Report

of the

Cost Assessment and Validation Task Force

on the

International Space Station

NASA Advisory Council

April 15, 1998

NASA Advisory Council

National Aeronautics and Space Administration
Washington, DC 20546

April 21, 1998

Daniel. S. Goldin
Administrator
National Aeronautics and
Space Administration
300 E Street SW
Washington D.C., 20546-0001

Dear Mr. Goldin:

The NASA Advisory Council has completed the independent assessment of the International Space Station (ISS) program that you directed be done. At our meeting on March 19, 1998, Jay Chabrow presented the findings of the Cost Assessment and Validation (CAV) Task Force of the Advisory Committee on the International Space Station (ACISS).

The Task Force assessed the validity of NASA's projections and provided its own estimation of the remaining cost and schedule for ISS completion. The Task Force members have considerable experience and broad knowledge of all aspects of program management and cost forecasting of technical development programs. The Council found the methodology and results to be credible.

The CAV Task Force reported that the most probable schedule slip is 24 months with a range of 10 months to 38 months. It also determined that additional funding in the range of $130 to $250 million annually will be necessary through completion of assembly. The Council believes these findings to be consistent with the level of growth that would be expected given the significant complexity of the ISS program.

Mr. Goldin, please be assured that the enclosed assessment is truly independent; neither the ACISS nor the Council has influenced or altered it.

The documents that NASA provided to Congress have been reviewed for consistency with the earlier drafts on which the CAV Task Force assessment was based. The assessment of those areas of Congressional concern is unchanged and is reflected in the report.

Sincerely,

Brad Parkinson

Bradford W. Parkinson

Enclosures

A. Thomas Young
12921 Esworthy Road
Potomac, Maryland 20878
(301) 926-2318
April 21, 1998

Dr. Bradford Parkinson
Chairman
NASA Advisory Council
NASA Headquarters
Washington, D.C. 20546

Dear Brad,

The Cost Assessment and Validation Task Force (CAV), with Mr. Jay Chabrow as Chairman, was established at the request of the NASA Administrator. The CAV charter was to perform an independent review and assessment of costs, budgets, and partnership performance on the International Space Station (ISS) program and to provide advice and recommendations. Enclosed is the CAV final report dated April 15, 1998.

The Advisory Committee on the International Space Station (ACISS) reviewed the CAV results at a committee meeting on March 12, 1998 and has completed a review of the final report. Special actions were taken by the ACISS to ensure that the CAV review and assessment was independent. ACISS comments from both reviews were provided to the CAV, and the Task Force had total authority to determine disposition. The CAV final report is truly an independent review and assessment.

Task Force members are experienced professionals with significant experience in the management of major space projects. Their conclusions are based on fact finding by participation in NASA meetings and visits to facilities of major ISS participants, analyses performed by the CAV, and the collective judgment of the members. CAV conclusions include a likely delay in the completion of the ISS assembly from one to three years beyond December 2003 and additional annual funding of between $130 million and $250 million relative to the ISS fiscal year 1999 budget to Congress. The CAV findings are reasonable and credible given a program of such complexity.

Sincerely,

Tom Young

A. Thomas Young
Chairman, Advisory Committee on the International Space Station

Enclosure

Cost Assessment and Validation Task Force
on the International Space Station
National Aeronautics and Space Administration
Washington D.C. 20546

April 15, 1998

Dr. Bradford Parkinson
Chair
NASA Advisory Council
National Aeronautics and Space Administration
Washington, DC 20546

Mr. A. Thomas Young
Chair
Advisory Committee on the International Space Station
12921 Esworthy Rd.
Potomac, Maryland 20878

Dear Brad and Tom:

The Cost Assessment and Validation Task Force has completed its independent review and assessment of the International Space Station (ISS). You will find the report content is largely consistent with the overall findings briefed to the NASA Advisory Committee on the ISS and the NASA Advisory Council at earlier meetings. The enclosed report contains the specific analyses from which the overall assessment was generated.

Two of the more significant findings in the report are estimates that the cost of the ISS will increase from $130 million to $250 million each year over the NASA fiscal year 1999 budget submittal, and that the program will extend beyond its current schedule by one to three years.

I can not say enough about the individual people who contributed their considerable time and vast experience to the generation of this report. We are extremely confident in the accuracy of our findings and hope that this report contributes to a better understanding of this vital space-based international resource.

Sincerely,

Mr. Jay Chabrow
Chairman, Cost Assessment and
Validation Task Force

Enclosure

REPORT OF THE COST ASSESSMENT AND VALIDATION TASK FORCE ON THE INTERNATIONAL SPACE STATION

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1.0 Executive Summary

The Cost Assessment and Validation (CAV) Task Force was established for independent review and assessment of cost, schedule and partnership performance on the International Space Station (ISS) Program. The CAV Task Force has made the following key findings:

- ***The International Space Station Program has made notable and reasonable progress over the past four years in defining and executing a very challenging and technically complex effort.***
- ***The Program size, complexity, and ambitious schedule goals were beyond that which could be reasonably achieved within the $2.1 billion annual cap or $17.4 billion total cap.***
- ***A number of critical risk elements are likely to have an adverse impact on the International Space Station cost and schedule.***
- ***The schedule uncertainty associated with Russian implementation of joint Partnership agreements is the major threat to the ISS Program.***
- ***The Fiscal Year (FY) 1999 budget submission to Congress is not adequate to execute the baseline ISS Program, cover normal program growth, and address the known critical risks. Additional annual funding of between $130 million and $250 million will be required.***
- ***Completion of ISS assembly is likely to be delayed from one to three years beyond December 2003.***

1.1 Background

The International Space Station emanates from a 1993 NASA cost reduction-based redesign of the Space Station Freedom. NASA committed to build the new design within a $2.1 billion annual funding constraint and at a total cost to completion of $17.4 billion. Now, nearly five years later, hardware manufacturing for many of the first U.S.-developed flight elements has been completed. The program is well into the test and integration phase, preparing for the start of deployment later this year.

Progress on the ISS Program has been achieved by overcoming a variety of challenges. In 1997, cost growth and delivery delays, both in the U.S. and abroad, made considerable news. In May 1997, the ISS First Element Launch (FEL) was deferred by seven months from November 1997 to June 1998. In September 1997, after coordination with the International Partners on out-year ISS assembly flights, a new manifest was released that reflected a slip of over a year in completion of ISS assembly. These events and others have raised questions regarding the total cost and schedule for ISS development and operations.

In September 1997, the NASA Administrator asked Dr. Brad Parkinson to establish a Cost Assessment and Validation Task Force, reporting through the Advisory Committee on the International Space Station (ACISS) to the NASA Advisory Council, for independent review and assessment of cost, schedule and partnership performance on the ISS Program. The letter of request is in Appendix A. The objective of the Task Force, chaired by Mr. Jay Chabrow, was to provide advice and recommendations for improvement of the ISS business structure and cost management practices and to determine the total cost over the life of the Program. The Task Force Terms of Reference are in Appendix B.

On October 6, 1997, the Senate-House Conference Committee submitted Conference Report 105-297. This report specified certain NASA reporting requirements to Congress as a precondition to the March 1998 Congressional release of $851,300,000 in FY 1998 ISS funding.

The following items were required of NASA by Congress:

- a detailed plan, jointly agreed to by NASA and the Prime contractor, for the contractor's monthly staffing levels through completion of development, and evidence that the contractor has held to the agreed-upon de-staffing plan through the first four months of fiscal year 1998,
- a detailed schedule, jointly agreed to by NASA and the Prime contractor, for delivery of hardware, and NASA's plans for launching the hardware,
- a detailed report on the status of negotiations between NASA and the Prime contractor for changes to the contract for sustaining engineering and spares, with the expectation that NASA would adhere to the self-imposed annual cap of $1.3 billion for operations after construction is complete,
- a detailed analysis by a qualified independent third party of the cost and schedule projections required for the above items, either verifying NASA's data or explaining reasons for lack of verification.

NASA requested the CAV Task Force to perform this independent assessment, either verifying NASA's data or explaining reasons for lack of verification. The letter making that request is in Appendix C, and the Task Force's assessment is in Appendix D.

Six additional experts made up the Task Force. Their biographies are in Appendix E. The members were selected to obtain a diversity of expertise in program management, cost estimation and formulation, technology development, and cost and schedule risk assessment, so that all aspects of the ISS Program could be analyzed and assessed. Task Force members have backgrounds in industry, the federal government, and the military and have experience in large-scale aerospace and other technology development programs.

1.2 CAV Task Force Organization and Process

Three members of the CAV Task Force, who were serving as technical consultants on the ACISS, attended detailed budget reviews at each of the Prime contractor's production sites in October, 1997. The official kick-off meeting of the Cost Assessment and Validation Task Force was on November 6, 1997

Since the team's initial meeting, members of the CAV Task Force have met almost weekly. The team was given open access to every facet of NASA's ISS Program. Fact-finding trips were made for meetings with ISS Program management, line support organization personnel, and the Program's Prime Contractor. The CAV Task Force met with representatives of the European Space Agency (ESA) and the Russian Space Agency (RSA) at their production sites to gain first-hand knowledge of their performance. Representatives of Alenia Aerospazio, Turin, Italy, who are responsible for the delivery of several U.S. and European elements also briefed the CAV Task Force on their progress.

The Task Force's fact-finding focused on major aspects of past performance trends, current performance, and estimated projections by the ISS Program. The main thrust was to identify and evaluate major risk elements that would likely contribute to further cost growth and schedule slip. Pertinent information was gathered through summary and detailed status briefings, special topics briefings, site visits, and personal interviews with ISS program and line management and support personnel, and in conversations with other government oversight organizations. The compiled information was reviewed to assess the major impediments which could affect timely completion of the ISS.

1.3 Findings

1.3.1 Development

The ISS Program has been diligent and resourceful in managing the unique challenges of this complex venture given the significant complexity and uncertainty of international involvement and the difficult task of staying within annual and total funding caps established prior to final Program content definition. The Program has not incurred any extraordinary technical or programmatic "show stoppers" to date. Although cost and schedule growth have occurred, the magnitude of such growth has not been unusual, even when compared with other developmental programs of lesser complexity.

The $2.1 billion annual funding limitation has resulted in spread-out procurements, deferred and untimely work, and inadequate contingency planning, all of which have induced schedule delays and have increased cost. NASA's cost and schedule plans have been optimistic from the beginning of the Program and continue to be so today. Budget and reserve levels have been, and continue to be, inadequate for a program of this size, complexity, and development uncertainty despite NASA's past contentions that the total funding level is adequate. It could alternatively be stated that the Program has more content than it has funds available to achieve.

In the Task Force's opinion, Program de-staffing goals do not adequately account for: work yet to be accomplished, mitigation of current and potential cost and schedule risks, and the retention of an appropriate skill mix through completion of development. The Task Force analyzed ISS de-staffing plans for several prior years and found they were not achieved for reasons similar to those noted above. Current development de-staffing plans require Prime contractor off-loads at a greater rate than all previous plans. Past trends clearly indicate that this is not a realistic assumption. Therefore, the Task Force believes that attempting to adhere to the current de-staffing plans is unreasonable and will introduce additional cost and schedule risks that could otherwise be avoided.

Management challenges will remain large and diverse considering the significant on-orbit assembly tasks; the size and breadth of the integration required; the splintered delegation of systems integration functions; and the required coordination responsibilities among NASA, its Prime contractor and International Partners. ISS Program management, primarily due to past annual funding constraints, has not fully developed and implemented cost and schedule risk mitigation plans to minimize or eliminate larger schedule stretchouts or increased costs.

<u>Major Development Risk Elements</u>

There are a significant number of cost and schedule growth risks in a program of this magnitude that have direct implications to the total development cost of the Program and to the schedule for completion of assembly. The following list represents the major development risk elements the Task Force identified in the ISS program.

- <u>Hardware Qualification Testing</u> The Program has produced over 300,000 pounds of flight hardware and is scheduled to double this amount by the end of 1998; however, much of the hardware and software production is behind plan or still undergoing development and qualification testing. Additional cost growth potential resides in the fact that various contractor staff will remain on contract longer than planned, as the Program completes qualification, integration, and verification testing activities.

- <u>On-Orbit Assembly Complexity</u>
This phase of the ISS Program requires simultaneous integration of launch operations, on-orbit assembly operations, engineering support, and logistics and maintenance support with mission operations over an extended period of time. The full assembly sequence for ISS will span a period in excess of five and one-half years, involving over 93 flights of multiple booster types to assemble and check out, on orbit, hardware from around the world. The overall complexity and scope of this effort is beyond the current experience base of NASA and the International Partners and, as such, contain cost and schedule uncertainties and risks. The resource estimates, in terms of schedule and budget, for this undertaking are optimistic.

- <u>Crew Return Vehicle Development</u>
The Crew Return Vehicle (CRV) is a new, crewed, vehicle development program which is required in early 2003 to support the autonomous, safe return of up to seven crew members. The CRV development and deployment is on the ISS Assembly Complete critical path. The X-38 is a NASA in-house program to develop some technology for the CRV vehicle. The X-38 Program is 10 months behind schedule. Currently, there is no integrated plan or acquisition strategy that would provide a seamless transition from the current X-38 Program to support CRV development and production requirements and schedule. Further, NASA's CRV budget and schedule allow only $5 million of expenditures in FY 1999, a production award in FY 2000, and only three and one-half years to operational need. In the CAV Task Force's opinion, current CRV Program plans will not support operational readiness requirements to meet the assembly sequence need date.

- <u>Multi-Element Integrated Testing</u>
Multi-Element Integrated Testing (MEIT) is a rigorous integration and testing program intended to successfully demonstrate systems interface compatibility and end-to-end hardware and software functionality. Major flight hardware is scheduled to undergo MEIT just prior to launch; however, hardware and software production activities have very little remaining schedule reserve between now and launch to address unanticipated problems. Resolution of problems or issues identified during MEIT will likely result in launch delays. The highly integrated and interdependent nature of the MEIT hardware and software need dates and the phasing of MEIT activity also introduce a high potential for multiple ISS launch schedule impacts.

  Additionally, the schedule impact of incorporating MEIT for the Phase III portion of the assembly sequence is not yet reflected in the Program plan or budget.

- <u>U.S. Laboratory Schedule</u>
The Laboratory is currently several months behind schedule, with a significant amount of qualification and integrated testing remaining to be performed. Software development and testing are also major concerns. Considering past trends there is a high probability of additional schedule erosion of several weeks or more.

- <u>Training Readiness</u>
Schedule slippage is affecting training readiness. In addition to oral and written language complexities, there are also issues with respect to detailed approaches to training that are cultural or philosophical in nature and are yet to be fully resolved.

- <u>Software Development and Integration</u>
Software testing and integration are traditionally the areas of space system development subject to the greatest schedule problems. The ISS has a

significant amount of software that has to be integrated across multiple domestic and international suppliers. While many software deliveries already have little schedule margin remaining, late flight hardware deliveries will place further pressure on software schedules due to hardware problems likely to be discovered during late stages of testing. Typically, late hardware problems are circumvented by software workarounds, thus increasing the time and effort required for software integration and testing.

- Parts and Spares Shortages
  To contain near-term spending to within the funding profile during peak development, decisions were made to reduce contracting for parts and spares necessary to support the current schedule. Various program activities were hardware-limited during the development and test phases. Not procuring adequate spares during the initial production run of some components may lead to quality and consistency issues as well as increased cost.

1.3. 2 International

Sixteen countries on four continents are engaged in building hardware and software for the ISS. Each country has its own governmental limitations. Partner countries have adjusted, and will continue to adjust, their level of financial involvement and schedule commitments, ultimately affecting U.S. costs and schedules. Further, modifications to the assembly sequence, ground operations, and on-orbit operations all require integration and various levels of coordination and joint approval. The U.S. developmental effort cannot be isolated from these occurrences and their associated impacts: the Program has experienced cost growth and schedule slippage associated with this broad level of international involvement.

This has been especially true in the case of Russia. The anticipated one billion dollar cost savings to the U.S. to be accrued from Russian provision of the Functional Cargo Block (FGB in its Russian language acronym) and an Assured Crew Return Vehicle capability, was a faulty assumption as far back as 1994. The continuing economic situation in Russia has also negated most of the $1.5 billion in schedule savings to be achieved through their involvement. Russian schedule slippage, due largely to failure of the Russian government to deliver promised funding, translates directly to the most recent Service Module schedule slips. With continuing funding shortfalls carrying into 1998, the absence of any hard indicators that adequate Russian funding will be provided soon, and the recent cabinet shake-up in Moscow, it is likely RSA elements will experience further delays.

The CAV Task Force notes that a diminished level of Russian participation could significantly alter the current ISS assembly sequence and final design. Proceeding forward with full knowledge of the past, present, and to some extent, the future economic environment in Russia without implementing adequate contingency capabilities to address likely shortfalls is tantamount to accepting a level of risk that could drive U.S. costs significantly higher. NASA contingency plans extending beyond the development of the Interim Control Module are not reflected in the current budget. The Task Force believes the level of exposure to increased cost from Russian delays justifies the funding of additional contingency activities.

Major International Risk Elements

The most significant cost and schedule growth risks identified relative to International Partner contributions are as follows:

- Russian-Built Service Module
  Inadequate funding will likely cause the Service Module schedule to slip a minimum of four months in addition to the eight months already acknowledged and incorporated into the Revision C baseline assembly sequence. Service Module subsystem deliveries are being affected,

and this could result in a day-for-day slip until adequate funding is supplied. Approximately $45 million dollars in FY 1997 Russian funding are still outstanding, and there are no hard indicators that adequate Russian funding will be provided any time soon for FY 1998 and beyond.

- Russian Logistics/Propulsion Support
  Current RSA plans reflect a late 1999 Mir deorbit. This plan, which calls for deorbit a year later than NASA had desired, foreshadows a Russian logistics impact to the current ISS assembly sequence. Russia's demonstrated Progress spacecraft production capacity and its recent launch rate capability do not support the view by RSA that it can meet its collective ISS and Mir requirements.

1.3.3 Operations

In the operations timeframe, the ISS Program management believes it will be able to meet its $1.3 billion annual operations funding limit. The Task Force believes this level of funding is inadequate to support the total scope of the technical and operational requirements.

