International Space Station
Payload Operations Concepts and Architecture Assessment Study

Final Report

Prepared for the

National Aeronautics and Space Administration
Office of Biological and Physical Research

By

Computer Sciences Corporation

Through

Management, Organizational, and Business Improvement Services
(MOBIS)
Contract GS-23F-8029H

February 2002

Preface

This report presents the results of the International Space Station (ISS) Payload Operations Concepts and Architecture Assessment Study (POCAAS). The report was prepared by the POCAAS Study Team. Computer Sciences Corporation (CSC) formed the team in response to a Request for Proposal (RFP) from the Office of Biological and Physical Research of the National Aeronautics and Space Administration (NASA).

The Statement of Work for the study required that the Study Team assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements. The Study Team was also required to recommend the potential for time-phased reductions in the cost of payload operations through efficiency improvements to existing systems, interim or permanent changes to existing requirements on systems, and changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations. At the first Study Team meeting, NASA charged the Team to focus on alternative concepts, rather than focusing on a detailed audit of current operations.

The Study Team comprised 19 members who were selected to provide a broad knowledge of payload operations in space. The Team members (Exhibit 1) were selected to provide a balance between specific knowledge of current ISS payload operations, experience with prior manned programs (such as Skylab, Space Shuttle, and Spacelab), and experience with unmanned scientific operations (such as the Einstein Observatory, the Hubble Space Telescope, and the Chandra Observatory). The Team included the following individuals:

- Researchers who have conducted experiments onboard the ISS as well as prior manned programs
- Former payload specialists who have flown Space Shuttle and Spacelab scientific missions
- An astronaut who flew on Skylab, as well as Space Shuttle and Spacelab
- Operations personnel who have designed and performed payload operations for both manned and unmanned space programs.

Appendix A contains biographical sketches of all team members.

Exhibit 1. POCAAS Study Team Members

Member Name	Key Background and Experience
Fletcher Kurtz, Study Manager	Director, MSFC Mission Operations Laboratory
John-David Bartoe*	Research Manager, ISS Program; Spacelab Payload Specialist
John Cassanto	Commercial Payload Developer for Shuttle, MIR, and ISS
John Cox	Manager, Space Station Freedom Program
Roger Crouch*	Senior Scientist for ISS, NASA Code M; Spacelab Payload Specialist
Larry DeLucas*	Researcher, Biotechnology; Spacelab Payload Specialist
Dale Fahnestock	Director, GSFC Mission Operations and Data Systems Directorate
Owen Garriott*	Skylab, Shuttle, and Spacelab Mission Specialist

Member Name	Key Background and Experience
Gerald Griffith	Payload Interfaces and Crew Safety, JSC Astronaut Office
Bob Holkan	Manager, Space Station Control Center and ISS Simulator
Chuck Lewis	Chief, MSFC Mission Training Division
Byron Lichtenberg*	Researcher, Life Sciences; Spacelab Payload Specialist
John O'Neill	Director, NASA Space Operations Management Office
Ron Parise*	Data Management Scientist; Spacelab Payload Specialist
Ed Pavelka	Chief, JSC Operations Division
Tom Recio	MSFC Operations Manager, Einstein Observatory and Spacelab
Al Sacco*	Researcher, Materials Science; Spacelab Payload Specialist
Carl Shelley	NASA manned operations and program management; ISS International Partnerships
Jerry Weiler	Chief, MSFC Mission Planning Division

* Prior Payload Specialists

The study was conducted between October 2001 and February 2002. During these four months, the Study Team met in four formal meetings for a total of 10 days; however, much of the Team's work was performed between meetings and coordinated through email and teleconference calls. The Team also formed five subteams to penetrate more deeply into the specific areas of researcher issues, information systems, operations control, planning, and crew support.

The Study Team initially received briefings from NASA personnel regarding the study objectives, the ISS budget, and a payload operations overview. The Team also requested and received NASA briefings on the following:

- Design reference missions to be used in the study
- Each of the four Telescience Support Centers
- Payload Operations Integration Function
- Payload Operations Integration Center
- Changes required to the Space Station Control Center to provide Payload Operations Integration Center (POIC)-equivalent services
- Request-Oriented Scheduling Engine (ROSE)

To validate findings with respect to difficulties currently experienced by researchers in using the ISS, the Study Team addressed a survey to all 61 principal investigators and payload developers currently participating in the ISS Program through Increment 6. Thirty-seven of the survey recipients responded, and their input was extremely valuable.

The Team members, individually and in subteams, also conducted extensive informal discussions with cognizant NASA personnel. The Team appreciates the openness and cooperation of NASA personnel throughout the study. In addition to the leadership and advice of Mark Uhran, the study sponsor, the Team acknowledges, particularly, the following individuals:

Carmine Bailey (Boeing)

Darrell Bailey

Dave Beering (Infinite Global Infrastructure, LLC)
Bob Bradford
Rickey Cissom
Barbara Cobb
Jan Davis
Jerry Geron (TBE)
John Jaap
Mike Kearney
Candace Livingston
Chris Maese
Diane Malarik
Mark McElyea
Ann McNair
Tim Owen
Bob Patterson
Ned Pendley
Lesa Rowe
Julie Sanchez
Doug Sander
Debbie Underwood
Teresa Vanhooser
Lisa Watson

The Executive Summary contains the Study Team's principal findings and recommendations, while supporting analyses and additional specific recommendations are contained in the body of this report. In keeping with the emphasis requested by NASA, the Team focused on the evaluation of alternative concepts and, therefore, did not perform a detailed audit of current payload operations.

Contents

Exhibits

Executive Summary

The Payload Operations Concept and Architecture Assessment Study (POCAAS) for the International Space Station (ISS) was established by NASA's Office of Biological and Physical Research (Code U) to assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements. The study evaluated the potential for time-phased reductions in the cost of payload operations through efficiency improvements to existing systems, interim or permanent changes to existing requirements on systems, and changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations.

This Executive Summary presents the Study Team's findings and recommendations. Additional detailed findings and recommendations are contained in the body of the report.

ES-1. The payload operations organization performed admirably during the first year of ISS research under extremely difficult circumstances.

More than 50 investigators have successfully conducted research on the ISS, and more than 50,000 hours of experiment run-time were conducted. This research was performed while the ISS was in the process of major construction, despite significant system anomalies.

A steep on-orbit learning curve was experienced in managing a very complex space facility, which imposed significant requirements and process constraints on the payload operations organization.

ES-2. ISS researchers find the payload integration process, including payload operations, to be unnecessarily and discouragingly difficult.

In comparison to past manned space programs, ISS requirements are too demanding, and enforcement of compliance to these requirements is too strict. There are too many repetitive reviews involving principal investigators (PIs) and payload developers (PDs). Processes are too complicated and inflexible.

Researchers judge the *reflight* of a Space Shuttle or Spacelab payload on ISS to be 2 to 4 times more difficult than the *original flight* on Shuttle/Spacelab. Reflight of an ISS payload on the ISS is not as difficult as the first ISS flight, but significant repetitive work can be reduced.

Recommendation. Reengineer and streamline the payload integration process, including payload operations.

ES-3. Payload operations are a relatively small component of ISS cost.

Of an approximately \$2 billion per year ISS Program budget, the ISS research budget of \$284 million constitutes 14 percent. Within the research budget, the current \$51 million payload operations budget constitutes 18 percent, or 2.6 percent of the entire ISS Program budget.

While the payload operations budget does not appear disproportionate to other ISS Program elements when judged against other comparable space programs, the payload operations cost can be reduced.

Recommendation. Considering the interaction among all payload integration activities, and the researcher issues, reduction in payload operations costs should be undertaken as part of a larger streamlining of ISS payload integration.

ES-4. Payload operations cost can be reduced if a combination of actions is taken.

Program requirements must be modified to allow alternative implementations (e.g., for reflight payloads). Program standards must be modified or interpreted to focus on intent, not rigid adherence (e.g, detailed formatting of crew displays and procedures).

Information exchange requirements among ISS organizations and with researchers must be streamlined to be more effective, less formal, and less redundant.

Operational processes and approval processes must be further simplified.

While some of these actions may be regarded as potentially reducing the efficiency of research resource utilization onboard the ISS, the Study Team believes that this need not be the case. The Study Team believes the increase in researcher satisfaction and reduction in cost greatly outweigh the risk.

Recommendation. Budget reduction should be preceded by a definitive program action, working with the research community, to identify and define specific changes to reduce complexity, increase flexibility, and reduce cost.

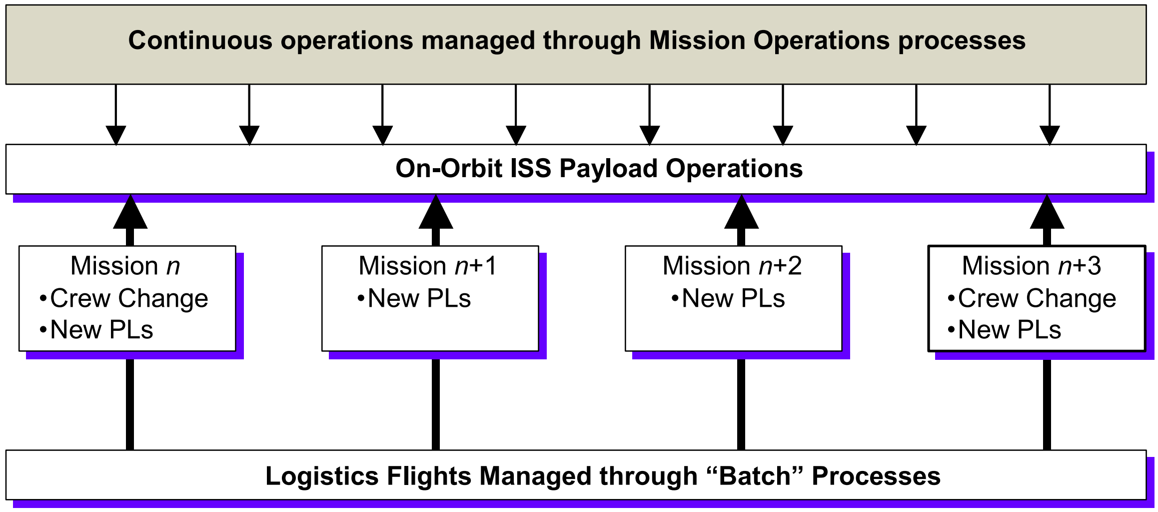
ES-5. ISS operations today are being largely conducted in “sortie” mode; an alternative concept for long-term payload operations is “continuous flow”.

In current operations, each Increment (or Expedition) is treated as an entity [planning, preparation, certification of flight readiness (COFR), crew changeout]. New payloads, however, are manifested and certified by Earth-to-orbit-vehicle (ETOV) flight.

The sortie mode of operations was logical, effective, and efficient for early ISS assembly operations. However, as the ISS Program moves toward sustained research operations on-orbit, continuous operations become the objective.

In the alternative concept of *continuous flow* (Exhibit ES-1), the Payload Operations Integration Function (POIF) manages on-orbit ISS payload operations more as a ship at sea. The operations processes currently used by the POIF to manage day-to-day operations during an increment are extended to eliminate the need to recertify payload onboard the ISS and its continuing operation. The POIF has already introduced this mode of operation to some extent in the management of crew procedures and displays. New payloads and payload supplies are logistically provided by ETOV sorties, as is crew exchange.

Exhibit ES-1. Continuous Flow Concept



A comparison of sortie (increment) mode to the continuous flow concept is shown in Exhibit ES-2.

Exhibit ES-2. Comparison of Sortie and Continuous Flow Concepts

Sortie (Increment)	Continuous Flow
• Based on concept that all payloads are "new" for each increment	• Based on concept that majority (75%) of payloads are continuing or reflights from previous ISS operations
• All payload hardware used in an increment must be certified for the increment	• Payload hardware remaining on-orbit was certified when launched (continuing integrity should be periodically reviewed)
• All payload hardware launched on a flight must be certified for the flight	• All payload hardware launched on a flight must be certified for the flight
• Payload crew procedures processed and certified for each increment • Payload displays reviewed and certified for each increment	• Payload procedures and displays established when payload launched and maintained through real-time (RT) operations
• PODF new for each increment	• PODF maintained through on-orbit configuration control
• Crew changeout regarded as beginning of new mission	• Crew changeout regarded as shift handover for ongoing payload operations
• Payload documentation system based on separate documents (or PDL entries) for each increment	• Payload documentation system based on one-time baselining with change control for reflight

Recommendation. Adopt continuous flow processes where possible to reduce repetitious increment-based activities.

ES-6. The current ISS payload operations architecture comprises four primary cost elements.

The four primary cost elements are as follows:

- Payload Operations Integration Function (POIF)
- Payload Operations Integration Center (POIC)
- Telescience Support Centers (TSCs)
- NASA Integrated Services Network (NISN) services

ES-6.1. The POIF provides essential ISS functions.

- Integrating ISS payload operations (U.S. and international partner)
- Facilitating performance of experiments by PIs and crew, and managing shared resources
- Controlling the U.S. payload communications and data handling (C&DH) system, which includes the payload multiplexer-demultiplexer (MDM) system the KuBand communications system, and the onboard communications outage recorders
- Controlling 11 onboard research facilities (8 EXPRESS Racks, MELFI, WORF, and ARIS)

POIF Cost Option 1. The Study Team recognizes that POIF cost was significantly reduced previously through continuous improvement processes that are in place. However, the Team believes that POIF cost can be further reduced through reduction of requirements, reduced rigidity in standards, streamlined processes, and adherence to a minimum service level. The Study Team performed a bottoms-up labor estimate for the POIF assuming incorporation of POCAAS recommendations. The results of this labor estimate are shown in Exhibit ES-3.

Exhibit ES-3. Minimum Service Level Cost Option (LOE/year)

	Current	POCAAS Bottoms-Up Estimate		
Function	**3 Crew, Pre-AC**	**3 Crew, Pre-AC**	**3 Crew, Post-AC**	**6 Crew**
POIF Management	16	7	7	7
Operations Integration – RT	10	9	9	9
Operations Integration – Prep	25	19	20	20
Planning – RT	10	7	8	9
Planning – Prep	30	16	20	21
OC/DMC – RT	28	28	35	35
OC/DMC – Prep	60	36	43	46
Crew Support – RT	9	9	9	9
Crew Support – Prep	53	27	31	55
Total	**241**	**158**	**182**	**211**

Note that the POCAAS estimate was performed separately for three ISS mission phases (three crew, pre-core assembly complete; three crew, post-core assembly complete; and six crew). These phases were defined by the POCAAS in a mission model that reflects the differing numbers and complexity of payloads that can be supported by the ISS and its logistics systems in these phases.

Three other POIF cost options were also evaluated.

POIF Cost Option 2. Delete planned Space Flight Operations Contract (SFOC) instructor support for crew training on payloads. The training would still be performed at the Payload Training Complex (PTC) at Johnson Space Center (JSC) by POIF staff, as it is currently being performed. The Study Team judged that it is more cost effective to focus payload training responsibility within one (POIF) organization.

POIF Cost Option 3. Provide POIF assistance to PIs/PDs above the minimum service level, where the PIs/PDs need and request assistance. This option recognizes that PIs/PDs vary in their experience level with space operations. This is especially true of first-time fliers, while PIs/PDs with prior experience and PIs/PDs supported strongly by Research Project Office (RPO) resources need only the minimum service level.

POIF assistance to inexperienced PDs has reduced development time, reduced overall cost, and resulted in better operations products. This assistance can also allow PIs/PDs to focus on their core competencies of science research and experiment development, while using experienced operations personnel to translate experiment requirements into operations products and formats.

This cost option requires a staff of 10 to 15 operations interface engineers. The precise number should be based yearly on an assessment of the planned payload manifest and, therefore, is expected to change over time.

The operations interface engineers, if maintained in a separate pool within the POIF, can provide an added role of advocacy for continuous improvement within the POIF, by aligning with the perspective of the researchers.

POIF Cost Option 4. Provide additional POIF resources to plan for payload operations with the IPs. Limited process and procedural preparation has been accomplished to date for IP payload operations interfaces.

A dedicated team of 5 or 6 operations personnel is needed in 2003–2004 to develop the IP interfaces and to support an increased level of simulations to validate procedures and train both IP and POIF staff. The precise size of this effort requires further analysis.

Implementation Considerations. The Study Team identified a number of implementation considerations that should be observed if the Team recommendations are accepted.

A balance should be maintained between Federal Government and private-sector (contractor) staffing. The Government component is essential both to exert Government responsibility and to maintain continuity in the core skill base. The current contract for POIF contractor labor is assumed to end in fiscal year (FY) 2004, due to expiration of the current NASA 50000 contract late in that year.

