S
 - o PAYLOADS, EXPERIMENTS, ETC.
 - o ASSUME CURRENT CODE M GROUND ENHANCEMENTS
 - o MCC MODS/UPGRADE

- o OPERATIONS SUPPORT FUNCTIONS
 - o SPACE STATION GROUND SUPPORT (STATION & USER) FUNCTIONS
 - o UTILIZE EXISTING SPACELAB POC FOR STATION SUPPORT
 - o SUBSYSTEM SUPPORT DURING ASSEMBLY AND VERIFICATION PHASES
 - o AUTONOMY AND PROOF OF CONCEPT CONSIDERATIONS WILL REDUCE SUPPORT TO ON-CALL OFFICE ENVIRONMENT WORK STATIONS FOR OPERATIONAL PHASE
 - o M&O OPERATION FOR COMM MANAGEMENT
 - o PLANNING FUNCTIONS
 - o TRANSITION TO ONBOARD DURING VERIFICATION AND OPERATIONS PHASE
 - o TRAFFIC MANAGEMENT
 - o MAINTENANCE/LOGISTICS INTERFACE MANAGEMENT
 - o CONFIGURATION/STATUS MANAGEMENT
 - o INVENTORY MANAGEMENT
 - o SCHEDULING REQUIREMENTS
 - o TRAINING/PROCEDURES
 - o CENTRALIZED MANAGEMENT FOR:
 - o SPACE STATION PROGRAM: HEALTH AND SAFETY
 - o STATION RESOURCE AVAILABILITY AND SCHEDULING
 - o SUSTAINING ENGINEERING FUNCTION

- o MAY BE DISTRIBUTED TO APPROPRIATE CENTERS,
WORK PACKAGES OR PARTNERS

- o UTILIZE PART TASK TRAINERS, MOCK UPS OR TEST BEDS FOR STATION-CREW AND USER-CREW TRAINING AS REQUIRED
 - o MAY BE INTEGRATED BY USE OF SSIS NETWORK
- o PLATFORM SUPPORT FUNCTION MAY BE SEPARATE (DISTRIBUTED) FROM STATION SUPPORT FUNCTION
 - o FUNCTIONS SIMILAR TO STATION SUPPORT WHERE APPROPRIATE
 - o POP AND COP SUPPORT MAY SHARE SUPPORT FACILITIES
- o POCC'S (PAYLOAD OPERATIONS CONTROL CENTERS) MAY BE DISTRIBUTED (S/T-INTERFACE SUPPORT)
 - o TWO EXAMPLES:
 - o GSFC - LIFE SCIENCES LAB SUPPORT
 - o MSFC - M & T LAB
 - o INTERNATIONAL
- o REMOTE TELESCIENCE SITES (S/T-INTERFACE SUPPORT)
 - o UNIVERSITY SITES
- o INTEGRATED LOGISTICS FUNCTION
 - o FACILITY ANALYSIS IN WORK
 - o FUNCTIONS
 - o MODEL AND DATA BASE MANAGEMENT
 - o INVENTORY MANAGEMENT ; ;
 - o INTERMEDIATE AND DEPOT LEVEL REPAIR
- o PRELAUNCH FUNCTION

- o FACILITY ANALYSIS IN WORK
- o PROCESSING/TEST & CHECKOUT AS REQUIRED

- o COST ANALYSIS
 - o DEVELOPMENT
 - o FACILITY REQUIREMENTS (C of F)
 - o FACILITY OUTFITTING
 - o FUNCTION CAPABILITY DEVELOPMENT
 - o COMBINATION (OF CODES S,T,E)
 - o RECURRING
 - o MODEL DEVELOPMENT IN WORK
 - o MODEL WILL PROVIDE
 - o SUPPORT TO THE DTC PROCESS
 - o PROVIDE EARLY RECURRING OPS COST ESTIMATES
 - o SENSITIVE TO ALTERNATIVE DESIGNS
 - o RESPONSIVE TO CHANGE IN CONCEPTS AND DESIGN
 - o TYPICAL PARAMETERS:
 - o FACILITY M&O OPERATIONS
 - o TRAINING, MISSION DESIGN, AND MISSION OPS SUPPORT
 - o SUSTAINING ENGINEERING
 - o PAYLOAD INTEGRATION
 - o SOFTWARE SUPPORT ENVIRONMENT (SSE)
 - o MAINTENANCE/CONFIGURATION/LOGISTICS INVENTORY
DATA BASE MANAGEMENT
 - o INTEGRATED LOGISTICS
 - o CONSUMABLES
 - o SPARES PROCUREMENT

- o ELEMENT PROCESSING
- o LAUNCH SERVICES

- o OPEN AREAS OF DISCUSSION
 - o SERVICING SUPPORT ROLE
 - o STATION/OMV
 - o PLATFORMS
 - o PAYLOADS
 - o OTV'S
 - o DISTRIBUTION OF FUNDING/DEVELOPMENT RESPONSIBILITY FOR USER REQUIREMENTS AND INVOLVEMENT (CODES S, T, & M)
 - o INTERNATIONAL INVOLVEMENT
 - o COMMERCIAL INVOLVEMENT