Major Operations Risk Element

- Maintenance and Obsolescence
  The CAV Task Force anticipates that upgrades due to normal wear and tear, obsolescence, and degradation will be required, and additional funding will be necessary to support these needs. This issue is addressed in section 4.3, but it is not quantified. It is noted as an item of significance and one that merits additional in-depth consideration.

1.4 Conclusions

Given the above considerations, the Task Force concludes that the Program has inadequate funding to cover normal developmental program growth, ISS cost and schedule risks, and necessary risk mitigation activities. The ISS will also likely experience a delay of one to three years in the completion of assembly.

Relative to budget formulation, the Program will likely need the full level of funding requested in the FY 1999 budget submission to Congress. The Program should plan for the development schedule to extend an additional two years with additional funding requirements of between $130 million and $250 million annually, including the period beyond Assembly Complete. The specific annual CAV Task Force funding recommendations are provided in Table 3-3. This level of funding and schedule extension results in a total assessed cost of approximately $24.7 billion from the 1994 ISS redesign through ISS Assembly Complete.

This level of funding should be sufficient to address threats that are reasonably likely to occur, with several noted exceptions: it does not cover catastrophic launch vehicle or payload failures, the withdrawal of an International Partner, or the development of a U.S. propulsion capability which the Task Force believes should be factored into an overall Russian contingency strategy.

1.5 Recommendations

1) The present program plan should be revised so that it is achievable within the financial resources available. Realistic major milestone dates should be established as the basis for development of the program plan and internally defined target dates should be used for execution. If necessary, program content should be eliminated or deferred to fit within funding constraints.

2) Develop and implement a comprehensive cost and schedule risk evaluation and mitigation strategy associated with the delivery of Russian contributions, particularly for the uncertainties associated with propulsion and logistics capability and the Service Module delivery.

3) Develop and implement Phase III MEIT to mitigate on-orbit systems assembly and integration uncertainties.

4) Consider merging the NASA X-38 and the CRV development programs, accelerating the start of the CRV to FY 1999, and increasing the budget by $120 million. The CRV schedule urgency coupled with relatively high levels of technical and budgetary uncertainty support the need to have a seamless transition of experience and learning from the NASA X-38 Program to the CRV Program.

5) Establish a specific organization and management structure with responsibility for Systems Engineering & Integration (SE&I) efforts, including sustaining engineering. The structure should include both government and contractor personnel from all participants and should be given clear management responsibility, authority and budget to carry out an integrated SE&I plan. NASA should also clearly delineate and document the systems integration responsibilities for which each party is accountable and currently performing.

6) Establish a competitive environment for support contracts, such as sustaining engineering, in order to reduce overall program costs.

7) Maintain the current level of research funding. Develop plans to maximize science utilization on-orbit during schedule stretchout.

8) Institute a system for determination of earned value performance measurement for the Non-Prime scope of effort. Non-Prime activities account for 65 percent of the total staffing in 1998 and are growing as a percentage of work performed. Implementing such a system would greatly increase the accuracy of status reporting and of Non-Prime cost and schedule projections.

9) Verify the appropriateness of a flat funding profile for the operations timeframe of the ISS, specifically assessing how obsolescence-induced upgrades will be planned and implemented.

2.0 ISS Program Overview

The mission of the International Space Station (ISS) Program is to build and operate a state-of-the-art orbital research facility some two hundred nautical miles above Earth. The ISS Program stems from a redesign of the Space Station Freedom Program in 1993 that President Clinton had directed NASA to do to lower its cost.

2.1 Freedom Redesign and ISS Schedule and Cost Commitments

On March 10, 1993, NASA established a Station Redesign Team to consider viable space station options that would continue to accommodate the International Partners within specific funding constraints and first-level goals established by the Clinton Administration. The redesign team developed three basic options, all of which required funding in excess of target budget guidelines and, in particular, above the $2.1 billion annual cap that the Clinton Administration proposed, and NASA accepted, at the culmination of the redesign activity.

The President's Advisory Committee on the Redesign of the Space Station judged two of NASA's options to be roughly comparable and satisfactory for meeting the Administration's objectives, excepting those of cost, which all options exceeded. That Committee, chaired by Dr. Charles M. Vest, assessed NASA's cost projections to be realistic, but recognized that the space station should be considered as an ongoing, evolving program of scientific and technological research.

The Advisory Committee further recommended that NASA and the Administration pursue increased levels of cooperation with Russia as a means of enhancing the capability of the Station, reducing costs, accelerating schedule, providing alternative access to the Station, and increasing research opportunities. It also recommended that the Space Station Program reorganize, reconfirming NASA's redesign team's recommendation to have one Prime contractor responsible for development and integration. These findings were published in June 1993.

The Station concept that NASA selected from this redesign activity was called Space Station Alpha. It was a downsized representation of Space Station Freedom with the capability for a crew of only four, and it was totally reliant on the Shuttle for transportation and supply. The original redesign options had projected Permanent Human Capability (PHC) in 2001 or 2002. But these scenarios also required peak annual funding levels of at least $2.8 billion. In June 1993, the Administration provided guidance to keep the Program within an annual expenditure level of $2.1 billion. NASA reassessed the assembly plans given this constraint and revised the schedule for achieving PHC, deferring it to September 2003. The cost for Space Station Alpha was assessed at $19.4 billion.

In December 1993, Russia was invited to join the partnership. It was thought that the Russian participation in the ISS Program would accelerate the assembly timetable and avoid substantial development costs in the areas of propulsion and navigation. It was also estimated that Russian contributions would nearly double the Station's on-orbit volume, allow an increase in crew size to six, and provide an earlier crew presence. After Russia agreed to participate, geographic constraints of launching elements from the Baikonur Cosmodrome in Kazakhstan necessitated a change of launch inclination from 28.5 degrees to one of 51.6 degrees. While this change negatively impacted the Shuttle's cargo carrying capacity for transport of elements and supplies to the Station by over 12,000 pounds per flight, the capability reduction was offset by the addition of 13 planned Russian assembly flights. Russian participation also allowed completion of ISS assembly to be accelerated from September 2003 to June 2002, a projected cost savings of $1.5 billion. The Russian provision of the Functional Cargo Block and an Assured Crew Return Vehicle were estimated to save another $1.0 billion. These savings were partially offset by new U.S. costs identified to integrate Russia into the Program. In total, a net estimated cost savings of $2 billion was projected from Russian involvement. Beyond that, Russia's involvement advanced foreign policy objectives such as demilitarization, privatization, and integration of Russia into the international community.

NASA stated at the time that it could develop the Space Station Alpha design within an annual fiscal constraint of $2.1 billion per year, and with Russian participation it could complete assembly of what had become known as the International Space Station for a total of $17.4 billion. These self-imposed funding constraints were established prior to the FY 1995 Congressional budget submission. The Program was carrying approximately $2.0 billion in reserves with approximately $500 million allocated primarily for unresolved management challenges. NASA's schedule and cost commitments were definitely success-oriented, especially considering the new realigned contracting approach with a single Prime contractor and that the specifics of Russia's involvement were just being definitized.

2.2 ISS Development

2.2.1 1994 Events

There were many early challenges to NASA's ability to maintain its cost and schedule commitments. In the spring of 1994, Space Station Freedom contracts had been novated, but NASA had not reached agreement with Boeing on a definitized Prime contract, and Boeing was far from reaching contractual agreement with the existing major subcontractors. This did not occur until the spring of 1996. NASA and RSA were still working on an Inter-Governmental Agreement (IGA) to bring Russia into the Program. It was not until March 1994, when NASA was able to conduct a full systems design review, that the redesign activity was considered complete. The initial baseline ISS assembly sequence was not officially established until November 28, 1994, reflecting FEL in November 1997, with ISS Assembly Complete by June 2002.

By April 1994, Canada had shifted its priorities away from human space flight and space robotics toward space communications, earth observation and technology development. As a consequence, NASA agreed to assume more responsibility (and more cost) for the extravehicular robotics function than had been foreseen in NASA's original agreement with the Canada Space Agency (CSA). As a result, Canada's Space Station utilization rights during the operational phase of the Program were reduced accordingly. NASA estimates at the time reflect that this reduction in CSA's commitment increased NASA's overall development costs at completion by over $200 million.

In June 1994, the Centrifuge Accommodation Module (CAM), which was part of the Space Station Freedom design but was not identified specifically in the Space Station Alpha assembly sequence, was brought back into ISS assembly plans; however, additional funding for this element was not requested or provided.

It was agreed that Russia would build and launch the first on-orbit element, the FGB, in the International Space Station assembly sequence. To assure U.S. ownership and control of the FGB, NASA decided to procure it through Boeing from the Russian manufacturer, facilitating Russian privatization and simultaneously allowing the first on-orbit element to be a U.S. element. This procurement cost the Program slightly over $200 million in reserves. It was also in this timeframe that a U.S.-developed CRV was added to the Program, yet no additional funding was requested by NASA. NASA carried the CRV as a threat against reserves until just recently, when funding was allocated in the FY 1999 budget submission to Congress specifically for the CRV.

The only notable U.S. developmental problem occurred late in 1994 when Boeing, the Prime contractor, incurred welding and tooling problems in the development of the Node Structural Test Article (STA). This resulted in an approximately four month impact to horizontal drilling of the STA. Recovery plans were put in place and the Program appeared to be largely on track to meet its commitments.

2.2.2 1995 Events

At the start of 1995, NASA had increased its reserve posture to slightly over $3 billion, though there was still significant concern about the adequacy of near-term reserves to carry forward into 1996. In increasing its reserve posture, NASA had reassessed its operations and Non-Prime budget estimates, reducing its cost projections by over $2 billion. However, a fourth Photovoltaic Power Module, additional truss structure and other lesser additions to the Prime contract had increased the amount of Prime contractor work by approximately three quarters of a billion dollars. NASA also realized that certain management challenges for cost reductions that it had carried in other areas were not going to be realized. Beyond that, new threats against the Program had increased significantly: NASA was now carrying the CRV, a Control Module for contingency against Service Module delays, additional "make operable" change threats, and other threats totaling $1.5 billion.

In mid-1995, Revision A to the baseline assembly sequence was adopted. There were no changes to the schedules for FEL or final assembly. The only significant changes concerned the addition of two new Russian flights for power augmentation.

The earlier Node STA slippage rippled through the boring and milling schedules for the other U.S.-manufactured pressurized modules. Boeing also began to show cost and schedule variances in other areas as well. Beyond the under-performance situation, there continued to be constant growth on the contract from program changes totaling approximately $340 million in 1995. This growth, coupled with the Boeing performance problems and an increase in cost of the Functional Cargo Block (above what NASA originally projected) depleted NASA's near-term development reserves. In the fall of 1995 NASA re-phased approximately $350 million in ISS utilization funding to replenish near-term reserves constrained by the annual expenditure cap.

As the development activity moved firmly into the manufacturing stage, NASA was beginning to review specific plans for implementation of ISS integration and test requirements. This review led to increased testing and verification procedures that NASA had to assess how to implement within already strained resources.

RSA presented a proposal to NASA in December 1995, for extension of the on-orbit life of its Mir space station in order to use it as a building platform for ISS. It also informed NASA of a decision to not use the Russian Zenit launch vehicle for assembly of the ISS. NASA agreed to assist RSA by providing additional Shuttle logistics flights and continuing the Shuttle-Mir program into 1998, but did not agree to use Mir as an on-orbit platform for construction of the ISS.

Not using the Zenit would necessitate up to four Progress launches for the Russian Science Power Platform (SPP) assembly and thus would cause considerable delay in its operational readiness. NASA agreed to launch the Russian SPP on the Shuttle to mitigate assembly impacts. While Russian Research Modules were affected to the greatest extent, Node 2, the CAM, U.S. Utilization flights, and the Japanese and European Research Modules were all delayed, with the CAM and European Columbus Orbital Facility (COF) being delayed beyond Assembly Complete. These changes were eventually reflected in Revision B of the baseline assembly sequence, which was not officially agreed to until the fall of 1996.

2.2.3 1996 Events

At the beginning of 1996, total ISS reserves were still being held at close to $3 billion. With the re-phasing of near-term funds from the utilization account to the development account, NASA believed it could maintain 1996 development schedules; however, near-term reserves turned out to be inadequate to address the many challenges that were to occur.

In the spring and summer of 1996, the Node STA and the Node 1 were both undergoing pressure testing. During these structural tests, stress exceedances were identified in the radial portals. NASA established a "blue ribbon team" of senior structural and aerospace program managers and engineers to identify actions necessary to resolve the problems. Additional strengthening struts were eventually added to the Node structure, and the problematic gussets were modified to more evenly distribute stress across the Node hatch. These "make operable" changes resulted in additional Node delays and contributed greatly to the Prime's cost and schedule growth in 1996.

In addition to the structural Node problems, a number of other development problems were experienced in design, test, and manufacturing. By the end of 1996, the Prime's cost overrun was nearly $200 million and growing at a rate of $16 million a month. Also, other program changes for "make operable" work continued to be required, with approximately $200 million of funding being used from reserves. Despite the difficulties, a total of 155,000 pounds of U.S. flight hardware had been completed by the end of 1996.

Good developmental progress was being made by the International Partners, with the continued exception of Russia. Throughout the year, there continued to be concerns about the lack of progress on the Service Module. While Russia continued to maintain that it could meet its April 1998, launch commitment for the Service Module, schedule milestones continued to be missed and deferred. NASA and the U.S. Government applied management emphasis at all levels in an attempt to obtain release of adequate Russian government funding for RSA to maintain its schedule commitments. Finally, in the fall of 1996, Russia explicitly informed NASA that it would not be able to meet its Service Module delivery milestone.

Throughout the year NASA had been assessing various contingency options should Russia not be able to meet its Service Module commitment. In December of 1996, NASA initiated development activities at the Naval Research Laboratory (NRL) for the development of an Interim Control Module (ICM). The ICM would provide adequate propellant and attitude control to continue to build the assembly sequence should the Russian Service Module be further delayed. The ICM would also be available to provide some assurance against Russian logistics shortfalls.

2.2.4 1997 Events

NASA entered 1997 with approximately $2.3 billion in reserves on the books through June 2002. Threats against those reserves, however, had grown to $1.9 billion. As in the two prior years, Prime contract cost growth continued. Additional Program changes were needed to make equipment operable, and continuous cost increases were being driven by Russian funding inadequacies and element delivery delays. In addition, requirements for maintaining an adequate workforce for sustaining engineering and for procuring the necessary on-orbit spares for maintenance and contingencies were being delineated. Definitization of these activities caused additional cost growth.

Russia finally committed funding to continue work for completion of the Service Module and for other ISS commitments in the spring of 1997. NASA and RSA worked together to minimize schedule perturbations and to find efficiencies and workarounds. In the final analysis, an eight month slip was agreed to and baselined into the ISS Program.

Russian plans to launch several Logistics Transfer Vehicles (which were similar to the FGB in design and were intended to minimize the number of launches required for ISS re-boost) were deleted and replaced with Russian Progress vehicles with less fuel capacity. This change introduced additional uncertainties relative to Russian production capacity to meet the higher flight rate required for launches. Significant changes were made to the assembly sequence, resulting in increased training requirements. At the same time, the Russian hardware delivery delays were causing additional challenges to achieving the planned training proficiencies utilizing actual flight hardware and software.

In April 1997, NASA informed the Congress of its plan to reallocate $200 million in new FY 1997 funds from the Human Space Flight Program to a new budget line item for "Russian Program Assurance" (RPA). This line item was established to fund contingency activities addressing Russian uncertainties. This line item, which Congress approved, allowed the ICM to be funded and other necessary changes to be made in order to integrate the ICM into the ISS without further depleting NASA's limited near-term reserves. NASA originally suggested that this line item be the source of funds to develop further contingency alternatives to buy down the cost and schedule risks that could result from other Russian shortfalls, but no additional money has been made available for that purpose.

In May 1997, all of the International Partners met and agreed upon a new near-term assembly sequence that accommodated Russia's schedule slippage. They decided to withhold a final decision on whether to maintain the schedule showing the Russian Service Module schedule at its projected launch date of November 1998 or to insert the NASA-funded ICM into the assembly sequence. The latter option would then provide Russia additional time to complete the Service Module. No new date was provided relative to Assembly Complete, but NASA indicated that it would slip beyond 2002.

The new assembly sequence reflected a number of significant changes. The first element launch, beginning ISS assembly, was deferred from November 1997 to June 1998. A number of new flights were also incorporated into the assembly sequence. Two new logistics flights protected the option to integrate the ICM into the assembly sequence either in place of the Service Module or at a later date for a propellant-related contingency. There was also a significant amount of replanning relative to logistics. The eight month slip in the assembly sequence resulted in a utilization gap in the research community's access to space, so, separate from the ISS assembly sequence, two new Shuttle utilization flights were added to the Shuttle manifest to maintain adequate research access. Approximately $25 million in ISS Program funding was applied toward providing pressurized research laboratory infrastructure for these Shuttle flights.

In September, after the International Partners were able to confirm that significant Russian funding was, in fact, being applied to the Program and that Russian subcontractors had confirmed that the money provided would allow the Service Module to hold its new schedule, Revision C to the baseline assembly sequence was approved.

Revision C maintained the option to insert the ICM in 1999 should Russia incur a shortfall in its ability to provide an adequate number of Progress launch vehicles for ISS propellant resupply and reboost. Revision C also reflected the addition of: a third Node; the rescheduling of the European COF back within the timeframe for Assembly Complete; and, integration of two new logistics vehicles into the manifest, the European Automated Transfer Vehicle (ATV) and the Japanese H-II Transfer Vehicle (HTV). The final launch provided in the assembly sequence was shown in December 2003. Specifics of NASA's offset agreements is documented in Section 2.4.

The third Node being provided as an offset by ESA is a significant development. The volume of the Node is roughly equivalent to the Multi-Purpose Logistics Module (MPLM) and, as such, offers the ability to add much of the crew habitability subsystems that were to be launched on the Habitation Module. This allows six-person PHC to be achieved with the on-orbit delivery of the CRV.