Capability should also be retained to rotate POIF staff between on-console real-time shifts and preparation work performed in the normal office work environment. This rotation is essential for retaining both staff and skills.

A phase-in of the POCAAS minimum service level model is required to accomplish changes in current requirements, documentation, and operating practices, and to avoid disruption to ongoing payload operations. Exhibit ES-4 shows a recommended phase-in profile. The profile reflects a transition in FY 2002–2003 to the minimum service level model. A transition from the three-crew, pre-core assembly complete payload traffic model (30 payloads/increment) to the higher three-crew, post-core assembly complete payload traffic model (40 payloads/increment) begins in FY 2005, based on the POCAAS mission model. Although IP payload operations may begin in FY 2005, the total payload workload does not change until FY 2006. The additional initial effort required for integration of the IPs into payload operations is separately accounted for in Option 4. The transition to the six-crew payload traffic model (70 payloads/increment) begins in FY 2008.

Exhibit ES-4. LOE Phasing for POIF Cost Options

FY	02	03	04	05	06	07	08	09	10	11
Cost Option 1										
Government	66	58	50	50	50	50	50	50	50	50
Contractor	175	142	108	120	132	132	147	161	161	161
Cost Option 3										
Contractor		15	15	15	15	15	15	15	15	15
Cost Option 4										
Contractor		5	5							
Total	**241**	**220**	**178**	**185**	**197**	**197**	**212**	**226**	**226**	**226**

The assumed Federal Government staff level in FY 2003 and subsequent is an arbitrary fraction of the total staff.

POIF Recommendations.

POIF Cost Option 1 — Minimum Service Level. The Study Team recommends that this option be adopted, with an appropriate phase-in, and conditional upon similar ISS Program changes in payload integration that are necessary for success of the option.

POIF Cost Option 2 — Elimination of SFOC Training Instructors. The Study Team recommends adopting this option. A level of SFOC funding must still be maintained to support PTC maintenance.

POIF Cost Option 3 — PI/PD Assistance. The Study Team recommends that this option be adopted, subject to a review of the planned payload manifest and the needs of manifested PIs/PDs.

POIF Cost Option 4 — IP Operations Preparation. The Study Team recommends reviewing this option with respect to IP agreements, processes, and timing. Timely preparations for IP payload operations are essential to avoid disruption and loss of science return.

ES-6.2. The POIC provides the essential core information technology infrastructure necessary to conduct payload operations.

The POIC performs the following functions:

- Real-time (RT) and near-real-time (NRT) telemetry processing

- Command processing
- POIC and remote command and display processing
- KuBand data distribution via the Payload Data Service System (PDSS) to the Internet
- Local and remote voice communications (HVoDS/IVoDS)
- Local video distribution
- Operations tools hosting

POIC development was completed within the past year, and a final major software delivery is scheduled for the second quarter of CY 2002. As development tasks were completed, the POIC contractor staff was reduced from 250 in March 2001 to a planned 125 in March 2002. Systems of this type typically require approximately 1 year to stabilize operation after completion of development.

The POIC systems, as designed and implemented, are highly capable, highly distributed, and relatively complex to operate. The Study Team found that technology refreshment is essential to reducing the cost of operating the POIC, as well as to maintain system effectiveness:

- Some POIC equipment is nearing end-of-life or economical operation
- Newer technology allows system consolidation and lower maintenance or operating cost
- Simplification and increased automation of operations, arising in part from newer technology, is essential to reduce labor cost
- Technology refreshment requires investment for reengineering hardware and software, and for acquiring new technology hardware

POIC technology refreshment should include the following:

- Performance of reengineering in FY 2002–2004 directed at cost reduction
- Consolidation of servers, with consideration of leasing operational servers beginning in FY 2004 and refreshing them at 3-year intervals thereafter
- Provision of sufficient robustness and reserve capacity to allow maintenance on an 8-hours-per day, 5-days-a-week nominal basis
- Completion of the ongoing transition from workstations to PCs for command and display functions
- Porting of the Payload Planning System (PPS) software to the IBM platform used for the Crew Planning System (CPS), and elimination of the current DEC platform
- Increased automation of configuration and reconfiguration control

These changes should allow the reduction of sustaining engineering and operations staffs in FY 2005 and subsequent by approximately 20 percent, in addition to substantial reduction in license and hardware maintenance costs.

Recommendation. Reengineer the POIC to reduce cost. Make a $6 million investment over the FY 2002–2004 time period above FY 2002 budget guidelines, and reduce the operating budget in FY 2005–2011, achieving a reduction of $36 million (18 percent) from the FY 2002 budget level over the 10-year period FY02–2011.

ES-6.3. The four Telescience Support Centers (ARC, GRC, JSC, and MSFC) are multifunction but research discipline-focused facilities.

- Real-time operations integration and control of ISS discipline-dedicated, facility-class racks
- Provision of remote operations resources for PIs/PDs located near the TSC
- Other synergistic Research Program Office (RPO) activities that vary by TSC

The Ames Research Center (ARC) TSC is designed around the operation of space biology payloads that include animal habitats and animal experimentation. These payloads require extensive ground control experiments in parallel with the flight experiments, and extensive prelaunch support to activities at the launch site. However, this class of experiment is a heavy user of crew time and is, therefore, expected to be curtailed during the three-crew mission phases. The ARC TSC also supports the Avian Development Facility (ADF) and the Biomass Production System (BPS) experiments.

The Glenn Research Center (GRC) TSC is designed around the integration of experiments using the Fluids Integrated Rack (FIR) and the Combustion Integrated Rack (CIR). However, the FIR and CIR are not scheduled for launch until CY 2005. Their operation, originally planned for use with multiple payload inserts per increment, is now expected to involve only one payload insert per increment during the three-crew mission phase. The GRC TSC also currently supports the Space Acceleration Measurement System (SAMS) payload.

The Johnson Space Center (JSC) TSC is designed around the integration of experiments using the Human Research Facility (HRF), which is currently in operation. Additionally, the JSC TSC supports other biotechnology experiments [currently Biotechnology Specimen Temperature (BST) and Biotechnology Research (BTR)], Active Rack Isolation System ISS Characterization Experiment (ARIS-ICE), Earth observations, and EARTHKAM.

The Marshal Space Flight Center (MSFC) TSC supports Material Science Glovebox (MSG) and Biotechnology Glovebox facilities, as well as Protein Crystal Growth payloads.

Recommendation. Transfer TSC budgets from payload operations to the respective RPOs, and treat the TSCs as science discipline facilities rather than common-use payload operations facilities. Their costs should be justified on the basis of the payloads they support, and judged relative to the cost of equivalent remote PI services. (Code U had already taken this action prior to the POCAAS). The RPOs should consider deferral of ARC and GRC capabilities (and costs) until those facilities are needed for facility rack support.

ES-6.4. NISN costs and increasing budget trends are counter to current commercial costs and trends.

The NISN budget for ISS payload operations services shows an increase of 10 percent per year through FY 2006. However, the budgeted NISN costs are more than twice the current cost for equivalent commercial services, and commercial long-line costs are decreasing at a rate of 40 percent per year.

Recommendation. Pursue alternative means of providing communications services at lower cost.

Recommendation. Defer the requirement for distribution of ISS onboard video to the TSCs and RPIs (approximately $780,000 per year). (This recommendation does not affect experiments with video data embedded in the experiment data stream.) Any experiments needing ISS video in their operations should be evaluated on a case-by-case basis, and less expensive means of video transmission sought. For example, NASA TV has been used in the past for this purpose.

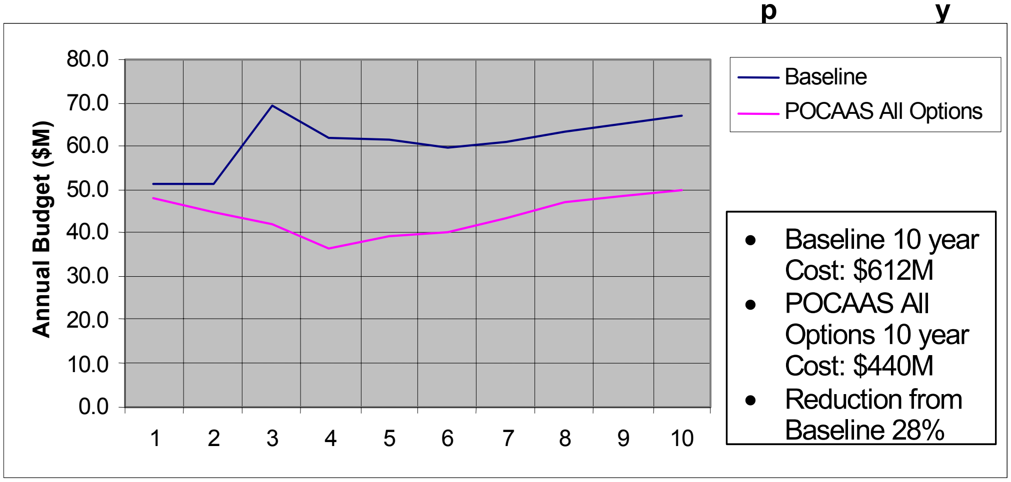
Recommendation. Defer the requirement for an increase in the current 50Mb/sec KuBand communications rate until a justified payload requirement is defined, which would remove $24.9 million from the FY 2004–2006 budget. Evaluate alternative implementation alternatives that are available at less cost to meet any defined requirement.

ES-6.5. The POCAAS options identified above result in a 28 to 32 percent reduction in the FY 2002–2011 payload operations costs.

Exhibit ES-5 illustrates the cost reduction over time. The options included assume an integrated ISS Program reduction in requirements and documentation imposed on payload integration and operation. The cost shown includes all payload operations budget items (POIF, POIC, PTC, TSCs, NISN, and PPS) and all POCAAS-recommended options.

Exhibit ES-5. Baseline Architecture Cost Option Summary

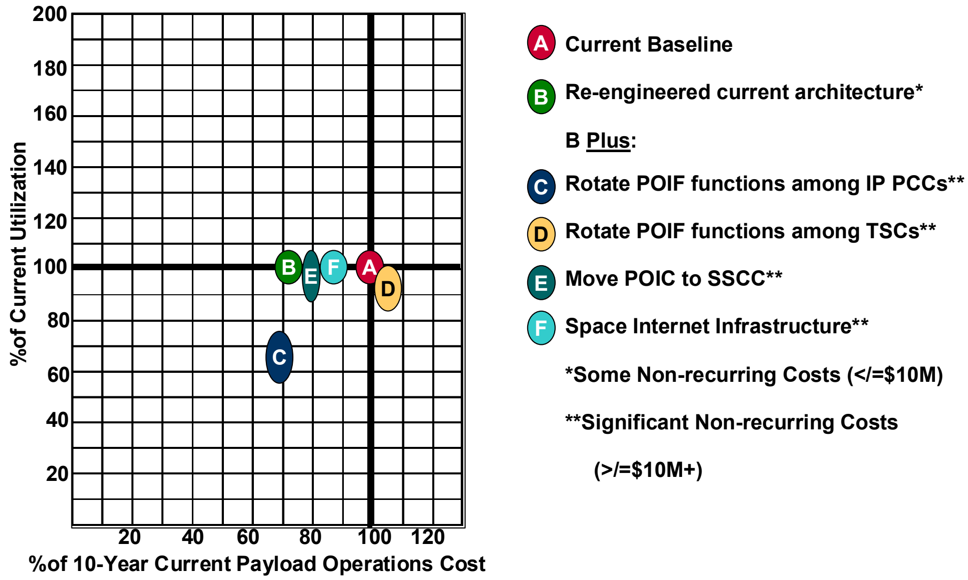
p y



ES-7. The Study Team considered a variety of alternative payload operations architectures, and evaluated six alternatives that encompass other variants.

A notional evaluation of the 10-year cost and research resource utilization of the six architecture alternatives considered is shown in Exhibit ES-6. Other evaluation factors were also separately considered.

Exhibit ES-6. Notational Research/Cost Evaluation of Alternative Architectures



The Study Team found that while the current architecture is sound, reengineering requirements, processes, and functions, as described previously in Section ES-6, can significantly reduce cost.

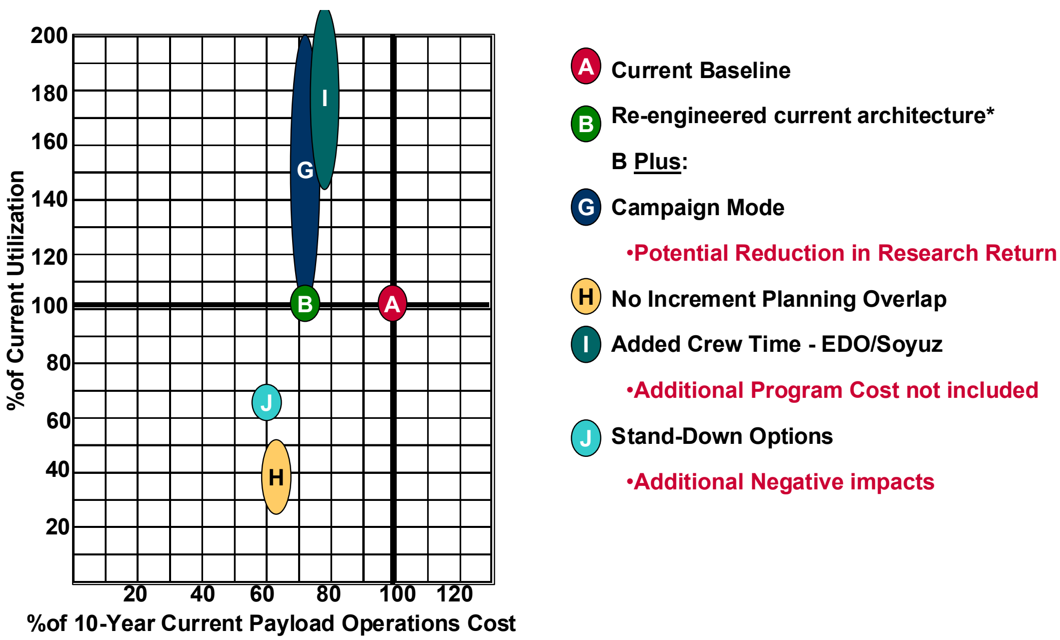
The alternative architectures studied have higher recurring costs than the reengineered current architecture, and each alternative has additional operating disadvantages. The alternative architectures have large nonrecurring costs associated with their implementation. None of the alternatives was found to have a strong technical advantage over the current architecture.

Recommendation. Reengineer the current payload operations architecture. The Study Team recommends against the alternate architectures studied.

ES-8. The Study Team evaluated a variety of alternate mission concepts and recommends two for consideration.

A notional evaluation of the 10-year cost and research resource utilization of the six mission concept alternatives considered is shown in Exhibit ES-7. Other evaluation factors were considered separately.

Exhibit ES-7. Notational Research/Cost Evaluation of Alternative Mission Concepts



In the campaign mode, the analysis assumed that one discipline was given overriding priority in assignment of resources available to payloads during an increment. Resources available in excess of the discipline requirements were then allocated to other disciplines. Each of the three major discipline areas (life sciences, microgravity sciences, and commercial applications) was given priority on an increment, in sequence.

Use of the full campaign mode increases overall resource utilization but has potential negative effects on research requiring frequent and continuing access to ISS. This situation occurs because only limited or no resources are available to the nonpriority disciplines on two of three increments.

However, the analysis suggests that partial campaign mode strategies, in which resource priorities are set over shorter time periods than an increment, or the priority discipline is given less than total priority, offer increased resource utilization while avoiding the negative effects on research.

Recommendation. The program should continue to evaluate campaign mode variants to maximize research achievements.

The Study Team believes that increased crew time for payloads is essential to realizing the research objectives of the ISS. Access of career researchers to ISS, either as part of the career astronaut corps or as payload specialists from the research community, is also essential to realizing the research objectives of the ISS.

Recommendation. The ISS Program should pursue increased research crew time, including extended duration orbiter (EDO)/Soyuz options, as possible within funding constraints.

ES-9. Recommended Summary Action Plan

1. Establish a standing ISS Program Research Operations Council, comprising experienced NASA researchers and senior NASA managers, with authority to oversee efforts to enhance research operations and reduce cost.
2. Formulate and annunciate a Program policy directed toward increasing flexibility in requirements, standards, and processes, with the goal of enhancing research, reducing cost of integration and operations associated with research, and increasing customer (i.e., researcher) satisfaction.
3. Develop a plan for evolution of research operations, and establish accountability for the accomplishment of the plan.
4. Conduct an audit of payload integration and operations requirements, with participation of experienced researchers.
5. Review information exchange requirements among researchers and Program elements, with a focus on eliminating duplication of inputs, reducing workload, and fostering communications.
6. Review payload integration and operations processes with the objective of simplification and workload reduction.
7. Move toward the concept of continuous operations.