The Russian-driven schedule delays offered NASA the opportunity to significantly increase the level of ground integration and verification tests planned, thus reducing the threat of having a costly functional integration problem occur on orbit. When the launch dates for U.S. hardware were slipped, NASA held Boeing to most of its contractual delivery dates. This provided some schedule margin between element delivery and launch into which NASA programmed MEIT. These end-to-end tests are meant to validate that the early inter-elemental systems will work as designed.

Early in 1997, NASA took necessary steps to focus Boeing corporate management attention on the ISS Program through the award and incentive fee process. Since then, Boeing has brought additional financial and managerial resources to the team. Boeing has developed a new baseline cost estimate that reflects a total increase of approximately $600 million over the life of the contract, with over $400 million of that increase already incurred. The Performance Measurement System used to track cost and schedule variances has been adjusted to reflect this new cost estimate at completion.

The Program has attempted to limit changes only to those deemed as "make operable" and those necessary to strengthen the Program's test and verification processes. These types of changes alone required usage of $600 million in Program reserves in 1997, shrinking total reserves through 2002 to approximately $600 million.

2.3 Current Status

Entering 1998, the Program continues to be hampered by some of the same problems that it faced in preceding years. While reasonable progress continues on the U.S. elements, there are many challenges ahead that will result in increased cost and schedule erosion. U.S. development problems continue to be overshadowed by Russian funding shortfalls and delays in their commitments; however, even the current Revision C schedule is not fully supportable due to U.S. production delays and the incorporation of much needed multi-element integrated testing. There is relatively little uncertainty associated with the launch dates of the first two U.S. element flights. The U.S. laboratory, however, is several months behind schedule and is unlikely to recover, although workaround plans are in place to hold its scheduled May 1999 launch. There continue to be recurring problems such as late part and component deliveries on downstream flight elements, similar to those that plagued earlier flight elements. While the Prime contractor headcount is being reduced from the development program, there has been considerable growth in civil service and Non-Prime support.

While disconnects between the level of funding and work planned on the Program appeared in previous years, the Program was always able to reflect an ISS funding level within the $2.1 billion cap. The FY 1999 budget to Congress, submitted in February, marked the first significant departure from the $2.1 billion commitment, with NASA requesting an additional $430 million for FY 1998. The FY 1999 submission also reflected $1.5 billion of additional funding in the Program through 2003. This included $626 million for the development of a CRV. With the level of funding requested in the FY 1999 submit, NASA believes it can absorb the current Service Module delay, without asking for additional funds.

Again, in 1998, it appears that the U.S. developmental schedule erosion will be overshadowed by significant Russian funding and schedule problems. As of the writing of this report, $45 million of Russian FY 1997 funding earmarked for the Service Module is still being delayed. Relative to FY 1998 funding, reports are that only a small monthly allocation based on the Russian Government's continuing resolution is being provided, and it has not filtered down to the contractors performing work. This situation has resulted in a minimum four month delay in launch of the Service Module, with day-to-day slippage until adequate and sustained funding is achieved.

At the General Designers Review (GDR) in January, it was clearly evident that a lack of adequate funding was going to further impact the assessed four month delay in the Service Module launch. With the recent events relative to the shake-up of the cabinet in Russia and the continued absence of any real evidence that funding is imminent, the CAV Task Force believes it is highly certain that further schedule slippage will occur. The Service Module is near the point where it could be completed and launched at a minimal cost. Unfortunately, continued developmental progress appears linked with the availability of government funds which continue to be problematic At this point, the lack of sustained funding also gives rise to a greater concern, that of Russian logistics support.

2.4 International Partner and Bilateral Agreements

Under the Space Station IGA and Memoranda of Understanding (MOU), each participating agency is incentivized to spend its tax dollars at home. The ideal outcome is to have no transfer of funds among the nations. With the international partnership, every country is responsible for a *pro rata* share of the operations cost necessary to sustain the basic infrastructure and capabilities.

To achieve a full common operations cost offset, ESA made using an ESA-developed ATV to carry logistics to the ISS a condition of its continued support. This agreement led to the October 1995 confirmation of ESA's commitment to a three-component ISS contribution: the COF, the COF utilization plan, and the ATV that will be launched by Ariane 5 and provide pressurized or unpressurized logistics services and re-boost for the ISS. Similarly, Japan is developing the HTV with the goal of not owing NASA for payload launch services, and thus, offsetting its common operations costs.

As the U.S. agreed to launch the European COF module and the Japanese pressurized and unpressurized modules, each country desired to determine what type of ISS contributions it could make to offset the Shuttle launch cost

In exchange for Shuttle launch services for the COF, NASA and ESA have reached an agreement in principle on the provision of Nodes 2 and 3 and utilization facilities. The U.S. development plans called for the Node STA, after testing, to be outfitted and flown as Node 2. This obviated any opportunity to do additional destructive testing on the STA that appeared to be needed to resolve flight certification concerns. The manufacturing process that was used by Alenia to build the MPLM for the U.S. results in a more durable structure, while also providing a considerable amount of additional on-orbit storage capacity. The Node 3 is large enough to accommodate most of the crew support equipment planned for the U.S. Habitation Module. Integration of this equipment into Node 3 allows the U.S. to defer some Habitation Module development activity to a timeframe when there will be less strain on its financial reserves. Having to provide support subsystems for the new Node 3 as well as the Habitation Module will result in an additional cost to the Program of approximately $125 million dollars.

In exchange for Shuttle launch services for the Japanese pressurized and unpressurized experiment modules, Japan will build the CAM, the Centrifuge Rotor, and a Life Sciences Glovebox; launch a NASA payload on a dedicated H-IIA flight; and build eight payload interface units. Having Japan build the Centrifuge equipment provides a mechanism to fund equipment that would otherwise impact other utilization capabilities or be delayed.

NASA also entered into an implementing arrangement with Brazil to provide some utilization facilities and logistics carrier support. In return, Brazil would receive access to certain NASA on-orbit utilization resources, totaling less than 0.5 percent of NASA's allocation, and the launch of 300 pounds of Brazilian payloads to orbit.

2.5 Overview of Current Baseline

The baseline for the Task Force's ISS Program assessment is the FY 1999 budget submission to Congress (Appendix F) and the Revision C International Space Station Assembly Sequence (Appendix G) and schedule dated 9/30/97. The FY 1999 budget submission to Congress recognizes several problem areas experienced by the Program during FY 1997 and early FY 1998 and provides increased levels of new obligation authority compared to the FY 1998 Budget. Additionally, there is funding identified for the development of a CRV commencing in FY 2000 (only $5 million in FY 1999).

The Revision C Assembly Sequence commences with launch of the Functional Cargo Block (FGB), scheduled for June 1998. ISS Phase II is scheduled to be completed after Flight 7A in August of 1999; ISS Phase III is scheduled to be completed after Flight 16A in December 2003. Approximately 93 flights, including assembly, crew transport, logistics, and resupply are envisioned through the completion of Phase III.

At the time of this report, the Program Office is establishing and reprogramming an assembly sequence revision that will reflect the completion of Development with the launch of Node 3 on Flight 17A. The ISS will support six crew members at that time, given the implementation of full crew return capability through procurement of a second Soyuz spacecraft or acceleration of the CRV.

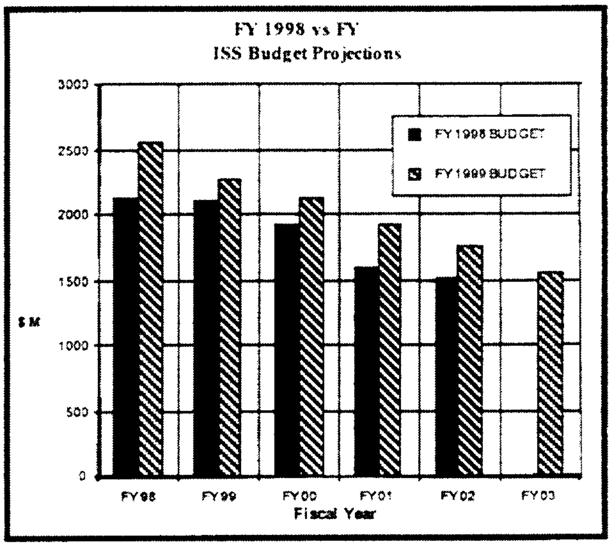


Figure 2-1

Figure 2-1 contrasts the FY 1998 and FY 1999 budgets. The major components of the FY 1999 budget submission to Congress are shown in Figures 2-2 and Figure 2-3.

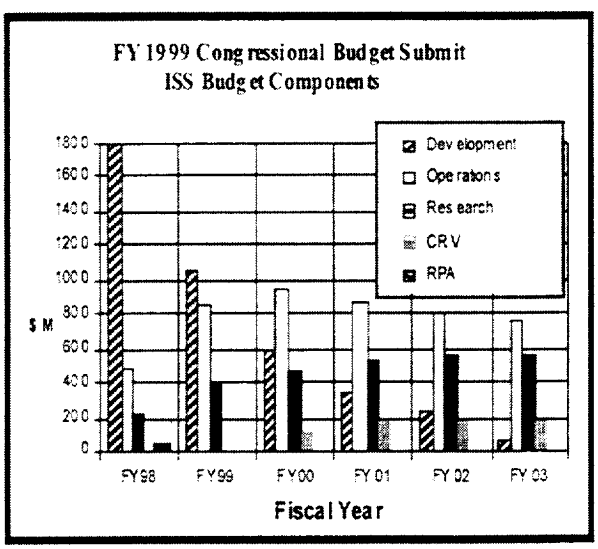


Figure 2-2

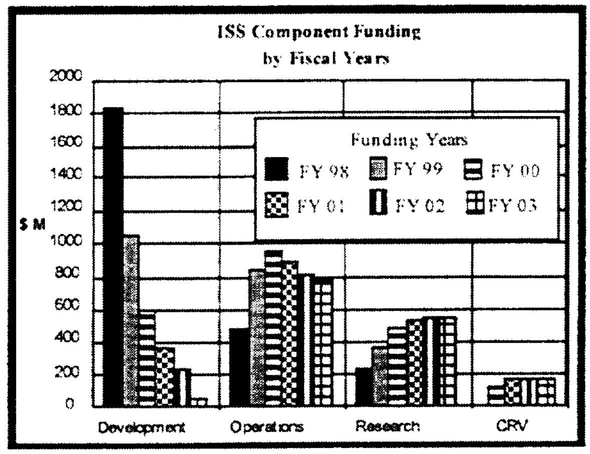


Figure 2-3

3.0 Analysis and Assessments

The baseline program cost and schedule were assessed in context of the risks described in Sections 3.1 and 3.2. The programmatic issues and the major risks were identified based on the Task Force's exposure to the ISS program over a four month period and represent the collective experience and judgment of the Task Force. Risks considered to be "catastrophic" were specifically excluded, e.g., withdrawal of an International Partner contribution or protracted downtime due to a failure of any of the principal launch vehicles.

Both the programmatic issues and the major risk elements described below represent those areas we feel are likely to adversely affect the baseline cost and schedule. The magnitude of these impacts is largely a matter of judgment. The Task Force, however, is unanimous in its opinion that program management has, to date, been optimistic, particularly in planning adequate schedule margin for critical events. The Task Force's quantitative analysis in Section 3.3 and the trend assessments in Section 3.4 take a more pragmatic view of current program status and the interdependency of upcoming critical events.

The results of the two separate approaches in Sections 3.3 and 3.4 are consistent and together form the basis for the CAV Task Force overall assessment.

3.1 Programmatic Issues

The FY 1999 NASA budget submission to Congress acknowledges that the ISS development program will incur cost growth over the original baseline commitment of $17.4 billion. The baseline program reflects NASA's commitment to the completion of Phase III (Flight 16A) of the ISS assembly sequence in December 2003. The Task Force finds that there is a high probability that the baseline program will incur additional cost growth and has attempted to quantify those cost growth issues considered to have the highest probability of occurrence.

It is noted that the potential for cost growth associated with the current phase of the Program is likely to be driven by slippage in the schedule. A significant part of the remaining effort is directed at sequential activities such as component qualification, integration and test. These processes are time-dependent. For example, a cost impact will be realized when a failure occurs during a qualification process. The failure requires rework and then a repeat of the qualification process. The sequential nature of the Program results in subsequent efforts being delayed and accomplished farther out in time. Thus, while total Program cost will increase, annual funding requirements are likely to be only marginally impacted as depicted in the funding profile of the current Program assessment.

The following details identify cost and schedule risks and provide the basis of quantifying the anticipated contribution to cost growth of the baseline program.

3.1.1 Russian Funding Commitment

There are significant benefits to be realized from Russia's contributions to the ISS Program as they provide critical propulsion, resupply, crew exchange, and crew return systems and capabilities. Because Russia is undergoing a fundamental transition in its economic, political, and social structures, however, its participation continues to create risks that can affect delivery of components necessary to meet schedule and cost commitments.

The new Russian constitution was not adopted until 1993, and the budgetary process is still in a period of transition. The government is attempting to establish monetary controls to cut non-budgeted expenditures and to make critical analyses of resource requirements of all government areas, including RSA. Although there is a funding commitment for the ISS at the highest government level, the funding process is erratic, and it is difficult to assess when the funds will actually be supplied, not to mention the adequacy of those funds.

For example, 1.8 trillion rubles ($300 million) were allocated to the Program in FY 1997. Of this amount, 1.5 trillion rubles ($250 million) were special funding through the Ministry of Economic Development. Much of this money, funded through promissory notes, was made available to maintain the Service Module launch date. The process for obtaining funds through floating promissory notes was eliminated by decree in August 1997, immediately prior to RSA's receiving its total allotment. This left approximately 480 billion rubles ($80 million) unpaid. Just this past January, President Yeltsin directed the government to provide the remainder of these FY 1997 funds to RSA by February 15, 1998. As of March 31, 1998, however, RSA had not received the total balance of FY 1997 ISS funds, and $45 million still remain outstanding. According to RSA, another $22.5 million is to be disbursed in April and $22 million in May to complete the payment of the FY 1997 funding.

As was the case in FY 1997, most of the Russian funds for ISS in FY 1998 will come in the form of supplemental funding. RSA's budget provides approximately $100 million in funding for ISS. As of the writing of this report, the Russian Federal budget had received approval of the lower house of the Federal Assembly, but had not yet been acted upon by the upper house. It is the Task

Force's understanding that RSA is receiving one-twelfth of FY 1997's national budget as part of a continuing resolution. This is allowing RSA to make some critical payments to suppliers. The Ministry of Finance and Ministry of Economics are to devise a plan for supplemental funding on the order of $200 million by the end of April. Past experience would suggest that it will come later in the year.

The Task Force does not possess the in-depth Russian economic forecasting expertise necessary to accurately predict the outcome of current monetary and economic policies of RSA's long-term funding profile. Meetings in Moscow with U.S. Embassy staff experts on the Russian economy suggest that financial challenges will continue for some time. At this point, if all necessary financial resources were supplied today, the Task Force believes RSA would still not be able to meet the Revision C launch schedule for the Service Module.

3.1.2 Prime Contractor Performance

The Task Force estimates that the Prime contractor will overrun the current baseline development contract by at least $400 million. This would bring the total overrun since definitization on the Prime contract to one billion dollars.

Beginning in mid-1995, the contractor experienced cost overruns to the target plan. These overruns began to increase significantly during the fourth quarter of FY 1996. At that time, the overrun stood at 4.4 percent of budgeted work performed to date. For the contract reporting period ending in the spring of 1997, NASA provided zero award fee. As a result, the Prime made some personnel changes to strengthen its management team, intensified its efforts to obtain and keep technical staff, and committed over $30 million of Boeing capital to build a systems/software integration facility.

As of October 3, 1997, the Prime contractor had exceeded the contract budget baseline by $398.2 million (8.9 percent of budget.) The contractor was also behind schedule by $139.1 million of scheduled effort. Because of the significant difference between planned schedules and cost and that of actual deliveries, NASA and Boeing agreed to rebaseline the contract deliverables to reflect a cost approximately $600 million above that of the initial contract, with over $400 million of that increase already incurred. The Performance Measurement System used to track cost and schedule variances has been adjusted to reflect this new estimate of cost at completion.

Still, cost and schedule variances continued to grow during FY 1997. The realized overrun was 19.6 percent of work performed during the period and trending upward. The quarterly increase during FY 1997 is noted in Figure 3-1.

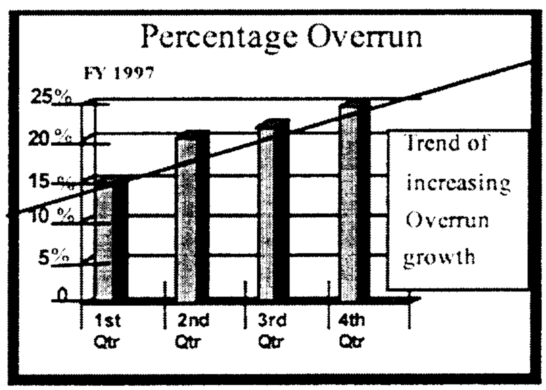
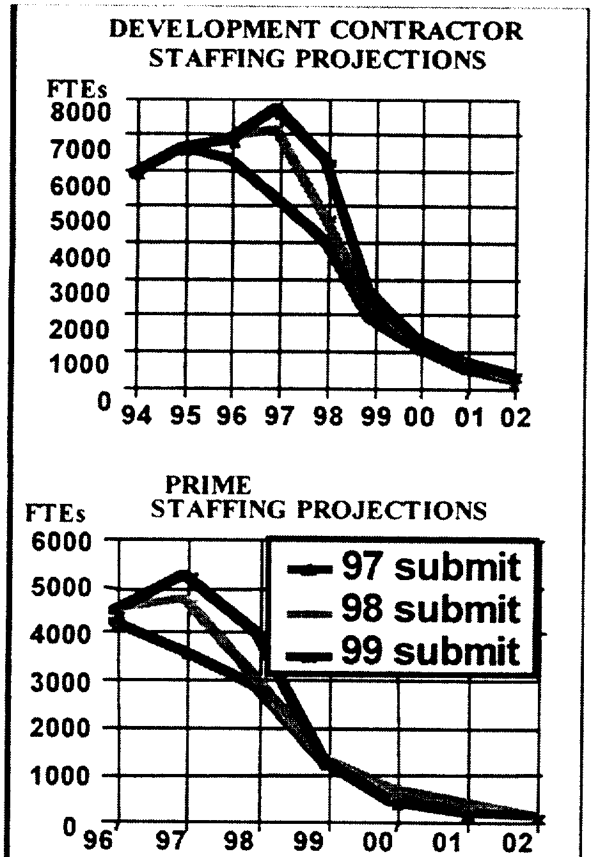


Figure 3-1

During the first quarter of FY 1998, the contractor, per its agreement with NASA, implemented a $600 million "over target baseline" adjustment to the total contract baseline. In developing its own budget, NASA internally assumed that the overrun would reach $817 million, or $217 million over the contractor estimate. NASA subsequently increased its internal overrun estimate to $849 million. The Task Force was also advised of a $50 million overrun absorbed by a major subcontractor.