Section 1. Introduction

1.1 Study Background

To understand the objectives and the results of the Payload Operations Concepts and Architecture Assessment Study (POCAAS), some background on the International Space Station (ISS) Program in general and ISS payload operations in particular is needed.

1.1.1 International Space Station Program

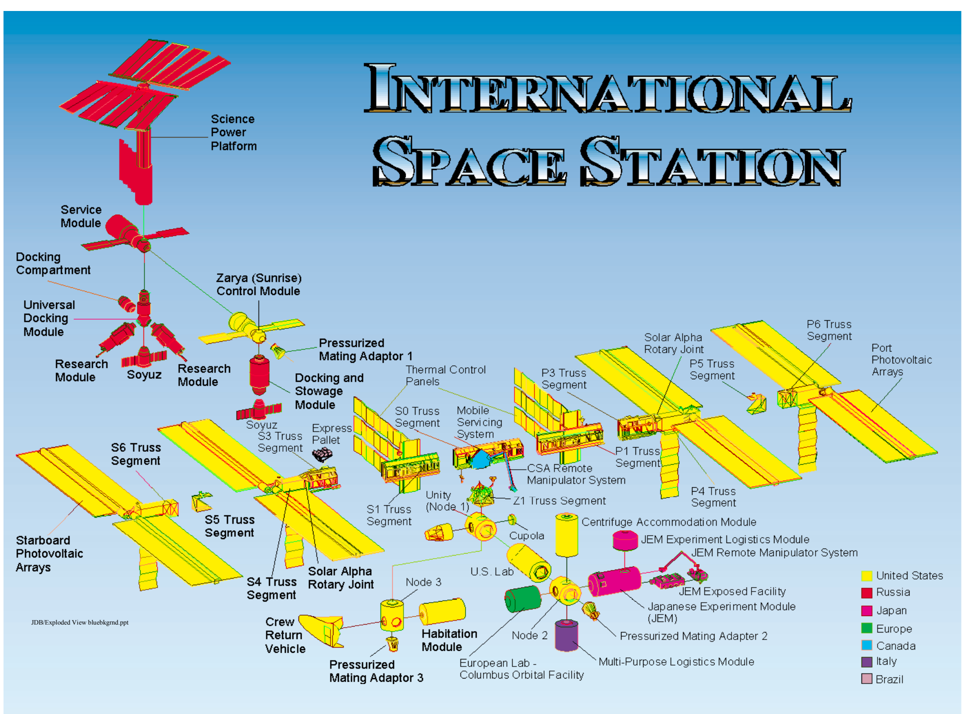
The ISS is intended to provide a quantum leap in the world's ability to conduct research on orbit. It serves as a laboratory for exploring basic research questions in commercial, science, and engineering research disciplines and is a testbed and springboard for exploration.

Key features of the ISS Program that affect payload operations include the ISS configuration, the international partnerships (IPs), and the ISS research objectives and allocations.

1.1.1.2 ISS Configuration and Operations

The ISS, when fully assembled, will consist of pressurized elements provided by the U.S., the European Space Agency (ESA), the National Space Development Agency of Japan (NASDA), and Russia, as well as other elements mounted on an external truss structure. Exhibit 1-1 illustrates the ISS intended configuration.

Exhibit 1-1. Expanded View of ISS Elements Color Coded by Provider



The truss structure supports solar arrays for power, cooling arrays for thermal control, payloads mounted on pallets, and antennas for communications with the Tracking and Data Relay Satellite System (TDRSS). When completed, the ISS will house seven crew members from different nations in a habitation and laboratory complex with a mass of more than 450,000 kilograms (1 million pounds) and a volume of 1,220 cubic meters (43,000 cubic feet) at sea-level atmospheric pressure.

The initial configuration provides living accommodations for three crew-persons, and a Soyuz capsule for emergency escape to Earth. The plan is to add living accommodations for an additional three or four crew-persons (total of six or seven) and to provide a crew rescue vehicle (CRV) capable of carrying the maximum crew back to Earth.

The number and complexity of the ISS systems require a significant amount of crew time for maintenance and operation, independent of any payload (research) operations.

Because the ISS is a manned space habitat, its operation involves significant logistics activities. These activities include transport of crew, experiments, and supplies to and from the ISS. Transport is provided by periodic launches of the Space Shuttle, by Russian manned and unmanned vehicles, and eventually by unmanned ESA and NASDA vehicles.

ISS operations are planned against increments and missions. An increments is the period of time that one specific crew complement remains on the ISS. Although originally planned to be 3 months long, increments are currently about 5 months long, and 6-month increments are being discussed. Missions are the activities associated with a particular transport launch to the ISS. Payload equipment delivery and return are keyed to missions.

1.1.1.3 International Partners

The ISS is truly an international endeavor. Although the U.S. has led ISS development, seven countries have contributed to its development. Each partner's responsibilities and rights are spelled out through a multilateral International Government Agreement and through bilateral Memoranda of Understanding (MOUs), which have the binding effect of contracts among the sponsor countries.

Among the rights allocated to each partner is a share in the research to be conducted on the ISS within the U.S, ESA, and NASDA elements. Each partner's share is characterized by a portion of the ISS resources that are available for research (e.g., volume, mass, power, cooling, and data).

Russia does not share within the U.S., ESA, and NASDA elements, but has full rights to conduct research within the elements that it provides.

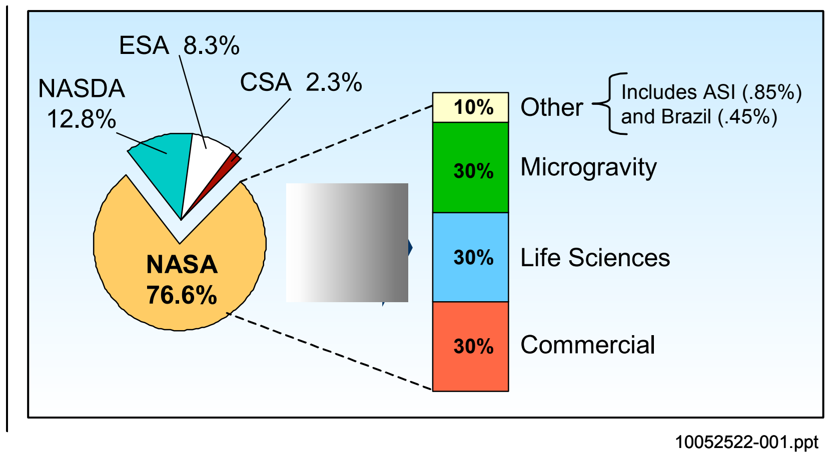
1.1.1.4 ISS Research

The ISS has already begun to fulfill its role as the premier world-class research facility in space. Experiments have been and are currently being supported. As it reaches its full potential, the ISS will support research in the areas of science, technology, and commercial endeavor that can benefit from a continuous microgravity, vacuum, and low-Earth-orbit environment.

Under the MOUs, the basic U.S. and IP research allocations are as shown in Exhibit 1-2. These allocations are further subject to various barter agreements among the partners. Additionally, the Space Station Utilization Board has established that the U.S. pressurized allocations within the pressurized modules will be suballocated as shown in Exhibit 1-1. These allocations are intended to be achieved over a reasonable period of time—not on a day-by-day, or even increment-by-increment basis.

Payload operations on the ISS were begun with Increment 0 in September 2000; three experiments were conducted during that increment. Payload operations are continuing in parallel with ongoing ISS assembly operations, although limited to the amount of ISS resources (crew time, upmass, power, etc.) available after ISS assembly and maintenance activities are scheduled.

Exhibit 1-2. Pressurized Resource Allocation



The maximum utilization of the research potential of the ISS will be a function of how well the ISS capabilities (and the access to those capabilities) serve the research and commercial communities. Critical aspects of research accommodation are the process complexities and costs involved in conducting experimentation on ISS, and the user-friendliness or transparency and affordability of the processes. This study was initiated to address those issues as related to the payload operations segments of the overall payload integration and execution process.

1.1.2 ISS Program Status and Issues Affecting the Study

In the Spring of 2001, NASA (together with the new U.S. Administration) began to address significant budget problems associated with the ISS. NASA chartered the ISS Management and Cost Evaluation (IMCE) Task Force to address the completion of the ISS assembly within terms of reference established jointly by NASA and the Office of Management and Budget (OMB). The IMCE Task Force Report (from NASA Website) reaffirmed that the fundamental purposes of the ISS remain…

> …scientific research and international cooperation. Specific objectives are:
>
> To provide the means to sustain humans during extended space flight. This will require a primary research focus on discovering any adverse effects of long-term human presence in space.
> Perform "world-class" scientific research that requires low gravity and is enhanced by astronaut interaction.
> Enhance international cooperation and U.S. leadership through international development and operations of ISS.

However, an OMB action to contain the ISS Program overrun reduced the ISS research budget from $500 million to $300 million. As part of the effort to achieve the ISS research objectives within budget constraints, NASA issued the RFP for the POCAAS study in September 2001.

The following ISS Program issues are associated with the budget overrun and affect payload operations:

- Availability and timing of ISS capability to increase the crew size from three to six
- Potential violation of the IP MOUs, and the effect of violation on ISS assembly schedule and operations
- Timing and configuration of core assembly complete
- Number of U.S. payloads supported by ISS resources and by the research budget
- Number of Space Shuttle launches per year, and its effect on payload manifesting
- Duration of increments and the frequency of missions

1.1.3 Payload Operations

Payload operations are defined as the activities necessary during real-time operations to support both researchers and the ISS crew in performing research onboard the ISS and the preparation activities necessary to accomplish real-time operations. They include the personnel and information technology infrastructure necessary to define and schedule operations to be performed; train the crew; operate ISS equipment supporting the experiments; support the crew on-orbit; command experiments from the ground; and achieve data and sample return to Earth. More definitive definition is provided in Section 3 of this report.

Payload operations are distinct from other program functions necessary to enable research onboard the ISS. Other payload-related program functions include the following:

- Designing and developing both experiment equipment and the supporting flight systems to perform research.
- Manifesting payload equipment and samples on transport vehicles to and from the ISS. Payload manifesting is constrained by available transport space and mass, after transport of supplies necessary for assembly and sustainment of the ISS and its crew.
- Performing analytical integration to determine the compatibility of payload design with ISS and its transport systems. Analytical integration is performed through a variety of engineering analyses.
- Conducting physical integration of experiment flight equipment and supporting equipment with their transport carriers.
- Managing the safety review process to ensure that experiment flight hardware does not cause any hazard to the ISS, its transport vehicles, and personnel or to ensure any potential hazards are safely controlled.

1.2 Objectives and Approach for the Study

The objectives of the study are summarized in below and defined more completely in the Statement of Work (SOW) (see Appendix A):

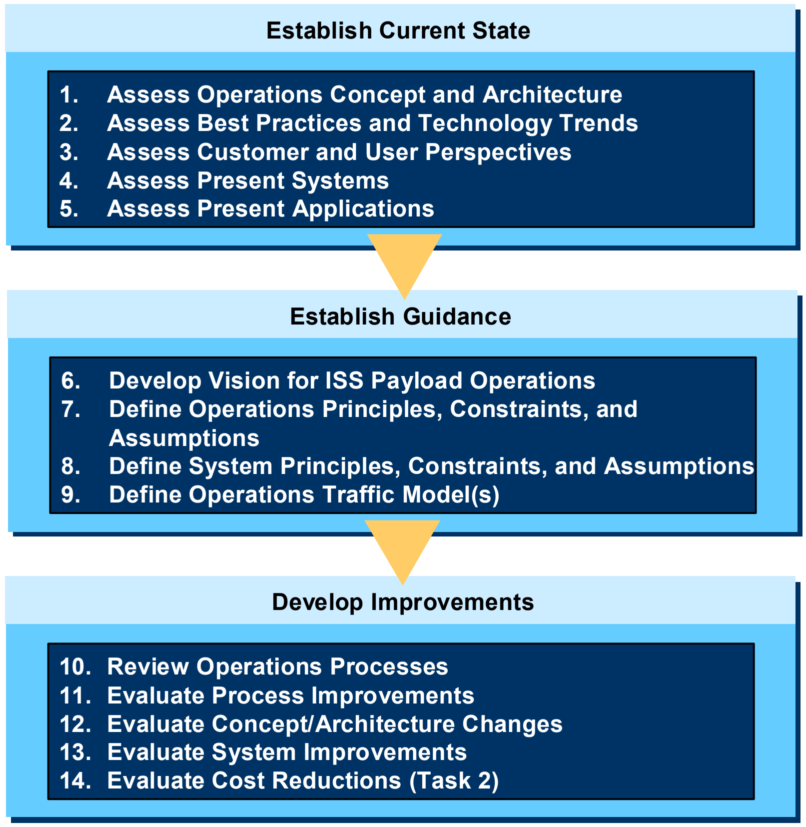
- **Task 1.** The contractor will assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements.
- **Task 2.** The contractor will recommend the potential for time-phased reductions in the cost of payload operations through the following approaches:
  - Efficiency improvements to existing systems
  - Interim or permanent changes to existing requirements on systems
  - Changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations.

Study guidance received from NASA place emphasis on changes to operations concepts that would result in significant simplification and cost reduction, as opposed to a detailed audit of current operations procedures. NASA guidance also directed that the study effort be confined to payload operations, although it was recognized that other program elements (e.g., manifesting, analytical integration) that strongly interact with payload operations are of equal importance to research success and cost.

The Study Team adhered to the objectives and guidance, but with the cognizance that the final success of the ISS lies in the research that it enables. Therefore, the Team has also given attention in the study to the need for payload operations to support effective research and to pursue the goal of making research onboard the ISS easier and more effective from the researcher's perspective, as well as making the payload operations for that research less expensive.

With these objectives in mind, the Study Team followed an adaptation of Computer Science Corporation's (CSC's) Business Area Architecture Methodology (Exhibit 1-3) to conduct the study.

Exhibit 1-3. Business Area Architecture Process



10052522-003.ppt

Based on the Team's understanding of the ISS Program objectives, the Team formulated its Payload operations vision and principles, which are presented in Section 2 of this report. Section 2 also includes an assessment of current ISS practices from a researcher's perspective, based both on the experience of Team members and a survey of other current ISS researchers. The researchers' assessment identifies issues with current ISS Program practices, not limited to payload operations, that need to be addressed. As such, the Study Team has attempted to address these issues, as they pertain to payload operations, in these recommendations.

In understanding current ISS payload operations, the Study Team established with the ISS Program Office a budgetary, mission, and current operations architecture baseline for the study. Because the program is currently in a state of flux pending resolution of larger budget issues, the baseline established for the study was essential to the quantification of cost results. While the qualitative findings of the Study Team are largely independent of the baseline, cost is a function of the specific mission requirements imposed upon payload operations. The program baseline is presented in Section 3.

Section 4 presents the Study Team's analysis of the current payload operations architecture against the vision and the mission requirements. Each element of the current architecture is described and analyzed, and findings are presented, which include observations, cost options, and recommendations.

Section 5 presents alternative payload operations architectures and mission concepts that might be used for ISS payload operations.

Section 6 specifically addresses the SOW requirement for recommended interim and permanent changes to current NASA user development requirements. These are actions that research teams might take to reduce payload operations costs.

Section 7 responds specifically to the SOW requirement for recommendations on changes to the ISS concept of operations, which take full advantage of the continuous operations environment afforded by the ISS. This section delineates operational characteristics of the ISS as opposed to other programs and addresses how those characteristics affect operations. The findings in this discussion have been incorporated into Sections 4 and 5, but are focused in Section 7 on the perspective of the continuous operations environment provided by long-term manned operations in space.

Section 2. Payload Operations Vision and Principles

This Section discusses the Study Team's vision for ISS payload operations, first-principles guiding the implementation of the vision, and other basic payload operations concepts. Also included is an assessment of current ISS practices from a researcher's perspective, based both on the experience of Team members and a survey of other current ISS researchers. Their assessment identifies issues with current ISS Program practices, not limited to payload operations, that need to be addressed. The Study Team has attempted to address these issues, as they pertain to payload operations, in the recommendations of the study.

2.1 Payload Operations Vision

The Team's vision of ISS payload operations is as follows:

- To facilitate the pursuit of flight research and make the complex operating environment associated with the ISS transparent to the end-user
- To make the researcher fully responsible for the success of his/her experiment, and to enable the researcher to interact with his/her experiment apparatus, as nearly as possible, in the same way he/she would interact in a remote Earth laboratory.
- To provide the integrated operations services necessary to facilitate the researcher's conduct of science at the minimum possible cost, consistent with the objectives of maintaining crew and ISS safety, and protecting each payload from damage or interference from other payloads.