Analysis of the effort remaining on the contract indicates a high probability that cost overrun as a percentage of work content will occur at increasing levels through completion of the contract. Since the contract was rebaselined, another $23 million in schedule variance has already occurred. The de-staffing plan is based on delivery schedules that have little reserve margins, and the CAV Task Force believes the Program has not adequately accounted for the significant level of qualification, integration, and verification testing activities which will be incurred. Historically, a high probability of rework or redesign is required as a result of problems routinely uncovered during testing. Significant amounts of flight hardware components have been produced but have not yet completed qualification testing.



Staffing levels continue to exceed past projections. New projections for de-staffing ignore past experience

Figure 3-2

Beyond that, the Task Force feels that Program de-staffing plans have overestimated the rate at which work will be completed and staffing will be released from the program. Figure 3-2 shows actual trends versus past staffing projections.

Total program schedule slip also creates a potential skills base risk. As flight hardware and software is completed, the associated skills base must be redirected elsewhere within or released from the Program. This could be occurring prior to qualification or system integration. The criticality of the issue will become manifest when testing identifies the need for rework or redesign. This situation is notably apparent at the lower-tier subcontractors. This risk is common to space programs, due to the unique nature of space-related hardware and software. The ISS Program Office has advised the Task Force of its intent to address skills base retention through the sustaining engineering workforce. Given the funding constraints, however, this workforce may not be adequate to completely resolve the issue.

3.1.3 Non-Prime Performance (NASA)

NASA and other Non-Prime contractors are directly involved in a significant portion of the development, manufacture, integration, and testing of ISS system hardware and software, the development and implementation of operations capabilities, and in the development of research projects. Non-Prime or NASA in-house expenditure is nearly equivalent to that of the Prime contractor and will exceed it in the outyears. In FY 1998, Non-Prime effort accounts for $1.2 billion or 47 percent of the ISS budget. Within two years, it will consume the majority of the ISS budget.

This effort also includes a significant component of civil service labor, which is outside of the program budget. The Program Office is limited to 400 civil servants, which are considered full-time staff and are charged directly to the Program. The FY 1999 budget submission to Congress reflected a total requirement for 2,157 civil servants for FY 1998, many of which are funded and matrixed to the Program from the various NASA centers (Figure 3-3). The total Non-Prime workforce (NASA and NASA contractors) is over 7200 Full-Time Equivalents (FTE) in 1998. This is almost double the number of FTEs employed under the Prime contract.

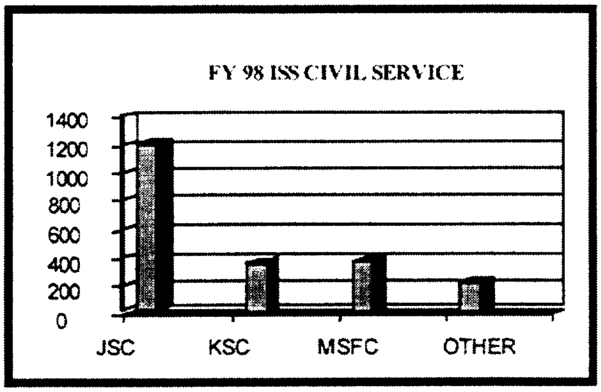


Figure 3-3

NASA is unique among Government agencies with respect to the degree of direct involvement in its programs. It not only manages commercial contractors, which is the typical Government role, but it also performs as a contractor. This is considered beneficial in that it has allowed NASA to develop a skilled pool of labor for functions that are of limited demand and have very focused requirements. It has certainly proved beneficial to the ISS Program in that it has given NASA a significant degree of flexibility to absorb Prime contractor effort in an attempt to reduce Program expenditures.

The Task Force notes that NASA does not have an earned-value Performance Management System (PMS) in place for much of the NASA and Non-Prime contractor effort. Because of the lack of a performance tracking system, the Task Force encountered considerable difficulty in evaluating NASA's cost and schedule performance to date and in forecasting its future. NASA and other Government agencies require prime contractors to maintain such a system to track performance. Given the scope and content of the NASA effort noted above, it would be prudent to institute a system of performance measurement for its own effort.

A Non-Prime PMS could have been useful in identifying the impact of Prime contractor effort absorbed by NASA. As noted above, NASA has absorbed considerable Prime effort in its attempt to mitigate the cost overrun. As also noted, the Task Force considers this flexibility, in the near-term, to be beneficial to the Program. The Task Force is concerned, however, that it could not identify the impact on the NASA budgeted effort, present or future. While the Non-Prime effort has underrun relative to cost in previous years, the Task Force could not determine if the NASA effort had been eliminated, naturally displaced, or deferred into the future due to schedule slips. The Task Force believes that work has been deferred and that this effort will be added scope to the effort that has been budgeted in the outyears. These efforts have the potential for significant cost impact to the Program which must be accommodated through an increase to the annual funding profile or additional schedule erosion.

The Task Force recommends that the Program institute a system of performance measurement, that would be applicable to Non-Prime (NASA and contractor) efforts including X-38 and CRV.

3.1.4 Contract Changes

The ISS Prime development contract has experienced considerable change activity. At the end of FY 1997, $1.4 billion in changes had been authorized. Of this amount, $730 million was authorized, but not negotiated with the contractor. The total amount of the change activity represents a 27 percent increase to the baseline budget estimate and is 31 percent of the budgeted effort completed to date.

The Task Force concludes that the complex nature of this program and the influence of International Partners will continue to contribute to change activity through completion of the contract. The Task Force estimates that the ISS Program will experience a $425 million increase to the development contract due to change activity. It does not assume an experience rate at the current level, but recognizes a significantly higher rate (20 percent) than the norm due to the atypical nature of the Program.

3.1.5 System Integration and Sustaining Engineering

The Prime contractor currently has contractual responsibility for ISS integration. NASA's intent has been to establish working groups or teams of contractor and NASA personnel to perform the integration functions. With the beginning of hardware shipment to the Kennedy Space Center (KSC), NASA assumed responsibility for management and technical portions of the system integration effort by default in areas where the Prime contractor was not technically prepared (in NASA's view) to accomplish the scope of the integration effort. While the contractor's technical capability has improved, NASA is still performing some of the systems integration technical and management functions.

There are also areas where NASA must act as the systems integrator because the contractor cannot represent the U.S. Government in dealings with the International Partners. In these cases, NASA and the Prime contractor have implemented a matrixed approach, with NASA performing top-level functions and the Prime contractor performing much of the necessary lower-level integration functions.

Similarly, NASA has assumed the responsibility for the overall sustaining engineering integration of the ISS. Each of the International Partners and participants is responsible for sustaining its specific on-orbit and ground segments.

During the multi-year program transition from hardware and software design and development to systems integration and test, launch, on-orbit assembly and operations, the systems engineering and other development engineering functions should also transition over the same period of time to a support or "sustaining" role on the Program. The Task Force believes that the Program's approach to sustaining engineering has several shortcomings.

First, the budgeted level of effort for sustaining engineering that NASA has programmed is likely to be inadequate. The Prime contractor estimated this effort to be on the order of $1.4 billion while NASA had originally budgeted $387 million. With the FY 1999 budget submission to Congress, NASA budgeted $952 million for Prime contract and $150 million for Non-Prime contract sustaining engineering. NASA and the Prime contractor have agreed on the content and tasks that need to be performed over the life of the ISS but not the scope of the tasks. A proposal for FY 1998 and FY 1999 only has been provided at this point for a budgeted value of $143 million. The Task Force believes that the sustaining engineering effort has been underscoped in the current budget submission and should be reassessed for Prime and Non-Prime contractors, NASA, International Partners, and other participants.

Secondly, the Task Force believes that the Program's approach to sustaining engineering could be improved by a focused management approach to encompass the broader, technical support activities of SE&I of which sustaining engineering is a natural element. The current NASA approach provides a level of engineering support to Operations after the development of all hardware and software items are completed and accepted by NASA. "Completion of development" is not a specific time on the Program's schedule but rather is spread over a number of years for the various component assemblies of ISS. The Task Force suggests that as the development engineering function is incrementally completed, the "sustaining" efforts required of the developers become an integral part of a continuing SE&I function and organization. As critical skill additions to such an SE&I organization, the sustaining engineering personnel provide crucial life-cycle support as hardware and software are assembled, integrated, tested, launched and operated on-orbit. After ISS Assembly Complete, the entire SE&I function (including the key sustaining engineers) should have a total Operations support focus; namely, mission and vehicle performance analysis, logistics, ISS health and status, hardware and software maintenance, and problem resolution.

An excellent SE&I management model for ISS is the two, nearly simultaneous NASA Viking Missions. NASA Langley Research Center, the Jet Propulsion Laboratory, the Prime contractor, the integration contractor, the element contractors, and the science teams were integrated into a single organization and management structure. The ISS implementation of a similar approach would naturally be larger and more complex because of the multiple launch and on-orbit events and the international participation. However, the larger size and complexity of ISS is all the more reason that such a structured approached should be considered.

The Task Force's overall assessment of the ISS systems integration effort is that it lacks a management plan and clear leadership approach. SE&I functions require focused analysis and implementation in a tightly controlled project environment. The lack thereof generally results in costly handoffs of responsibility, rework and delays. Matrixed or split management and leadership responsibilities are risky and ill-advised. NASA's view of its integration responsibility for sustaining engineering, as stated earlier, is what NASA needs to implement in the larger context of ISS SE&I. The Task Force believes that NASA must provide the day-to-day management and leadership of the more comprehensive and broader SE&I organization that the Task Force has suggested in order to help control and manage risks in the upcoming, critical integration phases of the Program.

3.1.6 Contingency Planning and Risk Management

The ISS Program has a process which addresses identification, assessment, mitigation, and monitoring of identified issues. It has established a reserve to fund anomaly resolution activities that are addressed through the risk management process.

The Task Force believes these reserve levels are inadequate for maintaining a reasonable level of contingency protection.

The Task Force finds that budget and schedule constraints have precluded ISS program managers from adequately planning for contingencies. Budget availability rather than technical requirements has, in certain circumstances, had a large influence on program planning. As a result, contingency planning, cost and schedule risk management, and risk mitigation have tended to be less proactive than they should have been. Instances of this problem extend across the program: the procurement of spares, the resolution of continuing parts shortages, implementation of MEIT throughout the Program, the lack of adequate contingency alternatives relative to Russian shortfalls, and inadequate schedule and cost margins.

Program cost and schedule increases will occur; however, the negative impact can be reduced if the Program has the reserves to develop necessary cost and schedule risk mitigation plans and then commits itself to implement these plans. This is an area in which NASA, the Administration, and Congress must have a clear understanding and an agreed-to course of action.

3.2. Major Cost and Schedule Risk Elements

3.2.1 Service Module

The Russians are continuing to make progress on the Service Module despite funding shortfalls and technical difficulties associated with the construction of this important element. The Service Module is three to four months behind schedule in addition to the previously-announced eight month schedule slip due to both funding and technical problems. Officially, RSA still maintains that it can meet a December 1998, launch date, but the Task Force's opinion is that a December date will not be met, and an additional three to four month slip is highly probable. Subsequent to the January, 1998 GDR, RSA signed an agreement with 13 of 14 critical Service Module vendors promising to provide outstanding funds by February 10, 1998. In return, the firms agreed to ship to RSA outstanding subcomponents that had been withheld pending payment. Since then there has been little forward movement relative to financing. While most subsystems have been delivered despite the lack of funding, there are subsystems that continue to be withheld.

If the remaining 1997 supplemental funding, decreed by President Yeltsin, is not received soon, the Task Force is virtually certain that further schedule slippage will occur. There is a potential that the flight article could be shipped directly from Khrunichev State Research and Production Space Center (KHSC) to Baikonur and undergo a lesser level of testing. This is contingent on the ability of the qualification unit in the Complex Test Stand to successfully complete its integrated tests. This alternative does reduce some scheduled work, thus saving time, but increases the risk due of problems being uncovered on orbit. The next GDR is scheduled for April, and the Task Force anticipates that a revised launch date will be established at that time.

Modifications have already been made to the FGB so that if the Service Module incurs a significant slip, NASA could launch the ICM, dock it to the FGB, and continue assembling the ISS. At this point in time, however, NASA is de-integrating hardware from the NASA-funded ICM that would allow it to dock with the FGB. Necessary hardware to dock the ICM to the Service Module will then be installed on the ICM. This decision reflects NASA's confidence that any further slips in the Service Module will be relatively insignificant with respect to the total Program schedule. From this point forward, the most likely ICM use would be as a contingency alternative should the resupply capabilities of the Russian Progress logistics flights fall short of projections.

3.2.2 Russian Logistics and Propellant Support

There are a number of concerns relative to Russia's ability to maintain its logistics commitments. Since Russia was invited to join the ISS Program in 1995, it has changed logistics carriers three times and has removed one launch vehicle from consideration for ISS assembly. RSA's inability to support Mir logistics flights in 1997 and 1998 (necessitating use of the Shuttle) when it desired to extend the Mir's on-orbit life is an example of Russia's programmatic desires being more ambitious than its funding or launch vehicles could achieve.

RSA's Mir deorbit plan is inconsistent with NASA's assessment of Russia's launch capability to support ISS assembly. NASA has urged RSA to begin deorbit operations for the Mir now; they will take approximately a year to complete. Current RSA plans reflect a late 1999 deorbit. The current projected Soyuz and Progress flight rate of 14 per year exceeds their current avionics production capacity of nine or 10 per year and their current launch rate of approximately six per year. Regardless of Mir deorbit, there are many concerns regarding Russia's ability to support its commitments: staff, facilities, and commercial pressures. The threat to the U.S. assembly is significant and demands immediate additional contingency implementation.

Further, Russian long-term funding uncertainties and its financial incentive to sell Station-reserved launch services on the commercial market could impact logistics planning. There are also concerns relative to the inability to retain skilled personnel at the Baikonur launch site due to a low wage scale. Collectively, these factors suggest that it is reasonable to expect perturbations in the logistics schedule.

At any period in time, a one-year ISS on-orbit fuel reserve is maintained. The only contingency development activity NASA has funded is the ICM. It has a limited fuel capacity and could only control and reboost the station for an active period of one year. NASA believes it could develop a new long-term replacement propulsion capability within a period of 24 months with adequate supplemental funding. This Task Force strongly supports development of a U.S. propulsion capability.

3.2.3 Hardware Qualification Testing

Component and subsystem qualification tests still lag significantly behind their scheduled dates, but additional slippage on most items has recently slowed. Nineteen major subsystem hardware items successfully completed qualification testing in the last three months, bringing the total qualification to 50 of 144 major items required through Flight 9A. As of the writing of this report, four qualification failures were open issues; namely, the Integrated Motor Control Assembly, the Early Port Communication Transceiver, the external DC to DC Converter Unit, and Vent Relief Valve.

Flight hardware component deliveries have also experienced significant schedule slippage but this situation also seems to have stabilized somewhat. Several major problems have been resolved recently in the S-Band and Ku-Band communications hardware. ISS element-level workarounds have become a way of life across all facets of the Program due to hardware shortages caused by lack of sufficient piece parts and other development problems.

3.2.4 Software Development and Integration

Because flight control and other types of applications software cannot be fully tested until the hardware to which it applies is delivered, software testing and integration is traditionally the area of space system development that is subject to the greatest schedule problems. The case of the ISS is no exception to this general pattern since several major pieces of hardware are apparently going to be delivered past their original scheduled dates. In addition to validating that the flight software is correctly integrated with its associated hardware, it is often the case that hardware problems discovered during late-stage testing very likely will have to be circumvented by software workarounds, thus increasing the time and effort required for software integration and testing. It is often more costly and inefficient to rework or rebuild a piece of hardware to make it conform to the original specification than to alter the software specification so that whatever hardware exists can be made to do the job required. While software modifications are often successful in recovering the desired operational capability, it does take additional time and cost to incorporate the needed fixes, and that time and cost is often labeled as a software schedule slip and cost overrun.

As is noted by all participants in the Program, including the Prime contractor and NASA Headquarters' Independent Annual Review team, maintenance of the schedule for conducting the MEIT has been and remains a major critical issue. The reason is that, for MEIT to occur on schedule, all relevant hardware and software must be completed and available. In addition, integration problems and schedule slips resulting from test "failures" or other less dramatic pieces of information uncovered during software and hardware testing are normal even in simple single contractor programs. The international nature of the ISS Program and the consequent need to merge software written in several countries to operate hardware built in several countries, intensifies the "normal" difficulties.

Software costs and delivery schedules have historically been the most optimistically underestimated portions of high technology programs. The more complex the hardware and programmatic interfaces are, however, the more difficult the software problems are, and the more likely and lengthy are the schedule slips and resulting cost overruns.

3.2.5 Crew Return Vehicle

The CRV, identified as a separate line item in NASA's FY 1999 budget submission to Congress, represents a new development critical to achieving permanent human presence on the International Space Station. The only alternative to the CRV is the Russian Soyuz vehicle, permanent dependence on which would re-introduce and make pervasive the significant production, operational and logistics limitations that appear to be characteristic of Russian participation in the ISS Program to date.

The ongoing X-38 Project at NASA's Johnson Space Center (JSC) is considered a technology demonstration and proof of concept for the CRV. Risk assessments and budgetary estimates for the CRV have been extrapolated by NASA from several years of X-38 experience. The first free flight of the X-38 occurred in March 1998. Five X-38 vehicles are planned, divided into two separate objectives as currently envisioned: a space test segment (two vehicles) and a comprehensive atmospheric segment (three vehicles).

While the X-38 Project has nominally made satisfactory technical progress, the program is ten months behind the original schedule. There remain significant technical and schedule challenges for both the X-38 and the CRV. The ISS Program also lacks a definitive, integrated development, transition and acquisition plan for the CRV. The major programmatic risks involve: the schedule mismatch between the X-38 space test program and CRV production start; and the fact that currently there is no plan for space flight tests of a production CRV.

The lack of a transition and acquisition plan represents an unnecessary critical issue that should be addressed immediately. The CAV Task Force believes that the schedule overlap and critical dependencies between the X-38 and the CRV programs require serious consideration be given to combining these programs. The ISS program is considering having significant international participation in the CRV production program. The Task Force believes that this participation will cost the U.S. by introducing additional integration and schedule risk. Additionally, the Task Force recommends accelerating the CRV program's start date to FY 1999 and increasing its funding profile by approximately 15 percent ($120 million) through the Initial Operational Capability (IOC).

3.2.6 U.S. Laboratory (Lab)

The U.S. Lab is currently behind schedule; a check of the Program's overall schedule as of March 15, 1998 shows the Lab to be approximately six weeks behind schedule. Based upon current schedule trends, the Task Force believes that a moderately conservative estimate of the Lab's current status would indicate a three to four month negative margin at Lab completion.

The Program recognizes that the optimistic schedule in place for the Lab will require many complex and innovative workarounds in order to incrementally recover from anticipated late hardware and software deliveries and other problems. The August 26, 1998, scheduled delivery to the KSC to support MEIT objectives is in jeopardy due to:

- anticipated late delivery of equipment racks and other Lab outfitting equipment, which now will require concurrent assembly and testing,
- continued delays in some hardware deliveries including ORUs, GFE GPS, BCDU, and ECLSS valve sets for the pressure control panel and vent relief valve, heat exchanger, etc.,
- continued late software deliveries and problems on Payload Executive Processor, Command & Control, GN&C, Workstation Host and Video Graphics, etc., and
- many retrofits and regression testing required.

The U.S. Lab is an example of a major ISS element that manifests many of the issues mentioned above in the Hardware Qualification and Software Development and Integration sections. The Task Force believes the Lab is a reflection of past issues and may be an indicator of possible similar future occurrences.

3.2.7 Multi-Element Integrated Testing

MEIT was proposed in 1994 as part of the original Program baseline. It was later eliminated from the negotiated contract to achieve a funding profile that would satisfy NASA funding constraints. In 1997, the Program acknowledged an eight month schedule delay necessitated by a slip in completion of the Russian-built Service Module. This provided an opportunity to reintroduce MEIT into the Program baseline.

The Task Force strongly endorses the concept of MEIT, but considers the schedule to be optimistic. Phase II of the Program marks the beginning of ISS assembly in space. MEIT testing is intended to successfully demonstrate element-to-element interface compatibility and end-to-end functionality and operability of flight hardware and software. Major flight hardware is scheduled to undergo MEIT just prior to launch. In some cases, notably Flight 5A (U.S. Lab), production schedules have zero margin for meeting the launch schedule. Further erosion of margin in flight hardware deliveries would exacerbate the launch schedule problem by extending the time required for MEIT.

MEIT is also carried out in connection with the Node emulator and Shuttle avionics, in particular, the Cargo Integration Test Equipment (CITE). The scheduled span of time(s) from completion of MEIT to launch of the elements is also optimistic, because MEIT will be performed in complex ground systems test configuration(s) which are very different configuration(s) from those required for launch. A number of lengthy test disassembly and launch assembly activities are planned during the period of 12/3/98 to 4/1/99. Major element tests such as EMC Qualification, GN&C CSCI Acceptance and high pressure O_2 and element leak tests are scheduled within this period. Launch processing improvements to the above time spans should not be expected due to the large number of tasks that have been transferred to the launch site in the interest of schedule compression.

At this point in time, there has been no definitive planning for incorporation of MEIT into the Phase III schedule. For all the vital and valid reasons that the Program found it advisable to incorporate MEIT into Phase II of the Program, it is as necessary, if not more so, to incorporate MEIT into Phase III. Phase III of the ISS Program involves a larger number of launches of many more configurations of hardware and software from the International Partners than does Phase II. In addition, the many internationally-provided pieces of equipment from different development cultures will need to be successfully time-phased into the launch schedule and physically integrated into the existing on-orbit configuration. The potential for a major negative program impact due to a mismatch between the scheduled delivery date of a program element and its actual delivery date increases dramatically during Phase III because of the complexity and diversity of the various elements in existence at that time. It is at this point that the lack of rigorous and unambiguous system integration responsibility and authority, that the Task Force expressed concern about earlier, becomes critical.

The hardware, software, ground test equipment, ground test software, and procedures required to implement MEIT for ISS Phase III need to be developed as soon as possible. A commitment to Phase III MEIT at this time, not dependent on the essentially random availability of the flight hardware involved, is a prudent step to avoid risk.

3.2.8 On-Orbit Assembly Complexity

Assembly of the ISS will involve 35 assembly flights over five and a half years, with astronauts and cosmonauts performing three times as much ExtraVehicular Activity (EVA) as all EVA combined since the Apollo Program.

The experience gained from the Shuttle-Mir program should be an indicator of the additional complexity and challenge of assembling a million pounds of ISS hardware two hundred miles above Earth.

The coordination of 11 Russian assembly flights, 23 U.S. flights, and four international assembly flights synergistically supported by 48 logistics flights will be the most complex and technically challenging achievement in human space flight since landing on the moon.

EVA is planned to be limited to six hours per day for assembly operations. The plan is that one-third of the EVAs will be performed by ISS crews. There are two contingency EVAs for each Shuttle flight (one for ISS and one for Shuttle). The program has additional consumables to accommodate each of these additional EVAs. Each Shuttle flight has three planned EVAs with the exception of one Shuttle flight, which has four. Interviews at JSC stated that the budget for EVA over and above that discussed above has little reserve and minimal flexibility. Without even addressing the functionality of thermal, power, control, communications and other considerations for the spacecraft to be safely maintained, it is difficult for the Task Force to accept that "most of the hard work is behind us". Additionally, the complexity of different ground control stations, multiple logistics carriers, elements built in different countries, space walk requirements as noted above, the integration and coordination across different cultures, add to and underscore the Task Force's concern with the program's optimistic date relating to Assembly Complete.

3.2.9 Parts and Spares Shortages

The ISS Program appears to have a solid approach to the identification of sparing requirements and to maintenance on-orbit. In addition to the use of theoretical Mean Time Between Failure (MTBF) rates, technical directors have defined their sparing requirements for worst-case scenarios, including the need for everything from jumper cables to replacement of failed Orbital Replacement Units (ORU). This process has defined much of the manifest for flights 2A and 2A.1 to accommodate spares. The identified sparing requirements have been large. In fact, an external "porch" was built on the outside of the Airlock to provide necessary storage space for spares.

In regard to on-orbit sparing and obsolescence, the ISS Program is attempting to consolidate hardware from different manufacturers in the NASA/Shuttle Logistics Depot (NSLD) or the National Payload Logistics Depot (NPLD) at KSC. There will be a transition cost for moving commercial and industry people to NSLD and NPLD to train NASA personnel. But, once again, paying this cost up front will mitigate the risk of paying excessive cost for single replacement units or, worse yet, not having the units downstream. As good as this process is, it also has a risk because some contractors have proprietary processes and do not want to participate in small quantity outyear procurements. This will require NASA to buy the companies' capital testing and/or production equipment to produce critical outyear spares in-house. The ISS Program is planning to reengineer or redesign critical parts (e.g., the Major Constituent Analyzer and some computer system components) so that, for example, the redesign of a circuit board or integral part of a system can be upgraded without changing the form, fit and function of the replacement part.

Funding constraints and lagging development have increased spares acquisition costs and eroded delivery schedules. To contain near-term spending to within the funding profile during peak development, decisions were made to reduce contracting for spares and parts necessary to support the current schedule for the ISS. Various program activities were hardware-limited during the development and test phases. Not procuring adequate spares during the initial production run of some components introduces quality and consistency issues as well as increased cost.

Although the normal industry approach is to produce spares late in production runs, discontinuities have occurred when flight production has slipped. When the spares acquisition organization has to pick out a production unit to garner for its spares procurement, manufacturing has to produce an additional unit for a replacement. If spares are not produced during the production run, additional costs are incurred, including the retention of critical engineering skills. In at least one instance, "EEE" parts (high reliability parts) were bought in two purchases. Spares acquisition missed the production run and paid the price for discontinuity in the form of lot charges and high costs for single acquisitions.

ORUs are currently being produced, but the qualification program is lagging, holding up spares acquisition. The Program has also experienced the opposite case: having to restart production lines that were shut down after flight unit deliveries were completed because adequate funding was not available to procure spares at the time.

To avoid issues such as this, it is critical that the ISS logistics and manufacturing functions jointly plan and coordinate spares requirements, insuring that delivered spares, production diversion, and backfill are always in proper balance.

3.2.10 Training

At the time of the writing of this report, there were instances where prototype training hardware was not yet available for training on key components of the various systems. Delivery delays of both hardware and software are having a direct impact on training preparation. Late hardware delivery and checkout often results in operational workarounds that must then be factored into training procedures. Delays in operational software delivery, integration, and testing are further impacting training, because astronauts interface with the ISS largely through the eyes and ears of the command and control, data analysis, and mission support software. Late deliveries can result in training personnel being outside the loop relative to late design changes in hardware and software. Existing training manuals and those currently being written are apparently based on the original design specifications, not on the as-built system that will likely depart from the original design in several noticeable areas.

It is imperative that early flights have integrated training procedures reflecting current hardware and software design configurations. Flight procedures must be adequately developed and tested using simulated conditions with the flight crews.

Furthermore, Russian and American training procedures have developed separately over the past 40 years and differ significantly in many respects. Classroom vs. hands-on, extensive written training manuals vs. simple lists of directions, and independent initiative on-orbit vs. dependence on decisions made on the ground are but a few differences of approach. When the CAV Task Force reviewed the training program, there was no agreement to merge the training approaches into one unified program.

The Program has provided its assurance that these crews will be fully trained on all critical systems prior to flight. The CAV Task Force is not taking issue with flight safety, only that significant cost and schedule risk exist in this area.

3.3 Quantitative Analysis

The space experience of both NASA and the Air Force support the view that significant schedule slips associated with only one or two of the cost and schedule risk elements investigated by the Task Force can, by themselves, force major delays in the overall ISS completion schedule, even if all other possible risks considered do not materialize. Software integration and test are often one of those critical issues that can delay a program far beyond expectations, even after all hardware is built and ready for operations. In the ISS case, the Russian-built Service Module could have much the same effect -- its unavailability at a critical point in the schedule would force an extended delay in all scheduled flights associated with human presence on the ISS. It follows from this analysis that it is not necessary that all possible cost and schedule risk scenarios come to pass for the Program to experience significant schedule slippage and cost growth. All that is required is that one or two strategically scheduled risk elements materialize.

Analyses by the Task Force, along with schedules produced by the Blackhawk Management Corporation (especially the most recent such schedule, dated February 17, 1998), indicate rather convincingly that virtually all initially allocated schedule margins associated with the events that the CAV Task Force has deemed critical have essentially been used up. While several program-identified risks, some of which have been closed and others of which remain at least partially open, have been covered by the initial schedule margins, significant risks that may have already adversely impacted the Program schedule are left without any margin of coverage.

Each significant risk will induce, with some degree of confidence, a probable schedule slip and an additional cost. The exact length of the schedule slip and the exact amount of additional cost are, of course, unknown at this time, but the most optimistic and most pessimistic scenarios in each case have been estimated by the Task Force. In each case, the eventual value of schedule slip or cost growth to be experienced is represented in our analysis by a number selected statistically from the interval between the most optimistic and most pessimistic values.

Estimation of probable cost magnitudes (along with their associated confidence levels) by statistical analysis allows the Task Force to provide estimates of required funding levels that are tied directly to the major sources of risk. The cost to Assembly Complete has been calculated on the basis of covering specific risks at specific levels of confidence. Statistical treatment of the dollar cost of overcoming the identified risks is necessary because of the high degree of uncertainty inherent at this time in how virtually all the risk issues identified are to be resolved, from Russia's ability to complete the Service Module in a reasonable amount of time to the Prime contractor's ability to test and integrate all the software from the various International Partners.

3.3.1 Schedule Impact Assessment

Consideration of feasible ways to resolve the major risk issues (i.e., the risk issues that have the potential to significantly impact ISS Program schedule and cost) leads directly to quantification of probable Program schedule and cost. Uncertainties in how much time and money will eventually be needed to resolve the issues can be bounded below by Program management's optimistic ("best-case") forecasts and above by the Task Force's understanding of the "worst-case" contingencies likely to affect the Program. Statistically, however, an "average" case (i.e., neither the "best" nor the "worst" case) will actually occur, so a statistical picture of ISS cost and schedule to Assembly Complete can be derived by modeling and simulation of risk-issue resolution options.

As an example, consider the logic of the Task Force's quantitative assessment of the probable schedule impact of the critical issues associated with the Russian-contributed Service Module. (See Section 3.2.1 above for the technical and programmatic details.) The optimistic (best-case) scenario envisions a four month schedule slip in delivery of the service module due to (1) current delays in Russian government funding provided to RSA, (2) current delays in delivery of subcontracted parts and components to Energia, and (3) the need to test and qualify parts and systems after delivery and integration.

The pessimistic (worst-case) scenario assumes a Russian failure to meet its commitment to deliver the Service Module and envisions a 24-month slip in the ISS schedule as the U.S. NRL prepares the ICM as a replacement. Intermediate schedule slips (the "average" cases referred to in Section 3.3 above) lasting between four and 24 months, with the longer slips increasingly less likely, can be attributed to (1) a longer-than-anticipated delay (e.g., 8 to 12 months) in Russian funding provided to RSA, or (2) need for rework uncovered during qualification testing of Service Module parts and the integrated unit.

A similar analysis has been carried out for each of the other risk issues identified as possibly exerting a significant impact on ISS Program schedule and cost. The specific risk elements considered by the CAV Task Force and their estimated optimistic and pessimistic schedule impacts are listed in Table 3-1 below.

The Root of the Sum of the Squares (RSS) of the optimistic (best-case) and the pessimistic (worst-case) slippages in Table 3-1 are statistical indicators of the probable minimum and maximum schedule slip in the total ISS program. The RSS takes account of the fact that there will be schedule slips attributable to some, but not all, of the risk elements identified. The RSS of the pessimistic slippages is approximately 38 months, a possible slip of a little more than 3 years beyond the currently scheduled Assembly Complete date of December 2003.

ESTIMATES OF SCHEDULE SLIPPAGE
ASSOCIATED WITH MAJOR RISK ELEMENTS

POST-REV. C SLIP (MONTHS TO ASSEMBLY COMPLETION)

RISK ELEMENTS	MOST OPTIMISTIC	MOST PESSIMISTIC
Russian Service Module	4	24
Russian Logistics Support	3	9
Flight H/W Delivery (Qual)	3	12
MEIT II (Cumulative)	2	6
Software Integration	2	6
Training (Cumulative)	2	6
Crew Return Vehicle	6	18
MEIT III (Cumulative)	3	6
U.S. Laboratory	2	6
Assembly Complexity	3	12
ROOT-SUM-SQUARE (RSS)	10	38

Notes: (1) Months of slippage suggested are reduced if some of the slippage occurs while a prior item is slipping, i.e. beneficial effects on certain critical issue issues of slipping of prior events is taken into account. For example, if the Service Module slips, then it is possible, at least in the optimistic case, that slippage of Training, Software Integration, and Crew Return Vehicle will not exert any ***additional*** negative impact on the overall ISS schedule. Slippage in Qualification Testing and MEIT, however, will probably not be covered by any slippage in the Service Module, since these items *apply to* the Service Module.
(2) The parenthetical note "Cumulative" attached to some critical issues means slippage due to that issue occurs over the entire ISS schedule, not simply the initial incident. This applies to Training and MEIT, which must be undertaken throughout the entire ISS schedule.

Table 3-1

3.3.2 Cost Impact Assessment

The various possible scenarios leading to schedule slippage have also been analyzed with respect to their impact on cost growth. In estimating ISS cost to Assembly Complete, cost growth is anticipated to arise from three distinct sources: (1) costs incurred throughout the program network by the need to maintain a "standing army" or other constant monthly expenditure flows while awaiting delivery of one or more critical components; (2) costs incurred by the U.S. due to failure of Russia to deliver the developed, integrated, and fully tested Service Module within 24 months of its scheduled delivery date and/or to provide required launch or logistics capability at any stage of the Program; and (3) costs incurred in completing specific risk-element work packages (listed in Table 3-1) for which the U.S. has assumed primary responsibility.

The transition to cost growth from schedule slip in situation (1) above has been made using the so-called "burn rate" (or rate of expenditure of funds) by those aspects of the Program that are either actively or passively impacted by stretchout of their schedules. In case (2), where the risk is that the Russian Service Module will not be available on schedule, no additional U.S. expenditures will be required unless the Russians fail to deliver the module within 24 months. If they do fail to provide it within 24 months, U.S. expenditures will be needed to complete and deliver one or two ICMs as replacement vehicles.