2.2 Payload Operations Principles

The fundamental principle for research operations is that the PIs, supported by their scientific and payload developer teams, are responsible for conducting and executing experiment operations, insofar as possible. The PI may delegate certain functions to the flight crew, or to other payload operations personnel, who may be required to exercise judgment in execution of their defined functions. However, both the crew and ground operations personnel are obligated to operate within guidelines, procedures, and training provided by the PI.

With this fundamental principle in mind, payload operations staff and infrastructure exist to

- Provide an operations environment where the researcher can achieve mission success.
- While
  - Ensuring the safety of crew and ISS
  - Avoiding damage to one payload as a result of operation of another
  - Avoiding interference among operation of experiments
  - Satisfying programmatic requirements, including international agreements on resource distribution

- Operate Payload Support Systems (PLSS) and Laboratory Support Equipment.
- Support the Flight Crew, both in operations of payloads and PLSS.

The term *PLSS* is used here to include a variety of supporting equipment, including such items as payload racks and their power, cooling, and data subsystems; payload facility equipment; and payload subsystems for acquiring, transmitting, and distributing data. A more complete definition of PLSS equipment is provided in Section 3, as part of the mission requirements.

2.3 Payload Operations Concepts

2.3.1 ISS as a Research Facility

ISS payload operations processes and systems should be designed first and foremost to support the use of the ISS as a research facility.

The Study Team believes that world-class research demands that payloads be flown with a minimum of delay and a freedom to try new ideas and approaches.

The Study Team recognizes that a new program such as ISS should begin with proven concepts and experience, and ISS payload operations were built on the experience gained from the Skylab, Space Shuttle, Spacelab, and MIR programs. However, the ISS environment is different in many ways from that of previous programs, and better ways of operating that are adapted to the ISS environment must be developed to achieve the vision.

Also, many flight and ground systems were designed and baselined 6 to 7 years ago. The ISS Program must include the capability to update these designs over time, so as to take advantage of new technology that will enable world-class research.

In reviewing current operations processes, the Team reached the conclusion that present processes are too lengthy, costly, and overly constraining for scientific purposes. Ralph Larsen, Chief Executive Officer of Johnson and Johnson (a leading pharmaceutical company), recently said “Bureaucracy is the enemy of research.” The Study Team believes that the ISS Program must streamline its processes to enable the vision.

2.3.2 Payload Operations as One Component

Payload operations is only one of many components necessary to enable world-class research onboard the ISS.

While the scope of POCAAS is limited to an analysis of payload operations, the POCAAS Team recognizes that payload operations alone cannot achieve the vision of the ISS as a research laboratory. While payload operations must be streamlined to facilitate research, those operations must be streamlined in consonance with the streamlining of other ISS Program activities.

2.3.3 Dynamic Change as a Way of Life

ISS payload operations should adopt dynamic change as a way of life. The dynamic change taking place in science and technology dictates that ISS payload operations should be under continuing review for new and better ways to do business.

The changing needs of the research community should be continually sought and incorporated as practical into ISS payload operations. World-class research in the year 2010 will not be conducted as it was in 1990, nor as it is in 2002.

For example, the Study Team believes that new commercial standard communications technology should continue to be introduced into the ISS Program over time, to facilitate a more transparent interface between scientific investigators on the ground and their experiments in space. ISS payload operations is a pioneer in the application of Internet technology to facilitate distributed payload operations. This initiative should be continued so as to take advantage of increasing Internet capabilities and should be extended to the space segment of communications. (This topic is discussed further in Section 5.1., Option.)

2.3.4 Recommendation for Research Operations Panel

The Study Team recommends that NASA should establish a broad-based research panel, or other means, to identify operational needs and concepts that will facilitate world-class research. This mechanism should perform on a continuing basis, as the ISS itself, the ISS research program, and technology evolve.

This study was focused by our SOW on the NASA payload operations activities and costs necessary to support ISS science operations during the assembly and early operations years. However, a long-term perspective is also needed to guide the evolution of processes and systems. This perspective should be established in conjunction with the definition of the ISS Research Program, as called for the IMCE Report.

2.4 Current Researcher Issues: The Reality of Current ISS Practices

The active researchers on the POCAAS Team identified a number of key issues that they believe are causing unnecessary cost for ISS research and are inhibiting researchers who would potentially use the ISS as a research facility:

- Current ISS payload practices (not confined to payload operations) are resulting in a documentation burden on the PIs that is significantly greater than for Spacelab or other past human space missions
- The ISS Payload Data Library (PDL) requires excessive researcher effort to maintain and is not always used by the NASA payload operations personnel
- ISS payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree
- ISS payload operations planning and execution practices are overly formalized with multiple approval levels
- Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily

2.4.1 Researcher Issue Validation Survey

To validate these issues in the larger community of ISS researchers, the Study Team sent a brief questionnaire to test the validity of these issues. The questionnaire was sent by email to all 61 PIs and PDs currently participating in the ISS Program through Increment 6. A copy of the questionnaire and the list of addressees are provided in Appendix C.

The questionnaire requested the respondents to indicate their disagreement or agreement with the key issues listed above, according to the following scale:

0 = Insufficient direct knowledge or experience on which to base a response

1 = Strongly Disagree

2 = Somewhat Disagree

3 = Somewhat Agree

4 = Strongly Agree

The scale was developed to provide a forced-choice response set, while allowing for the possibility that the respondent might judge they had insufficient knowledge to respond to a particular question. Respondents were additionally invited to provide comments or recommendations for each issue and were assured that their responses would be kept confidential as to source.

Prior to sending out the questionnaire and in some of the responses, the Study Team recognized that the issues were negatively cast. As such, the Team considered alternate approaches. However, the purpose of the questionnaire was to validate or invalidate the issues previously identified within the Study Team, and the Team chose not to create a more general survey. Therefore, in the background and instructions section of the questionnaire, we acknowledged the negative wording, called it to the attention of the respondents, and asked them not to be influenced by the formulation of the questions.

Dr. John-David Bartoe, NASA ISS Research Manager, served as the named point of contact. The questionnaires were sent in his name and responses were returned to him.

2.4.2 Survey Response

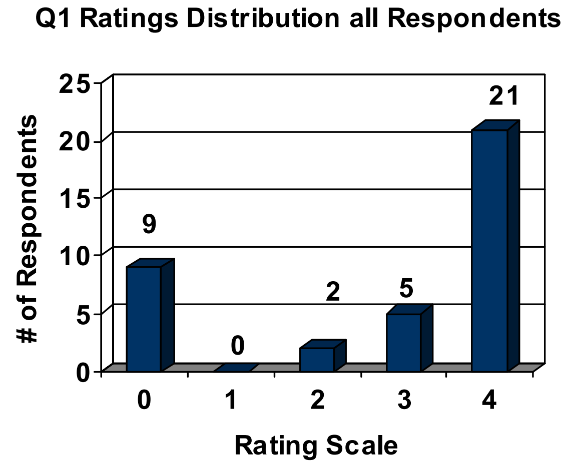
Thirty-seven responses were received from 18 PIs, 11 PDs, and 8 who were both PIs and PDs; the response rate of 61 percent (37 of 61) was better than expected for surveys of this type. The principle conclusion was that the ISS researcher community validated all five issues. The overall rating of agreement for the entire set of issues was 3.4, well exceeding the rating of 3 (somewhat agree), and each individual issue comfortably sustained an average rating on the "agree" side of the scale. The average range of agreement per question was from a low of 3.3 to a high of 3.7.

In addition to the scores, the high volume (96) and intensity of the voluntary written comments confirmed the key issues identified by the Study Team.

The scoring for each individual issue is summarized below together with a few sample comments. A detailed statistical analysis of the responses is given in Appendix C. A complete listing of comments is also provided in Appendix C. Because of the design characteristics of the survey, the results should be considered as indicative of trends and "pointers" to areas and topics requiring further explanation and clarification.

Question/Issue 1: Current ISS payload practices (not confined to payload operations) are resulting in a documentation burden on the Principle Investigators that is significantly greater than for Spacelab or other past human space missions.

The mean score was 3.7, indicating a strong level of agreement among the respondents. Some written comments were as follows:

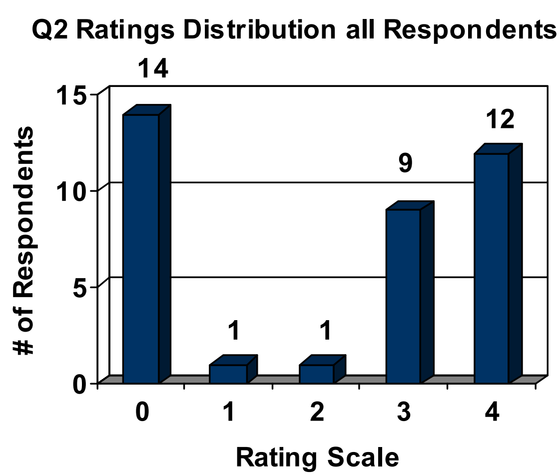


- "Compared with Shuttle/MIR the computer software design process, training approval process, differing standards at JSC and MSFC, competing committee structures, changing requirements…are more cumbersome and frustrating."
- "Major factor regarding burden is that NASA does not have a coordinator and there are a hundred people asking for information …."
- "…it is also significantly greater than for middeck payload….ISS….requirements can be trimmed."
- "I have been developing and successfully flying experiments since 1974 and have never seen it this bad or as confusing as it is…We should do business the way SpaceHab does…get the job done, with competent people and good help instead of endless process, unreasonable attitudes, and chaos…it now takes 2.6 times more support personnel and cost to REFLY a payload on ISS-EXPRESS Rack than it cost to develop the original payload and fly it on Shuttle or Spacelab.."

Question/Issue 2: The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA payload operations personnel.

The mean score was 3.4, indicating a high level of agreement among the respondents. The significant factor in the responses to this question was the higher number of 0 scores, indicating that the survey respondents had less direct involvement with PDL than with the other questions.

Some comments were as follows:



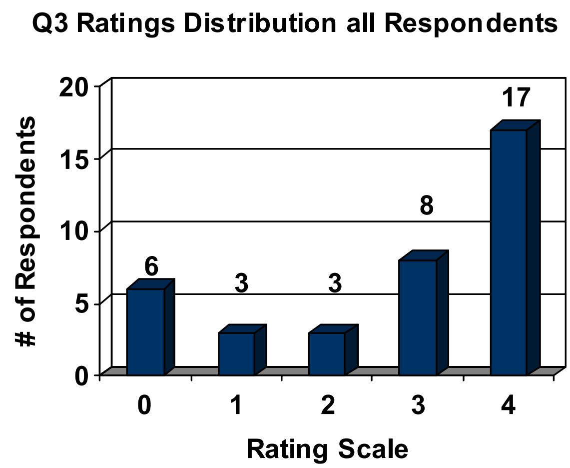
- "By the time one understands how PDL works and where the information is, the hardware is back from the mission."
- "PDL should be modified to be user friendly to the PD…PD should not have to enter the same information two times…concept is good, implementation of PD side fails…"

- "PDL is well organized….excessive effort is caused by the organization of PDL data by flight or increment…since many payloads will operate over several flights organize PDL forms so that launch and return flights are identified and all on-orbit data entered once…"
- "True, most of the time the payload operations personnel say they still require separate paper copies of procedures, CoCs, drawings, etc….be submitted directly to them…"
- "Dealing with the PDL is a nasty experience. This database is poorly suited to life sciences research…."

Question/Issue 3: ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree.

The mean score was 3.3, with some of the following comments:

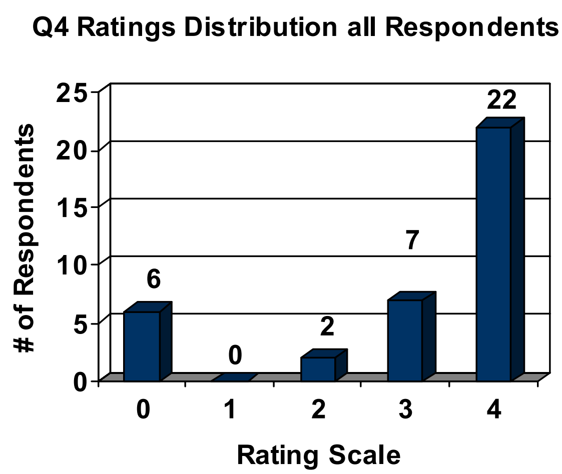
- "The problem is not really adherence. The contents of the standards and programmatic requirements are not focused on the needs of the investigators. The problem pervades the whole program."
- "…for pre-flight operations this is true…..support from POIC cadre for on-orbit testing has been excellent and accommodating…"
- "…process seems to require "simple to operate" experiments to conform to integration processes that may be appropriate for complex, interactive experiments…perhaps one size does not fit all…"
- "This is especially difficult when IDD and reporting requirements are constantly changing…change the payload operations philosophy that if a payload has been flown before it makes no difference…therefore it must be redesigned, rebuilt, etc…."



Question/Issue 4: ISS Payload operations planning and execution practices are overly formalized with multiple approval levels.

The mean score was 3.6, with some of the following comments:

- "Currently Operations Change Request must be submitted before discussions with flight controller…discussion before submission would ease the process…"
- "ISS should be used as a research lab…PDs should have access to people doing the work…crew should not be inaccessible…"

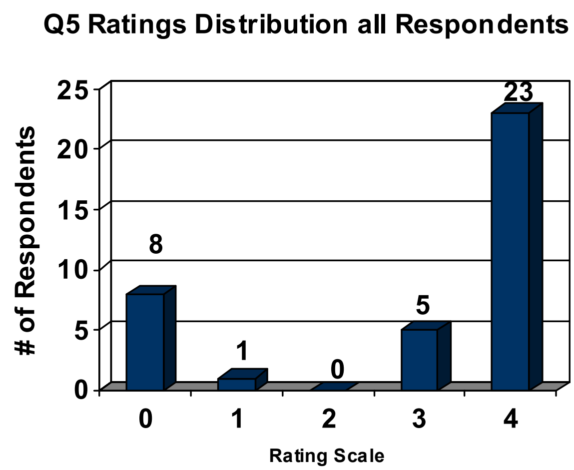


- "….pre-flight planning is overly formalized and rigid, short-term and real-time re-planning that occurs daily is very flexible…"
- "True, the way it is handled now is endless chaos…eliminate endless telecons and practice sessions prior to required program reviews…"
- "Many operations practices are a hindrance to actually getting the work accomplished in a timely fashion…"
- "When the PD submits an OCR via PIMS, the reviewers sometimes review and comment on the entire procedure instead of the documented changes…the PD has to defend a position that has already been approved/decided upon…"

Question/Issue 5: Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily

The mean score was 3.7, with some of the following comments:

- "Payload operations process and reviewing of procedures needs to be standardized…there were five reviews of experiment procedures…changes were due to differing standards."
- "There seem to be too many people involved in the 'paper work' aspect of ISS ops…Direct contact between the science team and crew is too limited."
- "This is definitely true although it has been improving some. There is still inconsistency in interpretation based on the individual doing the evaluation of a product, but the range of inconsistency has been narrowing…"
- "Not only multiple changes in interpretations, but the fact that different members of the payload staff had differing opinions as to what the requirements really meant."



- "Procedures regarding displays are hard to develop due to changes by the PDRP…procedures without displays are simpler to write…"
- "Changes in interpretation of procedure requirements occur often and seem unnecessary…overall procedure seems to complex…goes through too many channels…"
- "Some requirements have no value-added. Procedures go through too many hands and the PDs may not see the final product unless they ask…The process for submitting and revising procedures to the program is way too complex…"

2.4.3 Respondent Characteristics

The number of respondents distributed across RPO and Headquarters organizations is shown in Exhibit 2-1:

Exhibit 2-1. Distribution of POCASS Researcher Questionnaire Respondents by Codes

Position	Summary	RPO					Headquarters Code				
		FB	HLS	MRPO	OSF		M	UB	UF	UG*	UM*
PI	18	3	7	7	1		1	8	2	6	2
PD	11	1	0	5	5		5	0	1	3	2
Both	8	0	1	3	4		4	1	0	2	1
Total	37	4	8	15	10		10	9	3	11	5
*One PI worked with both code UG and UM											

At the time the questionnaire was sent out, Increment 4 was flying on the ISS. The following results represent the ISS-flight/increment-related experience of the 37 respondents:

- 23 had payloads flying during Increment 4
- 7 were flying a payload on ISS for the first time during Increment 4
- 19 had flown more than increment by Increment 4
- 6 will fly their first ISS payload on Increment 5 or 6
- 24 had flown payloads on at least one increment prior to Increment 4
- 22 will have flown multiple increments by Increment 6

Exhibit 2-2 indicates the substantive comment volume by question by researcher group. The greatest number of comments (47) came from payload developers who suggested they have more direct contact with the NASA payloads processes than the PIs might have, particularly some of those who are in the life sciences research discipline and who indicated that they are somewhat more "shielded" from these processes. The five additional PD inputs were received from PD associates who were not directly solicited in the survey.

Exhibit 2-2. Number of Substantive Comments Provided by Questions by Researcher Group

Researcher Group with Total number of respondents indicated in Parentheses	Question 1 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the Principal Investigators that is significantly greater than for Spacelab or other past human space missions.	Question 2 2. The ISS Payload Data Library requires excessive Researcher effort to maintain and is not always used by the NASA Payload Operations personnel	Question 3 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to an unnecessary degree	Question 4 4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels	Question 5 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily	Total Number of Comments by Group
PI (18)	5	5	5	5	7	27
PD (11 + 5 Additional Inputs)	10	10	9	9	9	47
Both PI//PD (8)	5	4	4	4	5	22
Column Totals	20	19	18	18	21	96

2.4.4 Examples of Researcher Experiences

To further expand on the issues identified from the researcher's perspective, examples were collected for three ISS payloads:

- Protein crystal growth
- Inorganic crystal growth
- Micro-encapsulation of drugs

Researchers on the Study Team have already flown these three payloads on the ISS. The payloads first flew on Shuttle missions and were modified or redesigned for ISS.

The examples provided encompass both payload operations and payload integration; both sets of examples are provided to illustrate the pattern of issues the Team believes is currently endemic to the ISS Program. The examples are summarized below in Exhibits 2-3 and 2-4. More details on the examples are provided in Appendix D.

2.4.5 ISS Payload Integration Process Improvements

The POCAAS Team applauds the accomplishments of the Program Office initiative to improve payload integration processes. The briefing by Jim Scheib to the ISS Independent Implementation Review on October 10, 2001, identified a number of improvements that were accomplished and an ongoing process for continuous improvement. The improvements achieved include the following:

- Comparison of ISS and Shuttle processes to consolidate practices
- Shortened payload engineering integration process

Exhibit 2-3. Payload Operations Examples

Example	Issue
Crew procedures	Reflight MEPS payload from Shuttle. Two-page procedure required 8 months and 77 revisions for ISS.
Crew training certification	PIs with multiple flight experience on Shuttle required to take training course for certification to train crew
PDRP authorization letter required to fly payload	Authorization letter required from PDRP testifying to experiment operability prior to flight
PDRP process	Longer and more expensive than necessary
Multiple inputs of identical information	Data must be re-entered into PDL for each payload, for each increment, and for each flight. Re-entered when hardware is moved
Non-use of PDL	During ZCG-FU turnover at KSC, Stowage had out-of-date drawing. Correct drawing was in PDL. PD required to resubmit separate copy.
Crew procedure change	Procedures conforming to standards get change requests from different crews; e.g., “check-mark” vs. “verify” use
Procedure commonality between ISS and SSP	ISS does not recognize existing SSP accepted procedures but requires new “usability certification”
Procedure delivery date	Requirement to submit final procedures for a reflight experiment at I-7 results in costly change process
Procedure configuration control for onboard experiments	No clear process for configuration control of experiment procedures onboard

Exhibit 2-4. Payload Integration Examples

Example	Issue
Electrical bonding of payload structures	Bonding certification requires two documents. Recertification is required again for experiment remaining onboard thru next increment
Label standard	Requirement to redo faceplate because of square versus rounded corners on lines grouping switches
Payload faceplate color	Shuttle reflight payload requires rework to change face plate color
Resubmittal of PIRNs and COFRs	PDs required to resubmit PIRN and COFR for every flight, even if remaining on-orbit
Microgravity testing of ZCG-FU hardware	$20,000+ spent accomplishing tests rather than accept engineering evaluation
Acoustics verification	Acoustic limits are unrealistic
Safety data packages	Ground and Flight Safety Data Packages contain much the same information, but require separate documentation and review processes
Document change review	PD teams required to review and comment to PIRNs, CRs, facility documentation, unbaselined documents, coordination copies, draft issues, initial release, and white papers
Program requirements on payloads document	Serious cost impact to all existing hardware and will impact costing of new hardware; doubles cost of payload development
Drawing requirements	Engineering drawing required for every item onboard ISS (e.g., standard K-Mart videotape cassette)

- “Fenced Resources” to enhance payload manifest stability
- Allocation of payload crew time as part of “Fenced Resources”
- Steps to consolidate review of procedures, displays, and planning data
- Creation of a streamlined integration process for “Small Pressurized Payloads”

While the Study Team recognizes the accomplishments already achieved, the obvious patterns of response in both the Researcher Issues Survey (Section 2.4.1) and the Examples (Section 2.4.3) are indicative of both dissatisfaction in the research community and unnecessary labor cost within the ISS Program. The patterns also indicate that issues exist in both payload operations and the broader payload integration, and that improvements must be sought by reengineering of payload integration, including but not limited to payload operations.

Recommendation. The current continuous improvement approach should be extended to focus on reduction of requirements and processes that are burdensome to the researchers, and to examine reengineering alternatives as well as continuous improvement. Reduction in requirements and streamlining of processes will reduce both payload operations and payload integration costs.

2.5 Observation: ISS Need for Payload Advocacy

The researchers on the POCAAS Team identified, and the full Team endorsed, the observation that the role of the ISS lead payload operations organization is important as an advocate for science within the Program. The Team believes that the payload operations leadership must have the stature and independence to fulfill that role.

The Team also observed that the MSFC payload operations organization is effective in providing this leadership role. Their knowledge and experience in payload operations integration represents a unique resource to the program.

This observation is not intended to diminish the importance to the program of similar skills that exist in individual scientific discipline areas resident at other NASA Centers and in the Space Shuttle Program Office at JSC.

3. Payload Operations Baseline

To understand current ISS payload operations, the Study Team established with the ISS Program Office a budgetary, mission, and current operations architecture baseline for the Study. Because the Program is currently in a state of flux pending resolution of larger budgetary issues, the baseline established for the Study was essential to the quantification of cost results. While the qualitative findings of the Study Team are largely independent of the baseline, cost is a function of the specific mission requirements imposed upon payload operations. The Program baseline is presented in this Section.

3.1 Payload Operations Budget

The baseline budget is the FY2002 President's Budget Submission (PBS). The budget elements associated with payload operations are contained in the ISS Research Budget, shown in Exhibit 3-1.

Payload Operations budget elements, within the context of this study, are contained in both the Research Programs and Utilization Support categories of the budget. These elements are further broken out in Exhibit 3-2. An expansion of the Payload Integration and Utilization line item is shown in the upper section of Exhibit 3-2. The budgets for the several TSCs are excerpted from within the Research Programs category, and shown in the lower section of Exhibit 3-2.

In Exhibit 3-3, the specific line items defined as Payload Operations in the context of this study are shown. These items are excerpted from Exhibit 3-2 and summed. Each line item is identified and briefly described below, and each function is then further discussed in Section 3.3 of this report. The payload operations budget as shown in Exhibit 3-3 is used as the payload operations reference budget in the further cost analyses provided in the POCAAS.

- The **TSC** budget lines are for each of the TSCs located at the NASA Centers shown. The TSCs and their functions are described later in this section.
- The **NISN (SOMO)** line item is the budget for the payload operations communications services obtained from the NASA Integrated Services Network (NISN), which provides communications services across all of NASA.
- The **Enhanced Communications for Payloads** line provides for an enhancement of the ground systems that process the ISS KuBand data downlink, increasing the capability to distribute data from 50Mbs (current) to 150Mbs (the current capability of the air-to-ground transmission segment).
- The **P/L Training – TSC (PTC)** line item funds completion of the development of the Payload Training Complex (PTC), which is located at JSC and is used to train ISS flight crews to operate payloads. The Training Systems Contract is the development contract for the Space Station Training Facility (SSTF), including the PTC, and is phased out as development is completed.

Exhibit 3-1. ISS Research Budget (FY2002 PBS)

	SAT	UPN	FY02		FY03		FY04		FY05		FY06		Total FY02-06	
			Rephase		Rephase		Rephase		Rephase		Rephase		Rephase	
FY01 President's Budget				451.6		535.7		540.8		552.3		534.6		2615.0
Research budget reduction				-168.0		-188.5		-202.1		-205.2		-216.8		-980.5
Research program			8.112	283.6	0.523	347.2	0.303	338.7	1.030	347.1	0.530	317.8	10.498	1634.5
Reserves			8.112	19.261	0.523	44.934	0.303	25.067	1.030	40.222	0.530	36.871	10.498	166.355
Content			8.112	264.345	0.523	302.221	0.303	313.673	1.030	306.927	0.530	280.976	10.498	1468.141
RESEARCH PROGRAMS			**5.360**	**132.664**		**179.267**		**179.939**		**186.124**		**159.791**	**5.360**	**837.784**
Gravitational Biology & Ecology	200	393		30.000		35.100		34.600		24.101		26.301		150.102
Biomedical Research & Countermeasures	300	394		21.882		27.914		25.606		26.516		25.526		128.444
Microgravity Research	400	398	3.560	61.652		97.046		98.594		114.957		87.889	3.560	460.138
Space Product Development	500	493	1.800	15.735		15.761		17.960		17.960		17.960	1.800	85.375
Earth Observation Systems	600	495		3.395		3.446		3.179		2.590		1.115		13.725
UTILIZATION SUPPORT			**2.752**	**131.681**	**0.523**	**122.954**	**0.303**	**133.734**	**1.030**	**120.803**	**0.530**	**121.185**	**5.138**	**630.357**
Flight Multi-user Hardware & Support	700	496	2.340	49.331	0.520	46.404	0.300	40.398	1.030	35.556	0.530	35.529	4.720	207.218
Payload Integration & Operations	700	479	0.412	82.350	0.003	76.550	0.003	93.336		85.247		85.656	0.418	423.139

Exhibit 3-2. Expansion of Payload Integration and Operations Budget Line

	SAT	UPN			FY02		FY03		FY04		FY05		FY06		FY02-06	
479 PAYLOAD INTEGRATION AND OPERATONS					**0.412**	**82.350**	**0.003**	**76.550**	**0.003**	**93.336**		**85.247**		**85.656**	**0.418**	**423.139**
NA	700	479-20	JSC	PAYLOAD SAFETY REVIEW PANEL		0.945		0.945		0.945		0.945		0.945		4.725
OA	700	479-21	JSC	PRIME		22.354		17.245		15.685		13.405		13.295		81.984
TA	700	479-24	JSC	NISN (SOMO)		4.100		4.500		5.000		5.500		5.700		24.800
TA	700	479-41	JSC	ENHANCED COMMUNICATIONS FOR PAYLOADS						16.044		5.252		3.561		24.857
DA	700	479-42	JSC	P/L TRAINING CAPABILITY – TSC (PTC)	0.400	1.000		0.400		0.420		0.257			0.400	2.077
MA	700	479-42	JSC	P/L TRAINING CAPABILITY – SFOC (PTC)		1.050		1.875		1.875		2.058		2.335		9.193
DA	700	479-43	JSC	PAYLOAD PLANNING SYSTEM (PPS)		0.300										0.300
OA	700	479-80	JSC	ISSPO SUPPORT (SAIC) Ned		1.105		1.105		1.205		1.205		1.205		5.825
EA	700	479-82	JSC	COMM OUTAGE RECORDER (COR)		0.066										0.066
	700	479-70	KSC	UTILIZATION GROUND PROCESSING		5.972		5.530		5.279		7.935		7.906		32.622
	700	479-71	KSC	HANGER L SUPPORT		2.358		2.550		2.708		2.815		2.929		13.360
	700	479-22	MSFC	P/L OPS & INTEG FUNCTION (POIF)	0.012	22.000	0.003	23.900	0.003	25.100		26.000		26.850	0.018	123.850
	700	479-23	MSFC	ENGG INTEG / P/L DATA LIBRARY (PDL)		1.600		0.600		0.550		0.550		0.750		4.050
	700	479-XX	MSFC	POIC & PDSS: P/L OPS & INTEG CENTER (POIC)		18.400		17.100		17.775		18.225		19.080		90.580
	700	479-43	MSFC	PAYLOAD PLANNING SYSTEM (PPS)		1.100		0.800		0.750		1.100		1.100		4.850

EXCERPTS FROM RPO BUDGETS																
				ARC TELESCIENCE CENTER		1.665		1.128		1.139						3.932
				JSC TELESCIENCE CENTER		0.218		0.218								0.436
				GRC TELESCIENCE CENTER		1.000		1.000		1.000		2.400		1.600		7.000
				JPL TELESCIENCE CENTER						0.144		0.750		0.766		1.660
				MSFC TELESCIENCE CENTER		0.360		0.369		0.350		0.325		0.325		1.729
						3.243		**2.715**		**2.633**		**3.475**		**2.691**		**14.757**

Note: JSC TSC presentation identifies full cost as $2,391,929/year (19.5 FTE)

Exhibit 3-3. Payload Operations Reference Budget

SAT	UPN		ITEM	FY02	FY03	FY04	FY05	FY06	FY02-06
FROM 39X RESEARCH PROGRAMS									
200	393-251	ARC	ARC TELESCIENCE SUPPORT CENTER	1.665	1.128	1.139			3.932
700	394-991	JSC	JSC TELESCIENCE SUPPORT CENTER (see Note)	0.218	0.218				0.436
400	398-251	GRC	GRC TELESCIENCE SUPPORT CENTER	1.000	1.000	1.000	2.400	1.600	7.000
700	398-551	JPL	JPL TELESCIENCE SUPPORT CENTER			0.144	0.750	0.766	1.660
700	398-961	MSFC	MSFC TELESCIENCE SUPPORT CENTER	0.360	0.369	0.350	0.325	0.325	1.729
FROM 479 PAYLOAD OPERATIONS AND INTEGRATION									
700	479-20	JSC	NISN (SOMO)	4.100	4.500	5.000	5.500	5.700	24.800
700	479-41	JSC	ENHANCED COMMUNICATIONS FOR PAYLOADS			16.044	5.252	3.561	24.857
700	479-42	JSC	P/L TRAINING – TSC (PTC)	1.000	0.400	0.420	0.257		2.077
700	479-42	JSC	P/L TRAINING – SFOC (PTC)	1.050	1.875	1.875	2.058	2.335	9.193
700	478-43	JSC	PAYLOAD PLANNING SYSTEM (PPS)	0.300					0.300
700	479-22	MSFC	PAYLOAD OPS & INTEG FUNCTION (POIF)	22.000	23.900	25.100	26.000	26.850	123.850
700	479-XX	MSFC	POIC & PDSS: P/L OPS & INTEG CENTER (POIC)	18.400	17.100	17.775	18.225	19.080	90.580
700	479-43	MSFC	PAYLOAD PLANNING SYSTEM (PPS)	1.100	0.800	0.750	1.100	1.100	4.850
				51.193	**51.290**	**69.597**	**61.867**	**61.317**	**295.264**

- The **P/L Training – SFOC (PTC)** line item funds training instructors provided by the Space Flight Operations Contract (SFOC) to train ISS flight crews in payload operations. As PTC development is completed, PTC maintenance is also phased over from the TSC contract to the SFOC contract.

- The **JSC Payload Planning System (PPS)** line item funds development of the interface between the PPS, which operates in the POIC, and the Crew Planning System (CPS), located in the Space Station Control Center (SSCC). The interface development is complete after FY 2002.

- The **MSFC Payload Operations and Integration Function (POIF)** budget item funds the staff at MSFC who integrate all ISS payload operations.

- The **MSFC POIC & PDSS** budget funds development and operation of the Payload Operations Integration Center (POIC), which provides information technology support to the POIF, TSCs, and remote principal investigators (RPIs). The POIC also contains the Payload Data Services System (PDSS), which distributes payload data to the IPs as well as to U.S. researchers.

- The **MSFC Payload Planning System (PPS)** line item funds maintenance of the software for the PPS, which is used to schedule all payload activities onboard the ISS.

In the Spring of 2001, the NASA Advisory Council (NAC) chartered the ISS Management and Cost Evaluation (IMCE) Task Force to conduct an independent review and assessment of the ISS cost, budget, and management. In addition, the Task Force was asked to provide recommendations that could provide maximum benefit to the U.S. taxpayers and the IPs within the President's 2001 budget request to Congress.

The POCAAS Study Team took note that the IMCE report made several findings relevant to the POCAAS:

- "The U.S. Core Complete configuration (3-person crew) as an end-state will not achieve the unique research potential of the ISS."

- "Scientific research priorities must be established and an executable program, consistent with those priorities, must be developed and implemented."

- "Additional crew time must be allocated to support the highest priority research."