ESTIMATES OF COST GROWTH
ASSOCIATED WITH MAJOR RISK ELEMENTS

POST-REV. C COST (BILLIONS OF DOLLARS TO COMPLETE)

RISK ELEMENTS	MOST OPTIMISTIC	MOST PESSIMISTIC
Total Schedule Slippage*	1.800	4.900
Russian Service Module**	0.000	0.400
Russian Logistics Support**	0.000	0.000
Flight H/W Delivery (Qual)	0.075	0.450
MEIT II (Cumulative)	0.010	0.080
Software Integration	0.075	0.375
Training (Cumulative)	0.010	0.060
Crew Return Vehicle	0.120	0.680
MEIT III (Cumulative)	0.040	0.230
U.S. Laboratory	0.050	0.250
Assembly Complexity	0.015	0.075
ROOT-SUM-SQUARE (RSS)***	0.174	0.968

* As indicated earlier, these dollar figures are costs incurred throughout the program network by the need to maintain "standing army" or other constant monthly expenditure flows while awaiting delivery of one or more critical components. They are not related to any one or more risk issues and are not included in the statistical analysis described below.

** As mentioned above, even if the Russian Service Module does not become available on schedule, there will be no additional U.S. expenditures required unless the Russians fail to deliver the module within 24 months. If they do fail to provide it within 24 months, U.S. expenditures in the amount of $400 million will be required to complete and deliver one or two ICMs as replacement vehicles. If the Russians later prove unable to provide the required numbers of Soyuz and Progress vehicles (regardless of whether or not the Service Module has been delivered) needed to carry out ISS logistics needs over the Program's life cycle, additional U.S. expenditures can be anticipated. Launch costs, including those of the several Shuttle launches required to orbit U.S. and foreign components, are beyond the scope of this study.

*** Not including the dollar values associated with total schedule slippage, Service Module risk, or Russian logistics risk.

Table 3-2

If the Russians prove unable to provide the required number of Soyuz and Progress vehicles to carry out ISS logistics needs over the Program's life cycle, additional U.S. expenditures can be anticipated. of which The CAV Task Force has left all discussion out that out of our computations. Finally, case (3) consists of those cost growth estimates attributable to the resolution of specific major risk issues that are listed in Table 3-2 on the previous page.

As in the case of schedule slippage, the RSS of the optimistic (best-case) and the pessimistic (worst-case) cost growth values (not including those due to total schedule slippage, the Service Module, and Russian logistics) are statistical indicators of the probable cost growth in the total ISS program, based on the estimated cost-growth levels in Table 3-2. The RSS takes account of the fact that there will be cost growth of various magnitudes attributable to some, but not all, of the risk issues identified. The RSS of the optimistic growth levels is $175 million, while the RSS of the pessimistic growth levels is $968 million, calculated with respect to the FY 1999 budget request of $20.3 billion. A Monte Carlo statistical analysis of the total cost growth indicates that the 50/50 probable cost growth due to the last eight risk elements in Table 3-2 is $980 million, required through Assembly Complete. While the probability is 50 percent that the cost growth estimate of $980 million will be exceeded, the probability is only 30 percent that the 70th percentile cost-growth estimate (according to the Monte Carlo simulation) of $1.08 billion will be exceeded. If a confidence of 90 percent is desired for establishing a budget for Assembly Complete, the appropriate cost growth to prepare for is $1.24 billion.

It is important to remember that the numbers in the previous paragraph cover only the last eight risk elements in Table 3-2. To those numbers must be added an amount to cover the eventual total program schedule slip. Optimistic and pessimistic bounds for that are listed at the top of Table 3-2. If we consider the 50/50 probable cost growth due to schedule slip, which is $3.3 billion, and add that to the 50/50 probable cost growth to the eight major risk elements, which is approximately $1.0 billion, we obtain a total cost-growth estimate of $4.3 billion over and above the FY 1999 budget request of $20.3 billion. Based on the statistical analysis we have conducted, then, our estimate of the 50/50 probable ISS total cost is $24.6 billion. It is important to remember, though, that this number does not include funding for possible extreme contingencies such as complete Russian failure to deliver the Service Module (which could add an additional $0.4 billion to U.S. expenditures) or Russian failure to provide the launch and logistics capability for which they are responsible. U.S. expenditures to cover the latter contingency are considered outside the scope of this task and therefore have not been estimated by the Task Force.

3.4 Trend Analyses

In addition to the quantitative approach described above, a separate assessment was developed based on the trend of program milestone schedules over the past four years and subjective judgment for future program execution. These results were consistent with the quantitative results in Section 3.3, and the two approaches formed the basis of the Task Force's overall assessment.

3.4.1 Schedule

Dates for the principal ISS milestones, FEL, Phase II Completion, and Assembly Complete, have been revised several times since the baseline schedule was established in September, 1994. The earlier schedule adjustments were to be expected, given the evolving nature of both the Space Station definition and the International Partner involvement. However, we believe the current Revision C assembly schedule continues to be overly optimistic and does not reflect the complexity of the remaining effort nor the reality of schedule threats identified to date and addressed in the previous section.

Figure 3-4 shows trends in the dates for major ISS milestones since the baseline was established in September 1994. During the three year period from the Baseline to Revision C, the Assembly Complete date has been delayed 18 months, and the total timespan to achieve Assembly Complete has increased by 18 percent.

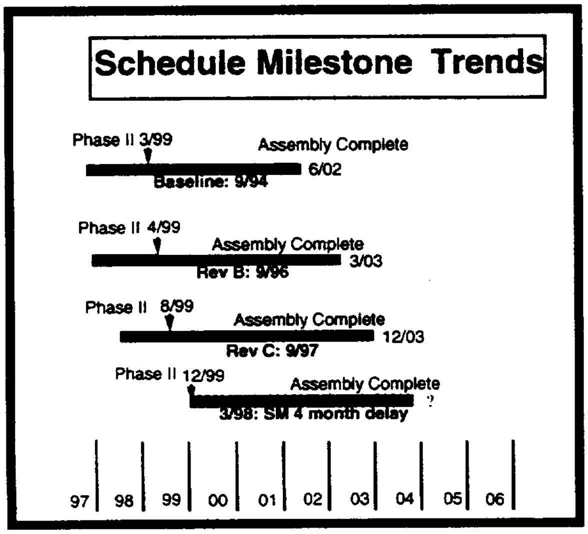


Figure 3-4

In order to project likely completion dates based only on experience to date, the various revisions to milestone dates were replotted as a function of time-to-go to the milestone. This is shown in the following Figure 3-5. For completeness, the 6 Crew Capable milestone, Flight 17A, is also included as part of the Task Force assessment.

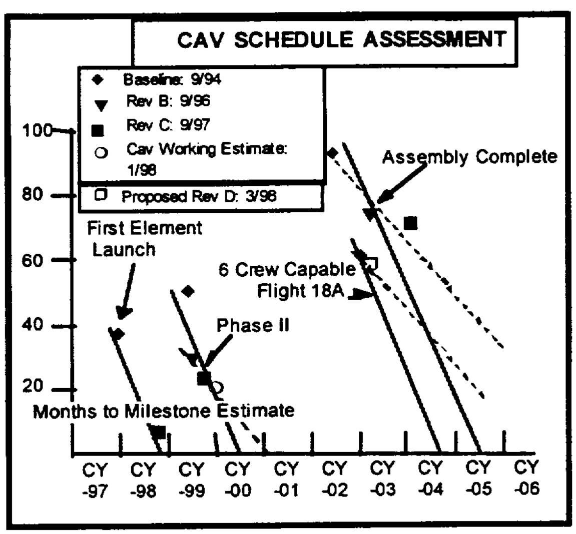


Figure 3-5

The assessment of schedule impact reflects the Task Force's collective judgment of current and anticipated threats and confirms the trend of schedule changes experienced to date. As shown in Figure 3-5, the Task Force's projection for the most likely Phase II completion is mid- to late-calendar year 2000, 6 Crew capability in late-calendar year 2004, and the full Assembly Complete expectation is not earlier than late-calendar year 2005.

3.4.2 Budget Impact

The schedule stretchout described above will impact the baseline budget. The principal components will be increased costs for both Development-related items and Operations-related items, specifically sustaining engineering and logistics and maintenance. As assembly of the ISS progresses, the distinction between Development and Operations becomes increasingly blurred. For assessment purposes, the Task Force combined the baseline Development and Operations budget lines and estimated a 15 percent increase through the remainder of the Assembly Complete period. This represents a reasonable target for off-loading personnel while maintaining critical skills and necessary resources during the full assembly period; i.e., until *at least* mid-calendar year 2005.

The Program Office plan for transition from Development to Operations funding at Flight 17A does not impact the Task Force's bottom line assessment of funding required to assemble and operate the ISS. The Task Force feels that a level funding profile, commencing in the FY 2004 timeframe, is appropriate for the life of the ISS, but recommends a validation of this approach by the Program. This validation should recognition the continuing development activities during the life of ISS. The fiscal year funding impact is shown below.

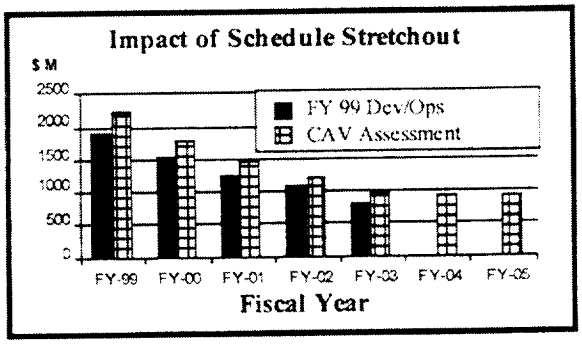


Figure 3-6

No adjustment is recommended for the Research budget line, even in light of the projected schedule stretchout. The Research funding line appears reasonable, containing adequate reserves, and the Task Force feels there will be opportunities for significant research during the protracted assembly period.

The impact of a schedule stretchout as shown above will essentially deplete the currently identified unencumbered reserves. Figure 3-7 shows the current (FY 1999 budget) unencumbered reserve and the net reserve, by fiscal year, after accommodating the higher budget profile resulting from a schedule stretchout. The CAV Task Force believes this to be an unacceptable reserve level given the risk areas identified and the need to maintain prudent reserves for other unknown threats. The Task Force recommendation is also shown in Figure 3-8 and represents an overall level of 13 percent unencumbered reserves.

The Task Force did not attempt to assess the impact of a schedule stretchout on the Program Operating Plan for FY 1998. At the time of the Task Force assessment, the Program was carrying a negative unencumbered reserve of $48 million. This included $200 million in required FY 1998 funding allocated since the Program Operating Plan 1998 Guideline, as well as some $285 million in additional threats then under review. Additional funding to offset the $200 million had been identified within the overall NASA budget and was the subject of ongoing Congressional negotiations. The Task Force's assessment, given the near-term threats identified at this time, is that the Program needs full funding in FY 1998 to the level provided in the FY 1999 budget submission to Congress to ensure successful Program execution during FY 1998.

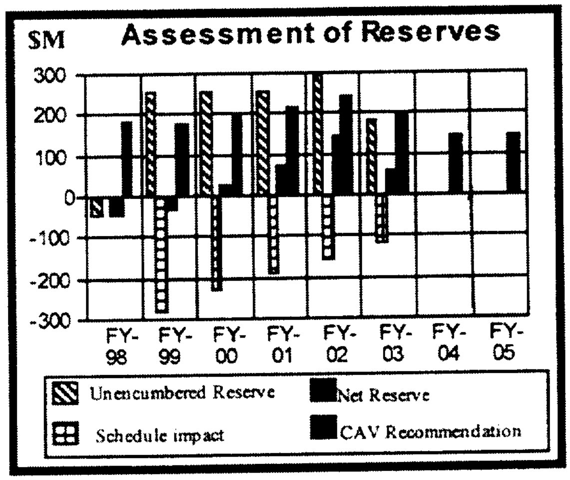


Figure 3-7

The majority of the threats and risk areas identified in previous sections will pose continuing challenges for ISS Program management. The Task Force is confident however, given the level of unencumbered reserve identified above and additional margin for the CRV, that the management team will be able to successfully execute the program.

3.5 Summary Assessments and Recommendation

In summary, the CAV Task Force recommends a revised budget profile that:

- provides adequate funding in FY 1998, as outlined in the FY 1999 Budget submit,
- accommodates a two year schedule stretchout to achieve Assembly Complete,
- provides an appropriate level of unencumbered reserves to address major risk areas through Assembly Complete,
- accelerates CRV development and provides additional funding protection commensurate with the maturity of X-38 technology demonstration and transition,
- provides an appropriate level funding profile for the life of the ISS (Table 3-3 contains the Task Force's recommendation), and

- the Task Force believes that the major threat to the long-term viability of the ISS is the uncertainty associated with the Russian funding commitment and the potential impact on the basic station infrastructure and utilization capability. The Task Force strongly recommends an immediate investment in developing permanent U.S. propulsion and logistics capability.

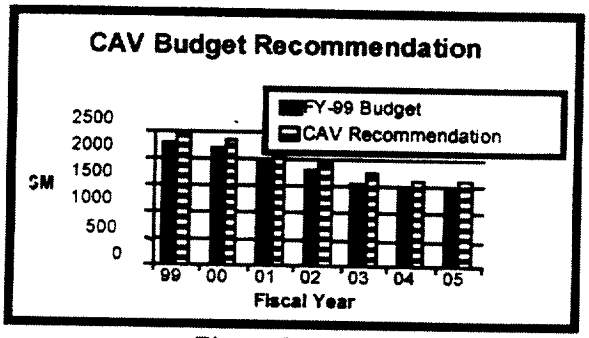


Figure 3-8

Fiscal Year	FY 99 Submit ($mil.)	CAV Recommendation ($ millions)	Cumulative Funding ($millioms)
1999	2,270	2,499	13,562
2000	2,134	2,324	15,886
2001	1,933	2,103	17,989
2002	1,766	1,896	19,885
2003	1,546	1,703	21,588
2004	1,466	1,584	23,172
2005	1,466	1,584	24,756

Table 3-3

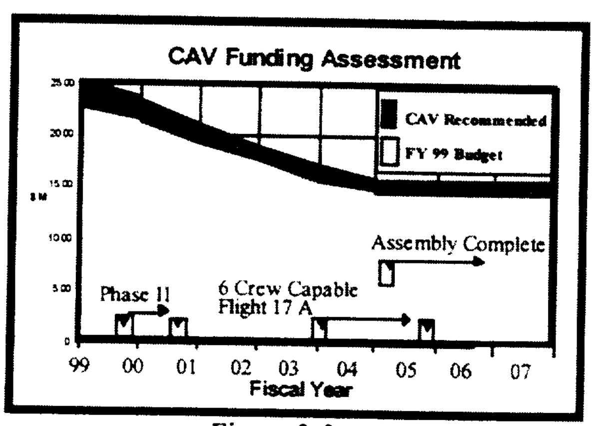


Figure 3-9

4.0 Other Observations

4.1 Full Cost Accounting and Civil Servants

The Federal Financial Improvement Act (1996) requires Government agencies to aggregate all costs associated with programs including civil servant salaries, travel costs, and infrastructure support. NASA plans to implement this requirement with its FY 2000 budget submission to Congress. To date, the costs associated with civil servants and infrastructure, e.g., facility costs, operation and maintenance of facilities including telephone, computer and utility costs, were accounted for separately. These costs will be included in the total cost of the ISS Program and increase the ISS budget significantly. It is important to understand that these are not increased costs, but have simply been accounted for in the budget separately in the past.

The total cost estimates in this report do not include these changes required under full cost accounting. It is estimated, however, that the number of civil service FTE working on ISS in 2000 will be 2,197 at an approximate cost of $176 million. This includes the cost for individuals who fulfill the contractual commitment claimed by the Prime.

The Task Force is concerned that workforce downsizing will likely result in a shortage of personnel, particularly those with the skills required for the work to be performed.

4.2 Shuttle Program Support

The Shuttle budget has been and will continue to be treated as a separate program under full cost accounting. With more than 35 Shuttle flights required to deliver ISS hardware to orbit, however, it could arguably be included as a Space Station cost, significantly increasing the total cost shown, while not being an additional cost to the NASA budget. These observations are not meant to set off alarms but are made to acknowledge that full cost accounting will cause so\me budget lines increase significantly, while other budget lines will decrease.

The Task Force does have a concern that, as the decisions regarding schedule changes are delayed and announced at the last minute, the Shuttle must be able to react in a cost-effective manner. Close coordination with the Shuttle Program must be maintained and as much advance notice as possible given in order to allow for economically effective adjustments to the Shuttle schedule.

4.3 Maintenance and Obsolescence

This phase of the ISS Program requires simultaneous integration of launch operations, on-orbit assembly operations, engineering support, and logistics and maintenance support with mission operations over an extended period of time. These activities are beyond the current collective experience of the ISS team and, as such, contain cost and schedule uncertainties and risks. The Task Force also anticipates that upgrades due to normal wear and tear, obsolescence, and degradation will be required, and a considerable amount of additional funding will be necessary to support these needs.

Giving the ISS Program credit for their current sophisticated spares program and their creative planning for future requirements, the Task Force's opinion is that there is no way to control spares currency, or lack of currency, for all International Partners, or the normal rate of obsolescence in space systems and computer technology which will cause major cost growth in outer years. This is not a pejorative opinion; it is one based on the reality of the current speed of technological advancement. It is extremely difficult to estimate the cost growth associated with this issue, but it will be major.

4.4 Launch Vehicle and Payload Failures

The Task Force did not assess the schedule or cost impact(s) that would be realized if the Program experiences one or more failures of a major payload element or segment while it is on-orbit or failures of the various launch vehicles with their attached payloads. It clearly needs to be recognized and understood that there is a high likelihood that one or more failures, including catastrophic failures, will occur over the span of 93 launches. The reliability of the better launch vehicles in the world is approximately 92 percent. This reliability figure would indicate that over the large number of launches of the Russian and U.S. launch vehicles and upper stages, the program will need to provide additional schedule and funding to recover from such eventualities.

5.0 Summary

The ISS Program at this stage has resolved many of the major programmatic open issues and is engaged in the very intense process of completing the development of the required hardware and software systems. The completion of the development and qualification of the hardware and software products continues to require additional time and effort beyond what was estimated and planned. This situation should be expected for development programs with high cost and schedule risk, particularly one as large and complex as ISS. Program management, however, continues to predict that the hardware and software developments will meet planned performance goals in the areas of schedule and cost, despite the fact that similar predictions in the past have not been realized by the Program. Late deliveries of development hardware and software have prevented the timely completion of qualification units and are forcing delays in the development of mission operations products and procedures. For example, the effectiveness of crew training procedures has been adversely impacted by delays in availability of basic hardware and software units. These delays have moved crew training, ideally a quiet background activity ongoing throughout the entire life cycle of the Program, onto the critical path of the schedule for Flight 5A (U.S. Lab) mission preparations.

Program management's "success-oriented" planning approach has necessitated a large amount of parallel and workaround activities, resulting in additional cost and schedule risks to the overall Program. In addition, fiscal year funding limitations and mandated de-staffing have required that other planned work efforts be deferred. The combined effect of these considerations has been to create unrealistic schedule and cost-to-complete expectations for the development Program as well as lengthening the list of critical issues. Several examples that have recently surfaced to illustrate the negative impact of this situation include the following: flight components being manufactured before their respective development and qualification programs are successfully completed; element systems-level environmental testing not being part of the Program baseline; crew training being planned using non-flight hardware and software systems rather than training on the versions that will ultimately be used; and crews scheduled for flights during the early assembly phase not having seen or trained on the hardware and software that was still being developed when they were launched. Another specific example is the U.S. Lab, whose software and hardware are planned to be incrementally updated by serially adding a number of systems over an extended period of time. Currently the Lab and its racks of electronics are several months behind in their delivery, integration and test milestones. Because of these circumstances, the U.S. Lab has become a schedule and cost issue of significant criticality that likely will require additional, unplanned redesign, rework, retest, redelivery, reintegration and retraining.

Overall ISS systems integration, test, launch, and flight operations need to be reassessed with respect to the schedule and cost to complete. While the Task Force recognizes that element system-level environmental testing is not now and has never been part of the ISS Program baseline (based upon NASA's experience in several earlier programs), this policy is not widely accepted in the aerospace industry. It is undeniable, though, that ISS development costs and schedules have been improved by omitting system level tests. This advantage, however, comes only at some level of increased technical, schedule, and cost risk. The current ISS plan calls for 45 assembly missions within approximately five years, including 33 Shuttle flights and 12 flights on Russian boosters. While it should be expected that, during the launch and on-orbit operations of this large amount of equipment, the Program can experience some number of launch and/or vacuum-related environmental problems with some of the equipment, this likelihood is not taken into account by the Program's contingency operational planning and equipment-sparing plans.

Unlike previous Shuttle flight experience in which each Shuttle flight is essentially independent of the preceding and following flights, payload operations for each ISS assembly flight are definitely linked to those preceding it. This linkage requires another dimension of systems integration that has never been required previously -- namely, integration between flights. There are also numerous (about 48) Soyuz and Progress logistics and resupply flights that are required during this period, in addition to the ISS assembly flights. These periodic logistics and resupply mission schedules and hardware availability are therefore also uniquely linked to the flight-to-flight integration and assembly complexity.

Nearly all of the 23 Shuttle assembly flights will require a large amount of EVA by the crews in order to assemble the ISS hardware. Flight support equipment alone for the ISS EVAs totals some 4000 items, exclusive of the hundreds of other items that are to be assembled. The crew training required for this number of configuration end items will be much more extensive than the collective experience of the U.S. and the International Partners. Additionally, the difficulty of training is further complicated by the necessity of having bilingual training in English and Russian.

It is likely, and should be expected, that the many interrelated Program events associated with the assembly, integration, test, launch, on-orbit assembly, resupply and mission operations of the many individual systems elements will experience a number of unexpected problems and surprises. Current Program schedules, however, including those encompassing the near-term events through ISS Phase II, lack adequate schedule reserves to accommodate more than a few unanticipated problems, and none of any long-term consequence. The severity of the impact of such occurrences will grow as successive development and qualification difficulties lead to required parallel work and compound late deliveries. For example, lack of adequate and timely spares for the ground and on-orbit test operations could cause serious schedule and costs impact to the highly integrated ISS master schedule.

The critical issues that the ISS Program faces in its development phase appear to be in conflict with the budget plan calling for a significant off-load of development personnel over the next 24 months. The Program plan and schedules need to recognize and account for a more realistic assessment of Program performance and the work content and schedule to complete the Program. Off-loading personnel to match an externally-imposed Program budget profile that inherently assumes that all the required work is being accomplished on time only aggravates and perpetuates unrealistic projections of actual performance. In reality, aggressive de-staffing to meet funding targets merely defers work that will, at some point, require even longer retention of existing personnel or, perhaps, even additional hiring to guarantee availability of critical skills. Currently, significant amounts of work have been deferred due to good-faith attempts to comply with the externally-imposed de-staffing schedule. Critical issues have been pushed downstream, thereby exerting additional pressure on future schedule milestones. For effective program execution, realistic schedule and funding profiles that incorporate contingency planning alternatives need to be developed and maintained.

6.0 Appendices

Appendix A: NASA Administrator Letter Requesting Independent ISS Analysis

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-000

September 17, 1997

Dr. Bradford Parkinson
Chair
NASA Advisory Council
Washington, DC 20546

Dear Dr. Parkinson:

I continue to value and encourage the NASA Advisory Council's independent analysis, observations, and advice on NASA's management and operations. A key factor in NASA's ability to gain increased bipartisan and public support for our programs has been the Agency's commitment to cost control. Given the near-term budget challenges that we have before us, it is imperative that we maintain this commitment and identify process improvements for the fiscal management of our programs. I request that you and the Council assist us and provide an increased emphasis on costs.

As a first example, I would like the Council to establish a cost control task force within its Advisory Committee on the International Space Station (ISS). This has urgency because of recent problems associated with cost control of the ISS. This task force would be directed to conduct a prompt, independent, and thorough analysis of the management, operational, and programmatic factors that affect cost growth and control of these research and development activities.

I would appreciate receiving the final recommendations of the Council coming from this analysis by the end of March 1998. I would be glad to discuss this matter with you further. It is my hope that the issues identified as a result of this review will be applicable to and lead to subsequent analyses by task forces on other major programs.

Sincerely,

Original signed by
Daniel S. Goldin

Daniel S. Goldin
Administrator

Appendix B: Terms Of Reference

COST ASSESSMENT AND VALIDATION TASK FORCE
TERMS OF REFERENCE
October 14, 1997

These Terms of Reference establish the Cost Assessment and Validation (CAV) Task Force of the Advisory Committee on the International Space Station (ACISS), a standing committee of the NASA Advisory Council (NAC). The CAV Task Force is chartered to perform an independent review and assessment of costs, budgets, and partnership performance on the International Space Station (ISS) program and to provide advice and recommendations to the NAC on the same. To accomplish this, the committee will hold in-depth reviews of all budgeting and estimating techniques being employed for managing costs on the ISS program, including rationale for costing assumptions, management of reserves, forward pricing techniques and acquisition procedures. The CAV Task Force will also review the contractual performance of all participants in the ISS program.

The objective of this activity will be to provide advice and recommendations for the following:

- Cost effective modifications to the present business structure and cost-management practices;
- Determining total ISS cost over the program life.

The Chair of the CAV Task Force is appointed by the Deputy Administrator. Membership will be comprised of senior persons who are nationally recognized experts with extensive experience in the disciplines of contracting, procurement, estimating, costs analysis, and technical and business management of high technology and space-based programs for both Government and industry. The Task Force will consist of six members. Term of membership is for the duration of the Task Force. Members will be appointed as Special Government Employees.

MEETINGS

The Task Force will meet three times in formal session. It will meet seven times in organizational or fact finding sessions.

REPORTING

The Task Force will report its findings and recommendations to the ACISS and to the NAC.

ADMINISTRATIVE PROVISIONS

The Executive Secretary will be appointed by the Associate Administrator for Space Flight and will serve as the Designated Federal Official.
Travel funds for Task Force members will be provided by the NAC budget from the allocation to the ACISS. Any other expenses associated with the Task Force will be funded by the Office of Space Flight.

The Office of Space Flight will provide staff support for the Task Force.

DURATION

The Task Force will terminate in 6 months from the date of these Terms of Reference or when its report has been submitted to the Administrator.

Appendix C: Letter Requesting CAV Response to Congressional Requirements

November 6, 1997

Mr. Jay Chabrow
President
JMR Associates Inc.
8841 Cortile Drive
Las Vegas, NV 89134-6142

Dear Mr. Chabrow:

Thank you for accepting the Chairmanship of the Cost Assessment and Validation (CAV) Task Force. The Task Force assessment of the International Space Station (ISS) costs is vital to the future of the ISS and the Nation's civil space program. This is a demanding exercise to accomplish by March 1998. NASA is fortunate to have a man with your background and capabilities to head this crucial activity.

The Terms of Reference for the Task Force are enclosed. As you know, they have been approved by General Dailey and establish the scope of activity for the Task Force. The CAV Task Force is chartered to perform an independent review and assessment of costs, budgets, and partnership performance on the ISS program and to provide advice and recommendations to the NASA Advisory Council on the same. The CAV Task Force will also review the contractual performance of all participants in the ISS program. The objective of this activity is to provide advice and recommendations for cost effective modifications to the present business structure and cost-management practices of the Space Station program, and to determine total cost over the program life.

In addition, the ISS program has been given requirements by the Appropriations Committees of both the House and the Senate to accomplish by March 1998 in order to secure release of the remaining $851,300,000 of this year's funding. The language in the Appropriations Conference Report reads "...$851,300,000 remains fenced until and unless NASA provides the following items to the Committees on Appropriations of the House and Senate, and the Committees subsequently approve the release of these funds:

1. A detailed plan, agreed jointly to by NASA and the prime contractor, for the contractor's monthly staffing levels through completion of development, and evidence that the contractor has held to the agreed-upon destaffing plan through the first four months of fiscal year 1998;

2. A detailed schedule, agreed jointly to by NASA and the prime contractor, for delivery of hardware, and NASA's plans for launching the hardware;

3. A detailed report on the status of negotiations between NASA and the prime contractor for changes to the contract for sustaining engineering and spares, with the expectation that NASA adhere to the self-imposed annual cap of $1,300,000,000 for operations after construction is complete; and

4. A detailed analysis by a qualified independent third party of the cost and schedule projections required in 1), 2), and 3) above, either verifying NASA's data or explaining reasons for lack of verification. Given how severe the program's budget problems are, the conferees are also mindful that future NASA budgets must be funded within discretionary spending caps in the five-year balanced budget agreement, meaning that budget outlays in FY 1999 for all discretionary spending will grow by just one percent. As a result, the conferees are concerned that future NASA budgets not force reductions in the current out-year projections for space science, earth science, aeronautics, and advanced space transportation because of the need to accommodate overruns in the space station budget."

We are looking to accomplish number four above by the CAV Task Force review. Through the course of your activity, please ensure that this congressional requirement is met. Many thanks, Jay, for taking on this challenge.

Sincerely,

Original signed by
Richard J. Wisniewski

Wilbur C. Trafton
Associate Administrator
for Space Flight

Appendix D: CAV Task Force Letter Assessment in Response to Congressional Requirements

March 25, 1998

Dr. Bradford Parkinson
Chair
NASA Advisory Council
National Aeronautics and Space Administration
Washington, DC 20546

Dear Dr. Parkinson:

The Cost Assessment and Validation (CAV) Task Force has conducted a careful analysis of the International Space Station technical challenges and its cost and schedule projections. The CAV findings are based on the FY99 Budget Submit to Congress, Revision C of the ISS Assembly Sequence and other material provided to the CAV over the total review period. The CAV has only recently received a draft copy of NASA's "White Paper" dated March 20, 1998, which is intended to respond to specific items called out in the NASA appropriations language contained in House Report 105-297. Assuming the NASA final response is consistent with program plans provided earlier to the CAV, the general comments provided below are applicable. The material presented in the final NASA response will be further reviewed and included in the CAV final report.

In the three areas of concern noted by Congress and addressed in the NASA response we provide the following general comments:

1. **A detailed plan, jointly agreed by NASA and the prime contractor, for the contractor's monthly staffing levels through completion of development, and evidence that the contractor has held to the agreed upon de-staffing plan through the first four months of FY 1998.**

   NASA and Boeing have agreed to a de-staffing plan which is consistent with the FY 1999 budget submit to Congress and with Revision C of the ISS Assembly Sequence. The agreed upon de-staffing goal reflects a reduction in Design, Development, Test and Evaluation (DDT&E) contractor staff from approximately 6,000 FTEs in October 1997, to approximately 3,600 FTEs by September 1998. The de-staffing plan is consistent with the "over the target" baseline cost goal that NASA and Boeing agreed to in October 1997. The "over the target" baseline was generated in anticipation of the Prime contract overrun of $600 million (Boeing estimate).

   The FY 1998 de-staffing plan for the prime contractor and prime subcontractors assumes an off-load of approximately 120 Full Time Equivalent (FTE) people from the prime contractor to NASA civil servants. The number of 120 FTE's was a working estimate provided to the CAV prior to completion of NASA/Boeing negotiations for FY 1998. The CAV has not seen the actual number of FTE's to be off-loaded in FY 1999 and beyond. Through the first four months of FY 1998 the prime contractor has under run the revised de-staffing goals.

   Although the prime contractor's staffing levels have generally tracked to the new plan, schedule slippage and work deferrals continue to occur and development schedules remain aggressive. A high potential risk for contractor staff to remain on contract will continue through qualification, integration, and verification testing. In the CAV's opinion program de-staffing goals do not adequately account for:

a) development work yet to be accomplished;
b) mitigation of current and potential risks; and,
c) retention of the appropriate skill mix through completion of development.

The CAV analyzed the ISS de-staffing plans for several prior years and found they were also not achieved for the above noted reasons, in addition to annual funding limitations imposed on the program. The current development de-staffing plan for the prime contractor and its subcontractors requires off-loads at a greater rate than all previous plans. The CAV believes attempting to adhere to these de-staffing plans is unrealistic and will introduce additional risk and costs that could otherwise be avoided.

2. **A detailed schedule agreed jointly to by NASA and the prime contractor for delivery of hardware and NASA's plans for launching the hardware:**

   The CAV has evaluated the Revision C assembly schedules between Boeing and NASA for delivering hardware. These Revision C schedules form the NASA FY1999 budget submit and are part of the total data the CAV Task Force reviewed and assessed.

   The CAV believes NASA's schedule is optimistic. While the Program has achieved a considerable amount of progress to date, delivering over 260,000 pounds of flight hardware through December 1997, much of this hardware is still undergoing development and qualification testing. Challenges that will arise in the process of performing hardware and software integration and integrated test activities, compounded by late qualification test results, indicate to the CAV that significant schedule risk remains. The CAV expects that additional schedule slippage and costs will be incurred beyond that which the Program is currently reflecting. Therefore, it is suggested that additional reserves be identified and expended to mitigate these risks.

3. **A detailed report on the status of negotiations between NASA and the prime contractor for changes to the contract for sustaining engineering and spares with the expectation that NASA adhere to the self-imposed annual cap of $1,300,000,000 for operations after construction is complete.**

   NASA and Boeing have reached agreement on both sustaining engineering and sparing levels for the early part of the program. Firm agreements are in place for 1998 and 1999 and negotiations are currently in work for the follow-on years.

   NASA and Boeing have negotiated a level of effort contract for FY98 and FY99 that reflects budgetary requirements that appear inadequate to support the total scope of the technical requirements. The CAV Task Force is concerned that a more significant effort will be required for ISS because of the complex need to simultaneously integrate launch operations, on-orbit assembly operations, engineering support, and logistics and maintenance support with missions operations over an extended period of time. The increased complexity is inherent in the assembly and operational nature of the ISS.

Relative to sparing, the CAV believes that funding constraints have forced a reduction in contracting for necessary spares/parts. This minimum sparing level could cause quality and consistency problems if later spares are not included in the same development production runs. Additionally, there may be a problem with availability of key parts needed to support the aggressive on-orbit assembly schedule.

While the Program believes it will be able to achieve the $1.3 billion annual operations projection, it is highly unlikely that total ISS annual expenditures can be contained within this amount. The CAV anticipates that upgrades due to normal wear and tear, obsolescence, and degradation will be required and a considerable level of additional funding for replacements will be necessary.

In consideration of the above findings, the CAV Task Force believes the program will require an additional level of annual funding between eight to ten percent of the program's annual budget forecast. The CAV Task Force further believes that the ISS will likely experience schedule growth of one to three years.

Sincerely,

Original Signed by
Jay Chabrow

Jay Chabrow
Chair, Cost Assessment and
Validation Team

cc: Daniel S. Goldin

Appendix E: Biographies of Members

Mr. Jay W. Chabrow, Chair is President of JMR Associates, Incorporated, consulting to technology-based companies. He is an expert with over 35 years experience in contracts, pricing, cost estimation, analysis, and procurement for aerospace projects. Previously, Mr. Chabrow was directly responsible for all contracts, pricing and cost data systems for TRW's Space and Defense Sector. In 1993 Mr. Chabrow was appointed by the White House to the President's Advisory Committee on the Redesign of the International Space Station and he has served on numerous advisory committees for NASA, DoD and the intelligence community. He was a consultant to the Assistant Secretary of Defense for Installations and Logistics (I&L) and was a member of ASPR-DAR/FAR pricing subcommittees. He was one of twelve national members selected to generate the Contractor Risk Assesment Guide (CRAG), providing estimating criteria for government and industry. Mr. Chabrow was a member of the Aerospace Industries Association's Procurement and Finance Executive Committee and currently is a member of the National Contract Management Association (NCMA) and is on NASA's Advisory Committee on the International Space Station.

Rear Admiral Thomas Betterton retired from active duty in January, 1992 after serving 35 years as a Naval Officer. During his career, over 16 years were devoted to the definition, development, deployment, and operation of major space-based sensing systems. Since his retirement, Rear Admiral Betterton, has been retained as a management and technical consultant by a number of aerospace related corporations. He has a wide variety of experience in material acquisition and life cycle support of naval weapons systems. Currently, he is a member of the U.S. Air Force Scientific Advisory Board and is a Fellow of the AIAA.