The IMCE Cost Analysis Support Team Report contained the following findings:

- "5.3.2 Payload Operations Facility. This is now, essentially, a fixed cost due to staffing reductions. Current staff is considered minimal. The staffing profile establishes the potential for higher than anticipated attrition. If such attrition is realized, it is anticipated that the cost of replacing and training staff would exceed current budget estimates and could impact operation capability.

- "5.3.3 Remote/Automated Payload Operation. Remote or automated payload operation has been suggested as a means of alleviating reliance on a smaller ISS crew. This would, however, necessitate redesign of payloads and incorporation of technology to support such operations. This would result in added cost. The cost would be dependent on stage of development. Higher cost would be associated with payloads in advanced stages of development. There is also the potential to shift additional cost to sponsors or the Payload Operations Facility."

The POCAAS Study Team agrees with the IMCE principal findings noted above and has given attention in its findings to the need for effective use of crew time available to payloads, as well as the need for an interim means to obtain additional crew time for research tasks.

The POCAAS Study Team does not agree completely with the findings of the IMCE Cost Analysis Support Team. Previous budget reductions have reduced POIF staff to a minimal level for the current mode of ISS Program operations. However, the Study Team believes that further reductions can be made if ISS Program operational requirements, standards of operation, and processes are relaxed to a more cost-effective level, as noted in the many researcher comments contained in Section 2.

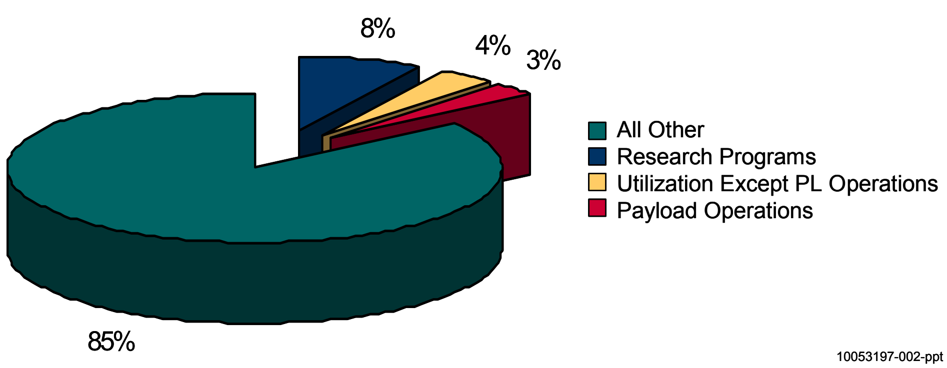
The Study Team also recognizes the performance and cost tradeoffs involved in remote or automated payload operations (telescience), versus manned operations. However, the Study Team observes that many ISS payloads are already designed for telescience and that telescience offers the ability to achieve increased scientific return during and after the period of ISS restriction to a three-person crew.

3.1.2 Budget-Related Findings

3.1.2.1 Payload Operations in Relation to the ISS Budget

The Study Team observes that the Payload Operations budget is only 3 percent of the Program Budget (Exhibit 3-4). However, the Team did not consider 3 percent of the total budget and 20 percent of the Research Program budget as a disproportionate fraction for payload operations in comparison to other programs. While payload operations cost can be reduced, as discussed in this report, other program element costs should be similarly reducible.

Exhibit 3-4. ISS Budget Components



3.1.2.2 Long-Term Payload Operations Planning

The Payload Operations budgets, as presented, appear to represent an extrapolation of today's costs, with consideration of workload variation, as opposed to a plan for evolution of the ISS to a laboratory facility for conduct of world-class science. None of the information presented to the Study Team indicated a long-term plan.

All operational programs undergo a learning curve after operations begin. Although the Team recognizes that payload operations (and other parts of the program) have undergone significant budget reductions within the last year (the first year of on-orbit payload operations), no indication of a continued learning curve in the budget projections exists. Also, while the budget reductions that have taken place can be considered to have been absorbed within the operational learning curve, no evidence exists of corresponding changes in operations requirements and methodology, based on the experience gained.

In a multi-year research program, changes in operations requirements and the resulting implementation must be anticipated, and should be planned for. These changes are, of course, dependent upon the multi-year research program itself. The Team found no evidence of an integrated plan for evolution of the research program and no plan for the evolution of payload operations through the multi-year program. Indeed, the Team experienced difficulty in obtaining research projections beyond the immediate (1 year) flight increments.

The Team also observes that the rapid progress now occurring across the broad area of information technology is a powerful dynamic affecting the way research in general is performed, as well as a powerful tool for increased productivity. However, the application of information technology advances in the payload operations infrastructure requires planning and budget investment, which can be recouped in reduced operating costs. The Team did not find long-term planning anticipating the changes in the way science will be done and in the application of information technology advances to facilitate science.

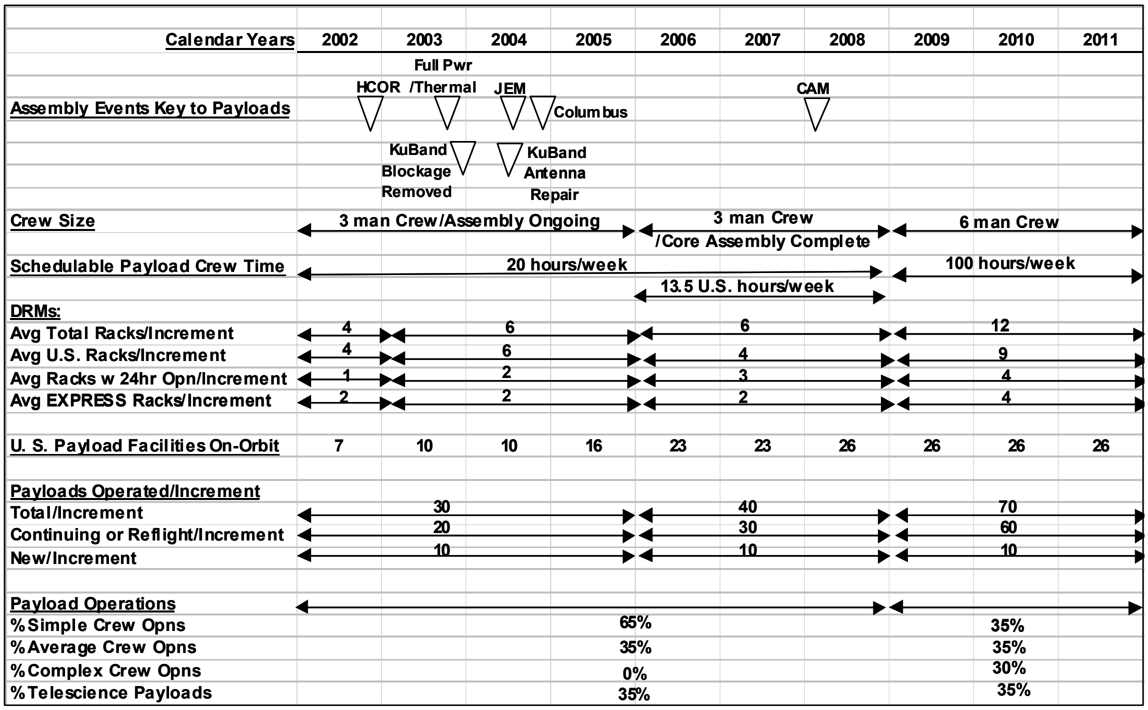
Recommendation. A multi-year plan for operations evolution should be established and maintained. The plan should be reflective of the evolution of research needs and should guide the introduction of technology and development of critical operations skills.

3.2 Program Requirements on Payload Operations

3.2.1 Mission Model

In consultation with the ISS Program Office, the POCAAS Team developed a Mission Model to help characterize the payload operations workload. The workload is depicted in Exhibit 3-5.

Exhibit 3-5. Mission Model for Payload Operations



Note: Model based on three-month increments

3.2.1.1 Assembly Events

At the time of this report, ISS budget constraints were under evaluation, and the continued on-orbit assembly schedule was under review. For purposes of the study, the assembly events considered key to payload activities are assumed as shown in Exhibit 3-5. The current KuBand antenna blockage will be removed when the ISS reconfiguration to provide full power and cooling capability takes place. The repair of the antenna to remove the current constraints associated with the failed gimbal heaters has not been manifested but is expected to occur in the time frame shown.

The Mission Model assumes that the ISS will achieve its full planned power and thermal control capability, and correction of current KuBand communications limitations, within the 2003 time frame. These accomplishments will significantly reduce POIF workload currently experienced due to these constraints.

The assembly of the JEM and Columbus modules in the 2004–2005 time frame will significantly increase the pressurized volume and facilities available to house payloads. With the accomplishment of these milestones, the IPs will begin their on-orbit payload activities, which will introduce new interfaces into payload operations. This milestone is defined as Core Assembly Complete for purposes of the POCAAS.

The delivery of the Centrifuge Accommodation Module (CAM) in 2008 will enable new research capabilities in biology, including more complex experiments. However, its use will be limited until increased crew time is available.

3.2.1.2 Flight Crew Size

The availability of flight crew time to support payload operations is a critical resource. The currently funded ISS Program contains accommodations for three crew persons on-orbit. The full ISS design, consistent with the International Governmental Agreement with the IPs, requires a six- to seven-person crew.

For POCAAS purposes, the crew size was assumed to transition from three persons to six persons in the 2009 time frame. During the three-person period, a division was made between pre-Core Assembly Complete, during which crew time is heavily engaged in assembly operations, and post-Core Assembly Complete.

3.2.1.3 Flight Crew Time

The amount of schedulable crew time available for payload operations has been established as an average of 20 hours/week prior to Core Assembly Complete. *Schedulable* is that time allocated within the crew's standard weekday work hours. The crew may elect to additionally use some of their discretionary time for payload activities, but these are not schedulable or predictable. The average number also varies from day to day and week to week, depending upon ISS assembly and maintenance operations schedules.

After Core Assembly Complete, the amount of schedulable crew time has also been assumed to remain to be 20 hours per week. After this milestone, although assembly activities are greatly reduced, maintenance activities are predicted to still consume the majority of crew time. Some projections are pessimistic that 20 hours per week of payload crew time can be maintained.

When a six-person Crew is achieved, a significant increase is expected in the time available for payload operations. The POCAAS has assumed this to be approximately 100 hours per week (6.5 hours per workday times 5 workdays per week times three crew persons = 97.5 hours per week).

3.2.1.4 Design Reference Missions

The ISS Program Office provided several Design Reference Mission (DRM) models to the Study Team. These models were obtained from a Monte Carlo analysis model of ISS payloads maintained by the Program Office. The DRMs evaluate the resource requirements of anticipated payloads versus the resources available onboard the ISS at a specific point in time and indicate the level of payload activity that can be manifested and accomplished for a given mission increment.

Nominal 3-month increments were assumed for the POCAAS, although current increments have been extended to 4 or 5 months. The IMCE Study recommended extension of increments to 6 months. The POCAAS assumed 3-month increments in its analyses but gave consideration to the effects of longer increments.

The DRM analysis shows that power, cooling, and crew time are currently limiting constraints on research manifesting. After final power and cooling capabilities are achieved (late 2003), Shuttle mid-deck transportation and crew time are critical constraints until a six-person crew is achieved.

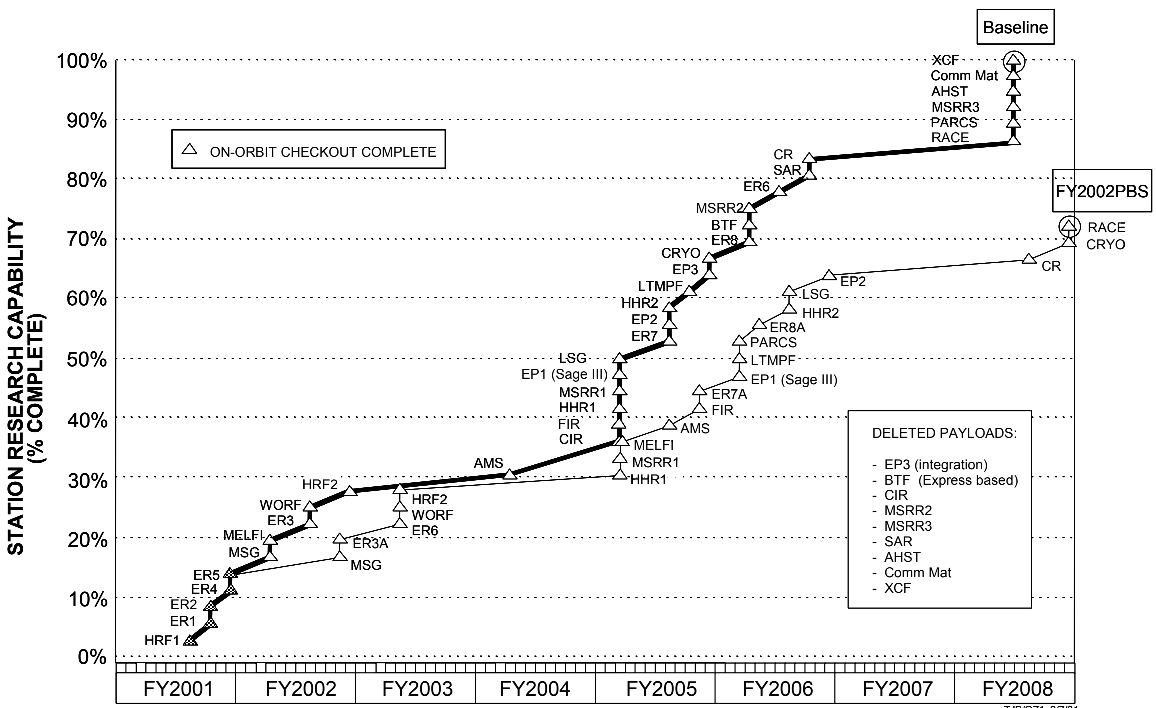
After a six-person crew is achieved, four approximately equal critical constraints will exist: up-mass, keep-alive power, mid-deck transportation, and on-orbit stowage.

3.2.1.5 Payload Facilities On Orbit

Payload Operations workload is driven by the combined U.S. plus IP payload activities onboard the ISS, but more strongly by U.S. payload activities. The U.S. is responsible for integrating all payload activities, but for conducting U. S. payloads only. U.S. payloads can be located in the Columbus and JEM but are still installed in U.S. racks and operated through the U.S. C&DH system.

U.S. Payload Facilities (EXPRESS and dedicated facility racks, other payload equipment) are transported to the ISS as indicated and increase the capability for research activities as they arrive. As the quantity of hardware on orbit increases, the responsibility of the payload operations staff for monitoring and managing the facilities also increases. The facility build-up assumed by the POCAAS is further expanded in Exhibit 3-6. However, the number of payload racks that are actually operated on an increment is limited by other resources, as reflected in the DRMs.

Exhibit 3-6. ISS U.S. Research Facility Delivery Plan



3.2.1.6 Payloads Operated Per Increment

The number of payloads operated per increment also drive payload operations. Timeline scheduling is performed by payload, and crew procedures, displays, and training are all dependent upon the specific payloads to be operated each increment. The total number operated per increment is determined by the resources required and available for the payloads. However, some payloads continue operations from one increment to the next, and some payloads are returned to the ground but then reflown on a later increment. Continuing or reflight payloads require less operations preparation work than new payloads (i.e., never flown before), although the amount of rework required for a reflight will vary with the degree to which the payload itself or the experimental protocol may be altered between flights.

3.2.1.7 Payload Complexity

The operations preparation work required for a payload also varies with the operational characteristics of the payload. Crew support complexity and telescience use were key factors considered by the POCAAS in its analyses.

The Study Team classified payloads currently and previously flown on the ISS in accordance with the crew support complexity definitions shown below. The payload complexity model previously shown in the Exhibit 3-5 Mission Model is based on this analysis. For purposes of analysis, three discrete definitions were used, although in reality crew support complexity varies in a continuum.

- **Simple payload.** Operated with simple procedures requiring little or no specialized crew training (example, Space Accelerometer Measuring System)
- **Average payload**. Procedures require crew activation of payload, periodic servicing, some experiment operations; requires limited training for specialized skills (example, HRF-PUFF)
- **Complex payload**. Requires crew activation of payload, periodic servicing, crew operation of experiment, and significant crew judgments to achieve scientific objectives; research understanding and training for specialized skills is important (example, Fluid Physics Module, Spacelab-1)

The emphasis in these definitions is on the intrinsic characteristics of the payload that drives the crew support requirements. The Study Team's distinction between *average* and *complex* payloads was carefully drawn to distinguish payloads that the Team believes represent the research vision for the ISS, but that are not possible within the 20 hours per week crew time constraint with a three-person crew.

The Study Team considered other definitions (e.g., those currently in use by the training function of POIF) but judged them less appropriate to the POCAAS. The current POIF definitions are less stringent than the POCAAS definitions above and reflect a current ratio of 30 percent Simple, 45 percent Average, and 25 percent Complex payloads.

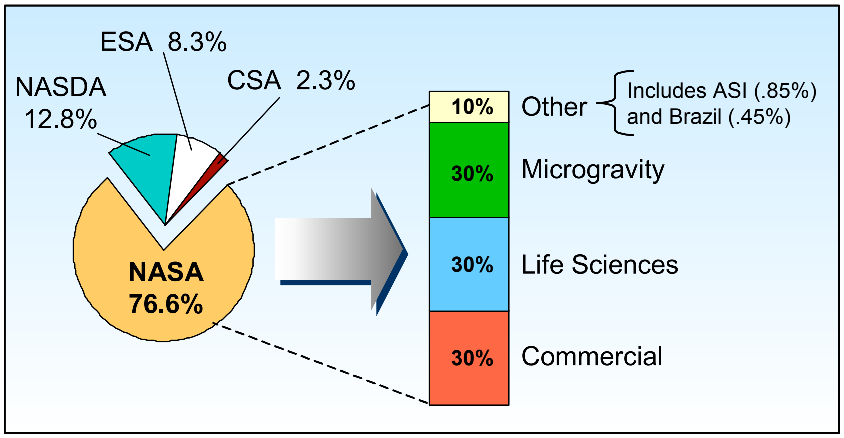
Telescience payloads are principally operated by PI teams through commands from the ground. All current telescience payloads still require the crew to move the payload itself or samples from and to the Orbiter and to install the payload in the ISS. Some require sample exchange or other servicing by the crew. Future payloads mounted externally on pallets will require installation but may require less crew servicing after installation.

Telescience payloads tend to be simple to average from the viewpoint of crew support but generate real-time activity in terms of command traffic and data return. They may operate continuously for extended periods and are typically operated from RPI sites that communicate through the Payload Operations Integration Center. The POCAAS classified current payloads as telescience only if their principal mode of research conduct was through telescience. Payloads that only use ground commands for housekeeping functions were not classified as telescience. Although not reflected in the Mission Model, the Study Team did consider that the use of telescience should be expected to increase over time, as researchers seek to overcome limitations on crew time.

3.2.2 Research Resource Allocation

The ISS resources allocated to research within the U.S./ESA/NASDA elements of the ISS are to be shared as illustrated in Exhibit 3-7. The sharing among the U.S. and the IPs is controlled by the MOUs established among the IP governments. The U.S. sharing of research resources among research disciplines is as directed by the Space Station User Board at NASA Headquarters.

Exhibit 3-7. Pressurized Resource Allocation



10052522-001.ppt

Sharing is to be achieved over a reasonable but unspecified time, but not on a daily or increment basis.

The Russians retain 100 % of the resources within the Russian elements.

3.2.3 Other Key ISS Configuration Constraints

Significant communications constraints exist on payload operations.

Payload commands are restricted to 8 commands per second, but the current effective limit is 1 to 3 commands per second. During periods when the SSCC is uplinking data to the ISS, congestion occurs, and the POIC has been requested at times to reduce command traffic. Commanding is performed through the S-Band communications channel.

The command rate restriction is based on sharing the current single S-band channel. The highest uplink traffic is file uplinking for crew procedures, software updates, and similar data traffic. This uplink traffic is executed and managed by the SSCC; the POIC places data files for uplink in an outbox, from which the files are retrieved and transmitted by the SSCC.

As telescience increases, and as crew size is increased, uplink requirements will increase.

The KuBand communications channel is used heavily to downlink payload data, as well as to downlink ISS television. During periods when there is no communication coverage through the TDRSS, both systems and payload data are recorded onboard and later downlinked via KuBand.

With the current configuration of the ISS, KuBand coverage is limited while in x-axis parallel to orbital plane (XPOP) attitude to about 34 percent, with an average AOS of 27 minutes. After flight 12A, ISS attitude will be restricted to local vertical-local horizontal attitude, and KuBand coverage will be reduced to about 29 percent, with an average AOS of 10 minutes.

After the photovoltaic array that blocks the KuBand antenna is relocated to its final planned location, and after the failed gimbal heaters on the KuBand antenna are repaired, KuBand coverage will increase to a maximum of about 55 percent.

Because of the communications limitations, and the significant use of telescience for payload operations, the addition of Timeliner capability is important. Timeliner is an onboard software system to allow the storage of timed command sequences, which are executed independently of ground coverage. This capability is planned for June 2002.

3.2.4 Program Requirements Findings

Limitation on conduct of research. The limitation of a three-person crew represents a principal constraint to payload operations. The limitation is not only in crew time for payload operations, but importantly with regard to crew selection. In a three-person crew, the majority of time on the ISS is spent in maintenance and housekeeping activities for the ISS itself, including extra-vehicular activities, with a current 20 hours per week available for schedulable payload operations. This level of crew time means that most of the payload time is spent in experiment installation, troubleshooting, servicing, and sample return activities, with little time for real scientific investigation by the crew. With this workload, the required crew skill set emphasizes generalists, rather than specialists, and technicians, rather than scientists. This greatly limits the opportunity to fly career scientists, who are willing to take a period of time from their scientific pursuits to train and fly in exchange for the opportunity to perform science in space, but who are unwilling to cease being scientists.

Restriction on science disciplines. The limitation of a three-person crew also affects the science disciplines, in that some disciplines are more adaptable to telescience and minimum crew time than others. Human life sciences and fundamental biology operations tend to be crew-intensive and will be most affected by crew time limitations.

Need for three-person crew operations concept. Because this will be the mode for a period of years, the development of the most effective three-person crew operations concept is essential. The use of telescience and autonomously operated experiments is essential to accomplishing maximum science with constrained crew resources. Therefore, the vision of easy, effective telescience must be pursued. "Layers" of infrastructure that separate ground-based PIs from accessing and operating their experimental apparatus must be minimized.

Because the unique value of the ISS is its onboard crew operations and frequent logistics access, experiments should also be designed to minimize the crew time spent in installing, activating, maintaining, and servicing equipment, so as to maximize use of the available crew payload time for real scientific activities.

Need for increased communications. With increased emphasis on telescience comes increased need for air-to-ground communications. Increased KuBand communications coverage should be pursued through such options as adding a second KuBand antenna and operational use of the NASDA KaBand system. (The KaBand system is compatible with the U.S. TDRSS, although it is planned for operation with NASDA's own communications relay satellite system.) Increased uplink capacity will be particularly needed, both for data file uplink and payload commanding.

Multiple experiment classes. Another unique aspect of the ISS is the broad range of scientific disciplines it is expected to support (life sciences, microgravity sciences, commercial payloads, other space sciences) and the variety of experiment designs (simple to complex, crew and telescience, discipline facilities, and individual payloads). This diversity dictates that a flexible portfolio of alternate operations service levels and processes must be developed. A one-size-fits-all approach will necessarily result in overkill and unnecessary cost for the majority of simpler payloads.

3.3 Current Payload Operations Architecture

This section discusses the current ISS payload operations architecture. The POCAAS defines *architecture* to begin with the operational functions to be performed, the allocation of functions to operations elements (i.e., facility and/or organization), and the relationship among the elements.

3.3.1 Payload Operations Functions

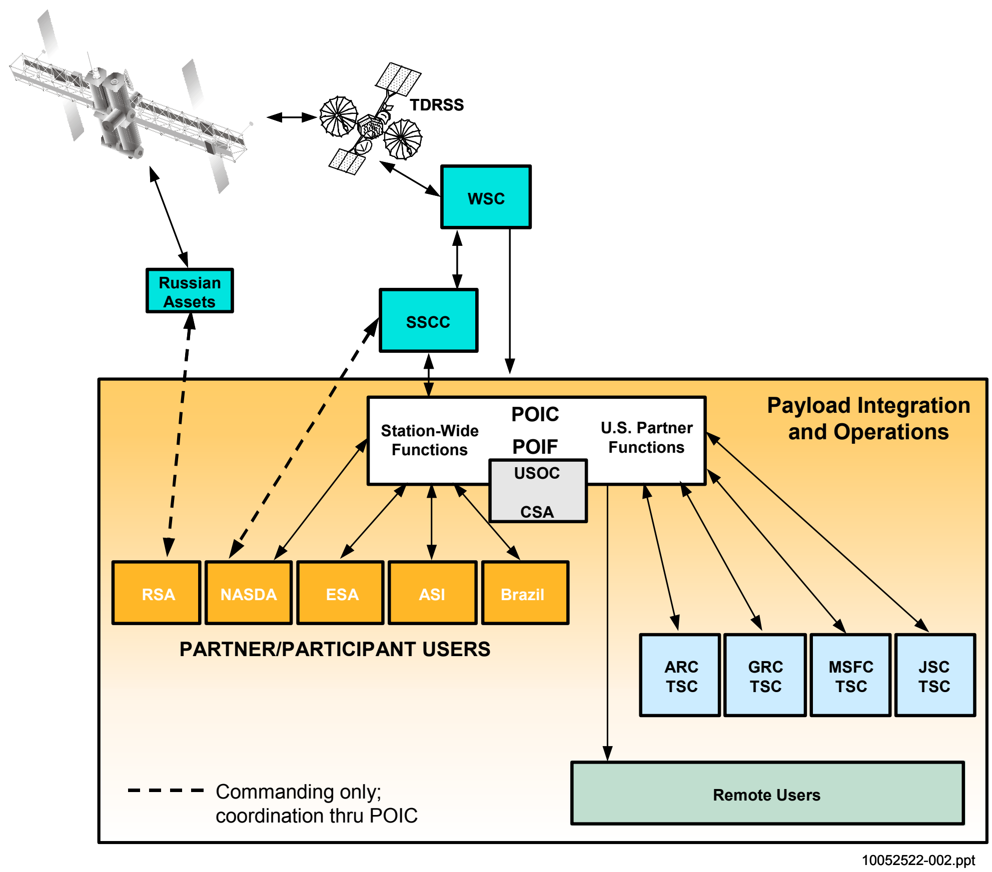
The functions identified by the POCAAS, and considered necessary for ISS payload operations, are listed below. These functions are derived from the payload operations principles and concepts described in Section 2 of this report.

- Coordinate and integrate all U.S. and IP payload operations
- Plan and integrate the timeline for operation of payloads
- Provide single interface to the SSCC for payload operations
- Perform real-time control of payloads and supporting systems
- Develop procedures and perform control of payloads
- Develop procedures and perform control of PLSS
- Integrate experiment procedures and flight displays
- Integrate and prepare the PODF
- Train flight crew and ground support personnel
- Ensure payload safety critical operations are conducted in consonance with established safety protocols
- Provide information technology infrastructure
- Distribute, process, and display telemetry and other electronic data for U.S. payloads
- Distribute KuBand payload data to IPs
- Process and transmit commands
- Implement payload telemetry and command database to enable processing
- Enable communications among all payload operations elements
- Provide tools to support information retrieval, planning, and coordination

3.3.1 ISS Operations Elements

ISS operations for both core systems and payloads are geographically distributed. This distribution is necessitated by the international participation in construction and operation of the ISS and by the diversity and long-duration aspect of ISS payloads. It is impractical to locate all operations functions in one location. The current ISS operations elements are shown in Exhibit 3-8.

Exhibit 3-8. ISS Operations Elements



WSC. The White Sands Complex is the communications hub for air-to-ground (A/G) communications with the ISS, through the TDRSS.

SSCC/SSTF. The SSCC, located at JSC, has operational responsibility and control for the ISS as a whole. The Space Station Training Facility (SSTF), also located at JSC, is the central facility where all ISS crew training is performed. The PTC is an element of the SSTF.

POIC/POIF. The POIC, located at MSFC, houses the central information technology infrastructure for payload operations and hosts the POIF. The POIF consists of the staff who plan and perform the integration of ISS payload operations, and who operate the PLSS.

USOC. The U.S. Operations Center (USOC) is a portion of the POIC that provides facilities for PIs who may wish to operate their ISS payloads from that location. The Canadian Space Agency (CSA) operates through the POIC and SSCC.

PCCs. The Partner Control Centers (PCCs) are operational facilities operated by each of the IPs (Russia, NASDA, and ESA) and located in each IP country. A PCC operates both the core systems and payloads in its respective on-orbit element, except U.S. experiments located in IP elements are operated through the POIC using the U.S. C&DH system. The ASI and Brazil PCCs operate only payloads (no core systems).

RPIs. As a basic principle of research, ISS payloads are operated by their PIs, usually from their home location due to the extended duration of operations. These investigators are remote from the POIC; therefore and are termed RPIs locations.

TSCs. Telescience Support Centers are established at the ARC, GRC, MSFC, and JSC. The TSCs are principally established to operate facility-class payloads onboard the ISS. A facility-class payload is typically a rack of equipment that enables investigations into a particular scientific discipline or subdiscipline by providing common systems and services required by multiple experiments in that discipline. In this sense, the TSCs can be viewed as a "super-RPI" site, because multiple PIs may use the facility-class rack resources through the TSC. The TSCs also provide other scientific discipline-related services.

NISN. The NASA Integrated Services Network provides the communications services necessary to link the other operational elements together.

3.3.3 Distribution of Payload Operations Functions Across Elements

The distribution of payload operations functions across elements is summarized in Exhibit 3-9.

3.3.4 POCAAS Findings Regarding Current Payload Operations Architecture

The Study Team did not identify any significant overlap in functions among operations elements. The Team noted that all of the U.S. elements are heavily dependent upon the POIC to provide basic information services.

The U.S. elements do not interact with the IP C&DH systems (nor do the IP C&DH systems interact among themselves.) Although the IP elements are dependent upon the POIC for distribution to them of KuBand data, the PCCs do not interact directly with the U.S. C&DH system. Thus, a compartmentalization of IT infrastructure is implicit in the ISS design.

These observations do not mean that some specific system functions might not be more cost-effectively redistributed among elements. (For example, the distribution of KuBand data from WSC rather than the POIC is a possibility). Architectural alternatives are evaluated in Section 5.

Exhibit 3-9. Functions Across Elements

Function	SSCC/SSTF	POIF/POIC	PCCs	TSCs	PIs/PDs
• Coordinate /Integrate	Integrate ISS	• Integrate all PL Operations • Single Interface to SSCC	• IP Core systems • IP PLSS • IP PLs	Research Facilities	N/A
• Timeline Planning	Integrate ISS	• Integrate all PLs	• IP PLs	Research Facilities	Experiments
• Real Time Control	ISS Core Systems	• U.S. PLSS • Support U.S. PIs	• IP Core Systems • IP PLs	Support PIs	Experiments
• Develop Displays/ Procedures	ISS Core Systems	• U.S.PLSS • Integrate all PLs	• IP PLSS • IP Expts	Research Facilities	Experiments
• Train Flight /Gnd Crews	• ISS Core Systems • Host PLs	• Integrate all PLs/Deliver U.S. PL Training	• IP PLSS • IP PLs	Research Facilities	Experiments
• U.S IT Infrastructure	ISS Core Systems	U.S. Payloads	IP Payloads	Research Facilities	Experiments
• Telemetry Processing	ISS Core Systems	• U.S. PL Data • U.S. C&DH	• IP Data • IP C&DH	• POIC (Trek) • Expts	• Expt Data Streams • POIC(Trek)
• Command Processing	Integrated ISS	• All PL Cmds • U.S. C&DH	• IP Cmds • IP C&DH	• POIC (Trek) • Expts	• Expts • POIC (Trek)
• TM/CMD Database	Integrated ISS	• All PL Data • U.S. C&DH	• IP Data • IP C&DH	• Research Facilities	• Experiments
• Communications (All WAN provided by NISN)	ISS Television Processing	Voice, Video and Data Distribution to PL Elements	IP Distribution	Internal Voice, Video, & Data Distribution	Within Experimenter Facilities
• Tools	CPS	• CPS/PPS • PIMS • OCMS	IP Tools	Research Facility Tools	Experiment Tools
• KuBand to IPs	N/A	PDSS	N/A	N/A	N/A

Section 4. Current Architecture and Cost Reduction Options

This Section discusses the elements of the current ISS payload operations architecture and possible cost reduction options. The following elements are discussed:

- Payload Operations Integration Function
- Payload Operations Integration Center
- Telescience Support Centers
- NASA Integrated Services Network

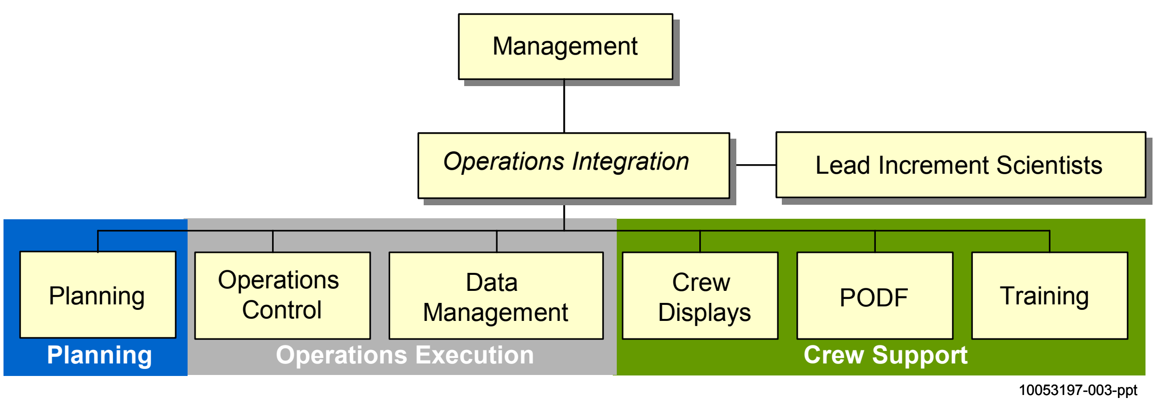
Each element will be discussed in sequence, together with cost-reduction options applicable to that element. Finally, all cost-reduction options will be discussed as a whole.