Dr. Stephen A. Book is Distinguished Engineer at The Aerospace Corporation, El Segundo, CA, serving as the Corporation's principal technical authority on costs of space and space-related systems. He was appointed to his current position in December 1995. From 1989 to 1995, Dr. Book held the position of Director, Resource and Requirements Analysis Department, leading the Corporation's efforts in cost research, estimating, and analysis. In prior positions at The Aerospace Corporation, Dr. Book worked on statistical test design, analysis of test data, and system optimization for a wide variety of Air Force space programs. Prior to joining Aerospace, Dr. Book was Professor of Mathematics at California State University, Dominguez Hills, where he conducted a vigorous research program, in theoretical aspects of probability and statistics, and he continues to teach evening mathematics courses. He earned his Ph.D. in mathematics, with concentration in probability and statistics, at the University of Oregon, Eugene, in 1970.

Ms. Virginia Durgin Until her recent retirement, Ms. Durgin served as the Associate Deputy Director of the Office of Finance and Logistics with the functional responsibility of Procurement Executive for the Central Intelligence Agency. She is an expert in contracts, pricing, cost estimating, analysis and procurement for the Central Intelligence Agency. Ms. Durgin managed the decentralized professional acquisition workforce during the past six years of downsizing while balancing increasing requirements. In 1993, Ms. Durgin served on the President's Advisory Committee for the Redesign of the Space Station and specifically worked on the Cost Subcommittee for cost realism. In an earlier role at the CIA, Ms Durgin initiated contracts for major modernization programs in excess of 3 billion dollars. Ms. Durgin is also the recipient of the Distinguished Intelligence Medal from the CIA.

Mr. Michael Peters is currently a Senior Cost Analyst for the Air Force Cost Analysis Agency. In his current capacity, Mr. Peters conducts life cycle cost analysis of major Air Force space system acquisition programs. Mr. Peters was responsible for the review of the Evolved Expendable Launch Vehicle (EELV) Program and has also been involved in the reviews of the National Polar Orbital Environmental Satellite (NPOES); Space-Based InfraRed Satellite (SBIRS); GPS II; Milstar and Titan IV programs. He initiated an ongoing cooperative effort between NASA and the Air Force to develop a common space systems cost database and methodology applicable to estimating future space system acquisition costs. Mr. Peters has conducted definitive studies on the economics of space development and the impacts of downsizing on the aerospace industry.

Mr. Robert J. Polutchko recently retired as the Vice President for Technical Operations, Lockheed Martin Aeronautics Sector. In this position, he was responsible for the technical management and oversight of all Aeronautics Sector programs and activities, including engineering, development, test, operations, and research. He was named to this position after serving as the Senior Vice President of Technical Operations for the Martin Marietta Corporation and Vice President of Technical Operations of the Space Group. He has also previously served as President of the Martin Marietta Information Systems Group and Vice President and General Manager of the Denver, Space Electronics Division. He is currently serving on a National Research Council panel of the Aeronautics and Space Engineering Board on long range R&D planning at NASA. Mr. Polutchko is an elected Fellow of the AIAA and received his B.S. and M.S. degrees in Aeronautical and Astronautical Engineering from M.I.T.

Mr. Eugene F. Tolman has an extensive record of accomplishments and awards for excellence in the Senior Executive Service of the Central Intelligence Agency. Mr. Tolman recently retired as Director of Technical Operations. In this capacity he was responsible for the formulation and development of technical missions supporting worldwide intelligence gathering and counter-terrorist activities. He has also served as Deputy Director for development of a major National Reconnaissance Office collection platform and Chief of Engineering of an associated ground station. Currently, Mr. Tolman is President of E. Forbes Tolman Associates and Vice President of Technology Applications for O-TECH International, McLean, VA.

Task Force Support:
Daniel L. Hedin, Executive Secretary
F. Patton Eblen, Administrative
Susan Y. Edgington, Administrative
Sandie G. Horton, Administrative
Angela Clark-Williams, Administrative

Appendix F: FY 1999 ISS Budget Submission to Congress

FY 1999 Budget to Congress

NOA $M

	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	TOTAL
SPACE STATION CONTENT	2106.0	2112.9	2143.6	2148.6	2501.3	2270.0	2134.0	1933.0	1766.0	1546.0	20661.4
DEVELOPMENT	1918.2	1749.4	1746.2	1809.9	1789.9	1055.5	589.9	355.4	237.9	64.0	11316.3
Flight Hardware	1609.7	1319.9	1471.0	1540.7	1529.0	931.4	502.3	320.8	217.5	52.0	9494.3
Test, Manufacturing & Assembly	99.0	91.9	73.5	95.7	97.4	33.7	25.9	21.1	12.7	6.2	557.1
Operations Capability & Constructior	151.0	190.0	127.4	115.7	115.1	64.3	43.4	13.3	7.7	5.8	833.7
Transportation Support	58.5	117.6	63.5	55.7	47.0	26.1	18.3	0.2			386.9
Flight Technology Demonstrations		30.0	10.8	2.1	1.4						44.3
OPERATIONS	0.0	108.9	120.0	142.6	490.1	840.3	951.6	881.5	805.1	763.9	5104.0
Vehicle Operations		36.2	37.5	33.5	312.4	574.8	659.2	573.1	501.6	492.9	3221.2
Ground Operations		72.7	82.5	109.1	177.7	265.5	292.4	308.4	303.5	271.0	1882.8
RESEARCH	187.8	254.6	277.4	196.1	221.3	374.2	475.5	525.1	550.0	553.1	3615.1
Research Projects	43.1	112.8	131.3	82.2	95.3	232.2	353.5	418.2	438.0	433.1	2339.7
Gravitational Biology and Ecology	8.1	27.0	30.0	10.0	18.0	53.6	80.0	95.0	87.0	80.0	488.7
Biomedical Research and Countermeasi	12.0	30.8	32.0	28.0	23.0	32.5	45.5	52.0	60.0	53.1	368.9
Advanced Human Support Technology					1.2	7.0	19.0	14.0	20.0	25.0	86.2
Microgravity Research	20.0	50.0	56.3	32.0	36.0	107.0	165.0	205.0	200.0	200.0	1071.3
Space Product Development			5.0	5.0	10.0	17.7	21.0	25.2	32.0	35.0	150.9
Engineering Technology				0.2	4.0	11.0	19.0	25.0	37.0	40.0	136.2
Earth Observation Systems	3.0	5.0	8.0	7.0	3.1	3.4	4.0	2.0	2.0		37.5
Utilization Support	21.0	36.3	64.4	54.6	89.0	140.0	122.0	106.9	112.0	120.0	866.2
Flight Multi-User Hardware & Spt		5.0	17.0	18.1	33.0	54.0	42.0	33.0	37.0	40.0	279.1
Payload Integration & Operations	21.0	31.3	47.4	36.5	56.0	86.0	80.0	73.9	75.0	80.0	587.1
Mir Support	123.7	105.5	81.7	59.3	37.0	2.0					409.2
Phase 1 Project	*70.8*	*50.1*	*29.2*	*28.2*	*21.0*						199.3
Mir Research	*52.9*	*55.4*	*52.5*	*31.1*	*16.0*	*2.0*					209.9
CREW RETURN VEHICLE							117.0	171.0	173.0	165.0	626.0

	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	TOTAL
US/RUSSIAN COOP. CONTENT	100.0	100.0	100.0	300.0	50.0						650.0
RUSSIAN SUPPORT	100.0	100.0	100.0	100.0							400.0
RUSSIAN PROGRAM ASSURANCE				200.0	50.0						250.0

Appendix G: Revision C of ISS Assembly Sequence

Launch Date	Flight	Delivered Elements
Jun-98	1A/R	FGB (Launched on PROTON launcher)
Jul-98	2A	Node 1 (1 Stowage rack), PMA1, PMA2, 2 APFRs (on Sidewalls)
Dec-98	1R	Service Module (Launched on PROTON launcher)
Dec-98	2A.1	Spacehab Double Cargo Module, OTD (on Sidewall)
Jan-99	3A	Z1 truss, CMGs, Ku-band, S-band Equipment, PMA3, EVAS (on SLP), 2 Z1 DDCUs (on Sidewalls)
Jan-99	2R	Soyuz - (a)
Apr-99	4A	P6, PV Array (4 battery sets) / EEATCS radiators, S-band Equipment
May-99	5A	Lab (5 Lab System racks), PDGF (on Sidewall)
Jun-99	6A	6 Lab Sys, 1 Stowage rack, 2 RSPs (on MPLM), UHF, SSRMS (on SLP) - (b)
Aug-99	7A	Airlock, HP gas (2 O2, 2 N2) (on SLDP)
Phase 2 Complete		
Nov-99	7A.1	2 Stowage racks, 3 RSPs, ISPRs (on MPLM TBR9), OTD, APFR (on Sidewalls), 2 PV battery sets (on SLP)
Dec-99	4R	Docking Compartment 1 (DC1)
Jan-00	UF1	ISPRs, 2 Stowage racks, 3 RSPs (on MPLM), Maintenance ORUs (on SLP)
Feb-00	8A	S0, MT, GPS, Umbilicals, A/L Spur
Mar-00	UF2	ISPRs, 1 JEM rack, 3 Stowage racks (on MPLM), MBS, Radiator OSE, PDGF (on Sidewalls)
Jun-00	9A	S1 (3 rads), TCS, CETA (1), S-band
Jul-00	9A.1	Science Power Platform w/4 solar arrays and ERA.
Oct-00	11A	P1 (3 rads), TCS, CETA (1), UHF
Nov-00	12A	P3/4, PV Array (4 battery sets), 2 ULCAS
Dec-00	3R	Universal Docking Module (UDM)
Dec-00	5R	Docking Compartment 2 (DC2)
Mar-01	13A	S3/4, PV Array (4 battery sets), 4 PAS
Apr-01	10A	Node 2 (4 DDCU racks), NTA (on Sidewall)
May-01	1J/A	JEM ELM PS (4 JEM Sys, 3 ISPRs, 1 JEM Stowage racks), P5, 1 O2 Tank (on SLP)
Aug-01	1J	JEM PM (4 JEM Sys racks), JEM RMS
Sep-01	UF3	ISPRs, 1 Stowage Rack, 1 RSP (on MPLM)
Jan-02	UF4	Truss Attach Site P/L, Express Pallet w/ Payloads, ATA, 1 O2 tank, SPDM (on Spacelab Pallet)
Feb-02	2J/A	JEM EF, ELM-ES w/ Payloads, 4 PV battery sets (on Spacelab Pallet)
Feb-02	9R.1	Docking & Stowage Module 1 (DSM1)
May-02	9R.2	Docking & Stowage Module 2 (DSM2)
May-02	14A	4 SPP Solar Arrays (on EDO truss), Cupola (on SLP), Port Rails (on SLP)
Jun-02	UF5	ISPRs, 1 Stowage Rack, 1RSP (on MPLM), Express Pallet w/ Payloads
Jul-02	20A	Node 3 (2 Avionics, 2 ECLSS racks)
Aug-02	8R	Research Module #1 (RM-1)
Oct-02	1E	APM (5 ISPRs), 1 O2 tank (on SLP)
Nov-02	10R	Research Module #2 (RM-2)
Nov-02	17A	1 Lab Sys, 4 Node 3 Sys racks, 3 CHeCS racks, 1 U.S. Stowage rack, ISPRs (on MPLM)
Jan-03	11R	Life Support Module 1 (LSM 1)
Mar-03	12R	Life Support Module 2 (LSM 2)
Mar-03	18A	CRV #1, CRV adapter - (c)
Apr-03	19A	5 Stowage racks, 1 RSR, ISPRs, 4 Crew Qtrs. (on MPLM), S5 - (d)
Jul-03	15A	S6, PV Array (4 battery sets), Stbd MT/CETA rails
Aug-03	UF6	3 RSRs, 1 RSP, ISPRs (on MPLM), 2 PV battery sets (on SLP)
Oct-03	UF7	Centrifuge Accommodations Module (CAM), ISPRs (TBD)
Dec-03	16A	Hab (3 Hab sys racks, 2 RSRs, ISPRs)

Additional logistics vehicles are not listed.

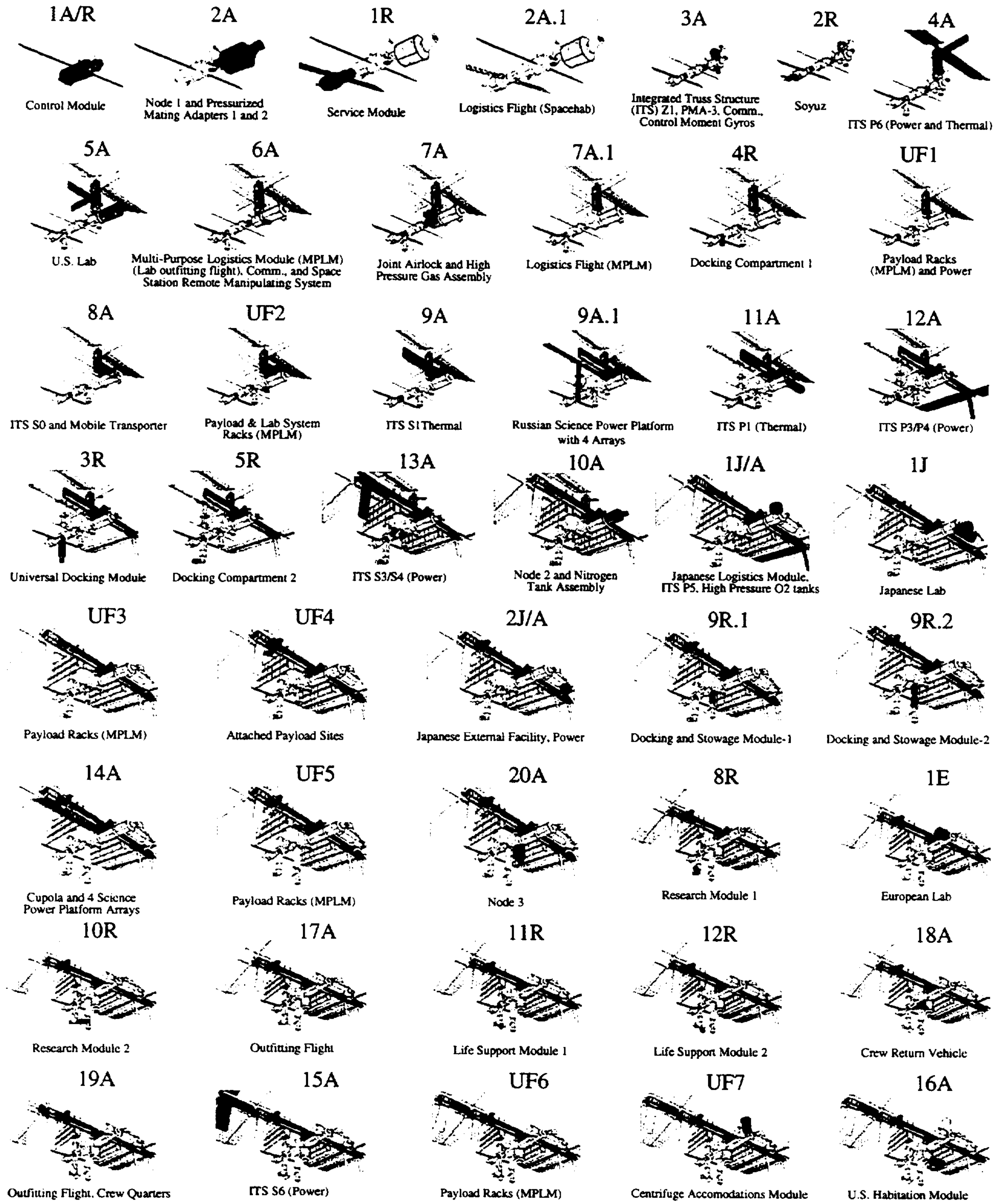
(a) - 3 Person Permanent International Human Presence Capability

(b) - Microgravity Capability

(c) - 6 Person Permanent International Human Presence Capability

(d) - Rack traffic assumes transition to 6 person crew on 19A.

Appendix G: Revision C of ISS Assembly Sequence (continued)



March 25,1998

Appendix H: Acronyms

AC	Assembly Complete
ACISS	Advisory Committee on the ISS
ATV	Automated Transfer Vehicle
BCDU	Battery Charge/Discharge Unit
C&DH	Command & Data Handling
C&T	Communications and Tracking
CAV	Cost Assessment and Validation
CAM	Centrifuge Accommodation Module
CITE	Cargo Integration Test Equipment
COF	Columbus Orbital Facility
CRV	Crew Return Vehicle
CSA	Canadian Space Agency
CSCI	Computer Software/system Configuration Item
DCMC	Defense Contract Management Command
DDCU	DC-to-DC Converter Unit
ECLSS	Environmental Control and Life Support System
EMC	ElectroMagnetic Compatibility
EPS	Electrical Power System
ESA	European Space Agency
EVA	ExtraVehicular Activity
FEL	First Element Launch
FGB	Functional Cargo Block [sic] (Functionalui Germaticheskii Block)
FTE	Full Time Equivalent person
FY	Fiscal Year
GDR	General Designers Review
GFE	Government-Furnished Equipment
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
HTV	H-II Transfer Vehicle
ICM	Interim Control Module
IGA	Inter-Governmental Agreement
IMCA	Integrated Motor Control Assembly
ISS	International Space Station
JSC	Johnson Space Center
KSC	Kennedy Space Center
KHSC	Khrunichev State Research and Production Space Center
MDM	Multiplexer/DeMultiplexer
MEIT	Multi-Element Integrated Test
MOU	Memorandum of Understanding
MPLM	Multi-Purpose Logistics Module
MSFC	Marshall Space Flight Center
MTBF	Mean Time Between Failures
NAC	NASA Advisory Council
NASA	National Aeronautics and Space Administration
NRL	Naval Research Laboratory
NSLD	NASA/Shuttle Logistics Depot
NPLD	National Payload Logistics Depot
ORU	Orbital Replacement Unit
PHC	Permanent Human Capability
POP	Program Operating Plan
RPA	Russian Program Assurance
RSA	Russian Space Agency
RSS	Root-Sum-Square
SDOM	Station Development and Operations Meeting
SE&I	Systems Engineering and Integration
SM	Service Module
SPP	Science Power Platform
STA	Structural Test Article