4.1 Payload Operations Integration Function (POIF)

4.1.1 Current POIF Description

The POIF comprises the staff who plan and perform the integration of ISS payload operations and who operate the PLSS. The POIF is organized around nine major functions, shown in Exhibit 4-1. The descriptions of these functions provided below are intended to be illustrative and are not exhaustive. Many of the functions require coordination of activities with other ISS Program functions (e.g., SSCC, JSC Crew Operations, ISS Payload Analytical Integration), which are not fully described.

Exhibit 4-1. Major POIF Functional Areas



Management. Management provides the overall direction of POIF as an organization. Because POIF is conducted with an integrated staff of NASA Government and contractor personnel, both Government and contract management is included. Currently this function includes all line management staff, administrative support, business and contract support, and staff for scheduling and metrics collection functions.

Operations Integration. The operations integration function includes the Payload Operations Directors (PODs) who direct the operations preparation activities for mission increments, as well as the PODs who operate in the POIC directing real-time payload operations activities on a 24-

hour-a-day, 7-day-a-week shift basis. This function also includes safety engineers, stowage engineers, and ground system integration engineers.

Lead Increment Scientists. The lead increment scientists oversee and coordinate all research activities during payload operations execution. They are provided by the ISS Program Office and report to the Research Planning Working Group (RPWG).

Planning. The planning function supports operations integration and execution by developing timelines for payload operations activities. Timelines vary from pre-increment on-orbit operations summaries (OOS), which establish at a daily/weekly level which payloads can be operated together, to short-term plans (STP), which are integrated SSCC–POIC products detailing daily ISS activities. The planning function requires the following:

- Collection of requirements from each payload developer that describes the activities required to operate that payload, together with the resources needed for each activity (e.g., crew time, power, etc.). Constraints on activities are also identified (e.g., predecessor activities). Payload Activity Requirements Coordinators (PARCs) are assigned to payloads by research discipline.
- Development of planning models. The payload requirements are translated into mathematical models used by the Payload Planning System to construct timelines.
- Development of OOS. Currently a baseline OOS and a final OOS are constructed for each increment. The OOS is used for advanced planning of payload operations, and by the payload analytical integration function to aid in evaluating payload compatibilities for manifesting purposes.
- Development of STP. Shortly before each increment begins, an STP is developed for the increment, and updated throughout the increment.
- Real-time support. A timeline change officer (TCO) is staffed 24 hours a day, 7 days a week in the POIC to evaluate and coordinate changes that occur in the timeline during real-time execution. Changes may be initiated by crew request or performance, by PI request, or by contingencies that occur during operations. The TCO is supported by the payload planning manager (PPM), timeline maintenance manager (TMM), and payload planning/scheduling engineer (PPSE) staff, who use the Payload Planning System (PPS) to evaluate changes and update the timeline. The support staff operates on a nominal 8-hours-a-day, 5-days-a-week basis.

Operations Control. The operations control function integrates the operation of payloads by their respective PIs, through the coordination and configuration of shared services necessary for experiment operation. Operations control manages and configures command system use to enable RPI and TSC commanding. Operations control also monitors, configures, and performs problem resolution for the PLSS. PLSS includes the EXPRESS Rack subsystems, as well as other laboratory support equipment (LSE). Operations control is responsible for managing all files uplinked to the ISS. The operations control function also operates payloads delegated to it, some of which support other experiment operations. An example is the Active Rack Isolation System (ARIS), which reduces microgravity perturbations within the rack environment but is also used for the ARIS-ICE).

The operations control function is performed principally in real-time operations, through the operations controller (OC), command procedures officer (CPO), the payload rack officer (PRO), and the payloads systems engineer (PSE) positions in the POIC. However, significant preparation work is required on a continuing basis to prepare for real-time operations. Preparation tasks include familiarization with new payloads and PLSS equipment, consulting with PIs on the operating plans for their payloads, and defining, modifying, and verifying POIC command and data displays.

Data Management. The data management function configures the payload components of the U.S. C&DH system to achieve data return in response to payload requirements. It also operates the ISS television systems, including the configuration and pointing of onboard cameras. Configuration and management of the KuBand system is particularly significant, because it is the main channel for return of payload data, television data, and onboard recorded data. The function also oversees operation of the POIC systems that collect and distribute data.

Data management is performed principally in real-time operations, through the data management coordinator (DMC) and photography and television operations manager (PHANTOM) positions in the POIC. The bandwidth integration timeliner (BANDIT) and weekly implementer of systems and resources for data (WISARD) positions also support the function on an 8-hour-a-day, 5-day-a-week basis. Operations preparation tasks include collecting data return requirements from the PIs, ensuring that payload data parameters are properly entered into the C&DH database, and providing scene definition for onboard television operations.

Crew Displays. The crew display function integrates and reviews PI requirements for onboard computer displays. The integration function involves collecting PI display designs and communicating them to ISS Program implementation functions, while the review function ensures that displays are functional from a crew and human factors point of view. The review function is performed against standards established by the ISS Program.

Payload Operations Data File (PODF). The PODF function is required to collect and review payload crew operating procedures, and to convert approved procedures into MPV format for uplink to the ISS. Procedures are reviewed against standards established by the ISS Program, and may be verified through interaction with the crew during training activities. The PODF function also is responsible for developing and maintaining procedures for PLSS and facilities assigned to the POIF (e.g., EXPRESS, WORF, ARIS, and MELFI).

The PODF is principally a pre-increment function, but also staffs a 12-hour-a-day, 5-day-a-week position in the POIC to process procedure changes occurring during on-orbit activities.

Training. The training function coordinates and integrates flight crew training for operating payloads. The function includes establishment with the PIs of training requirements and planned methods; collection, review, and in some instances preparation of payload training material; preparation of EXPRESS training materials; and coordination of the delivery of training to the flight crews. The function also includes management of training and simulations for ground support personnel, including POIF staff, TSCs, and PIs.

The training function is performed primarily pre-increment, but because of the familiarity of training personnel with both specific flight crews and crew operations, the training function staffs the payload communicator (PayCom) position in the POIC during on-orbit operations. The

PayCom is responsible for effective communications among all payload ground staff and the crew.

4.1.1.1 POIF Operations Preparation Schedules

Current POIF operations preparation schedules for an increment are shown in Exhibits 4-2 and 4 3. The lead times for products have been reduced, and POIF continuous improvement activities are seeking to further reduce lead times.

Exhibit 4-2. User Input Summary

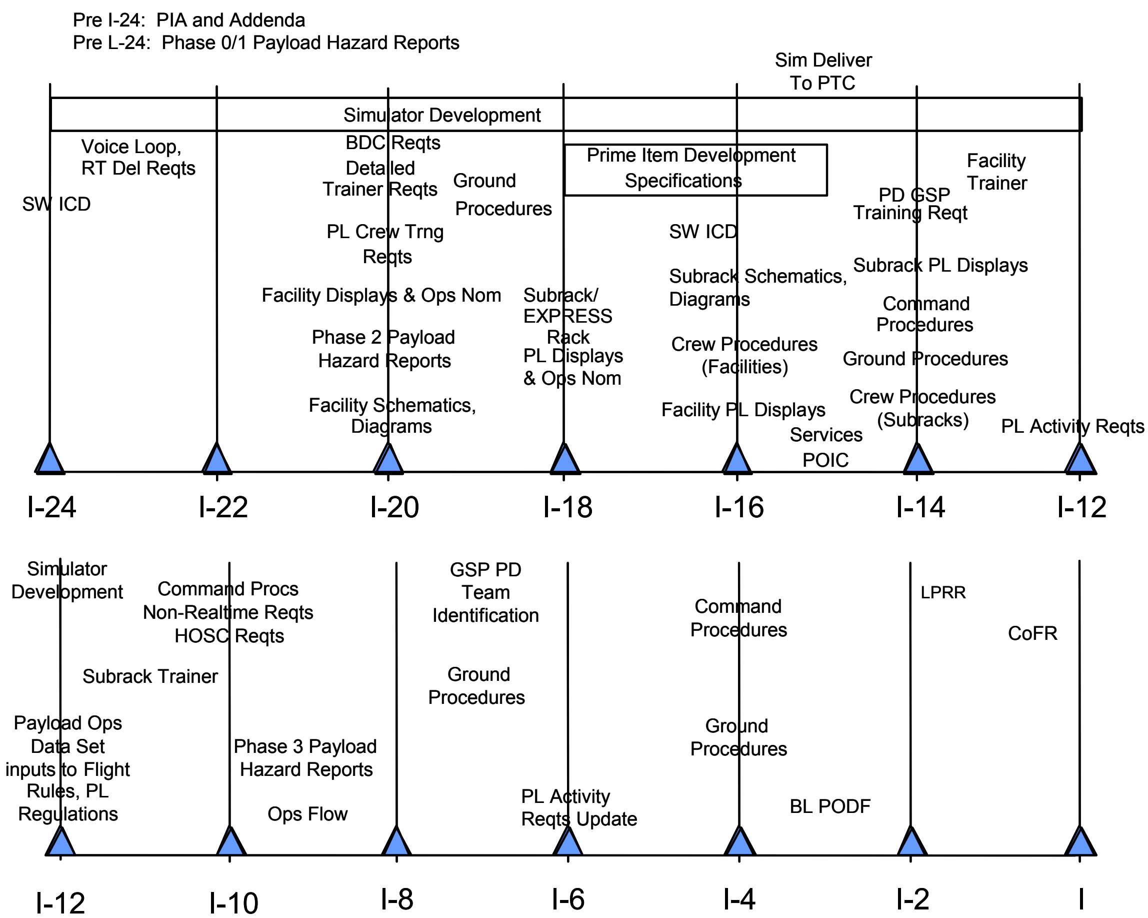


Exhibit 4-3. Generic Schedule Roll Up (1 of 2)

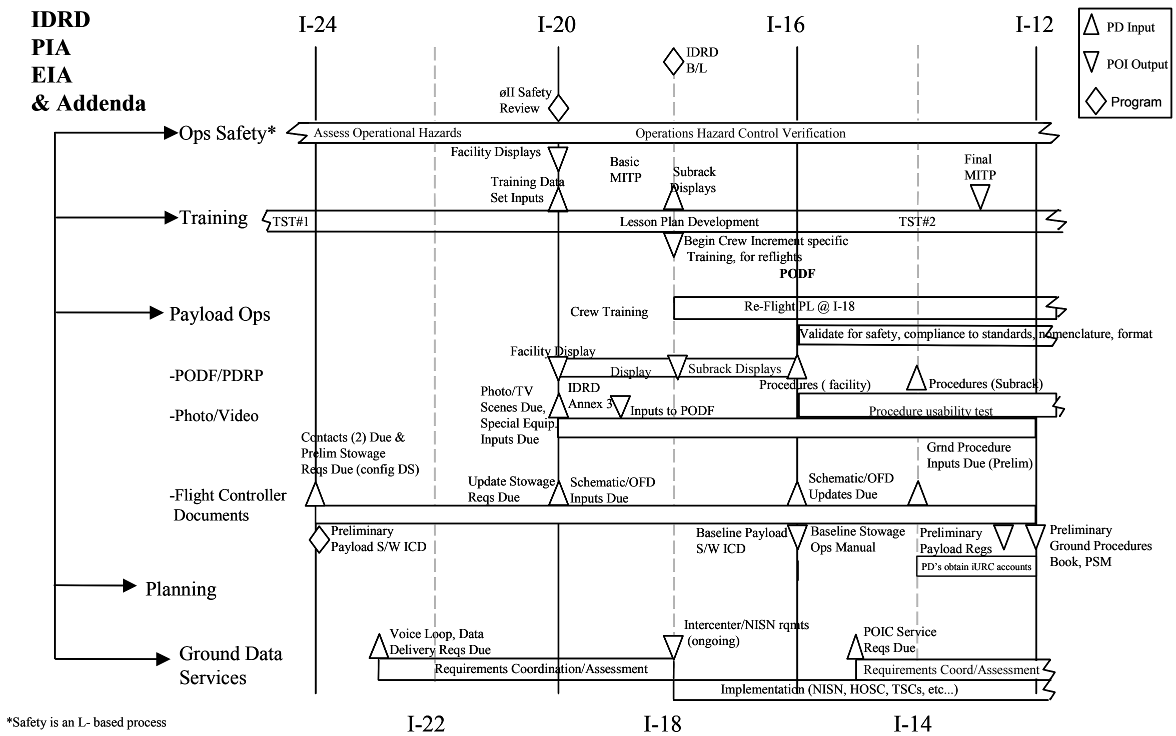
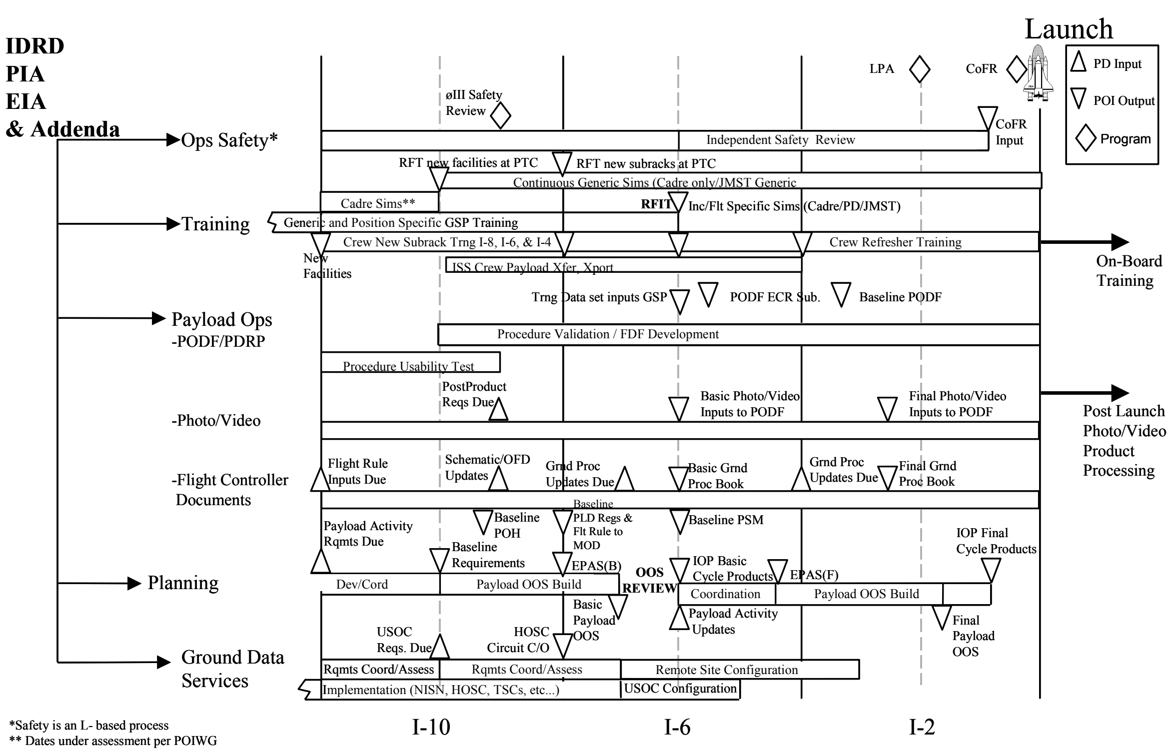


Exhibit 4-3. Generic Schedule Roll Up (2 of 2)

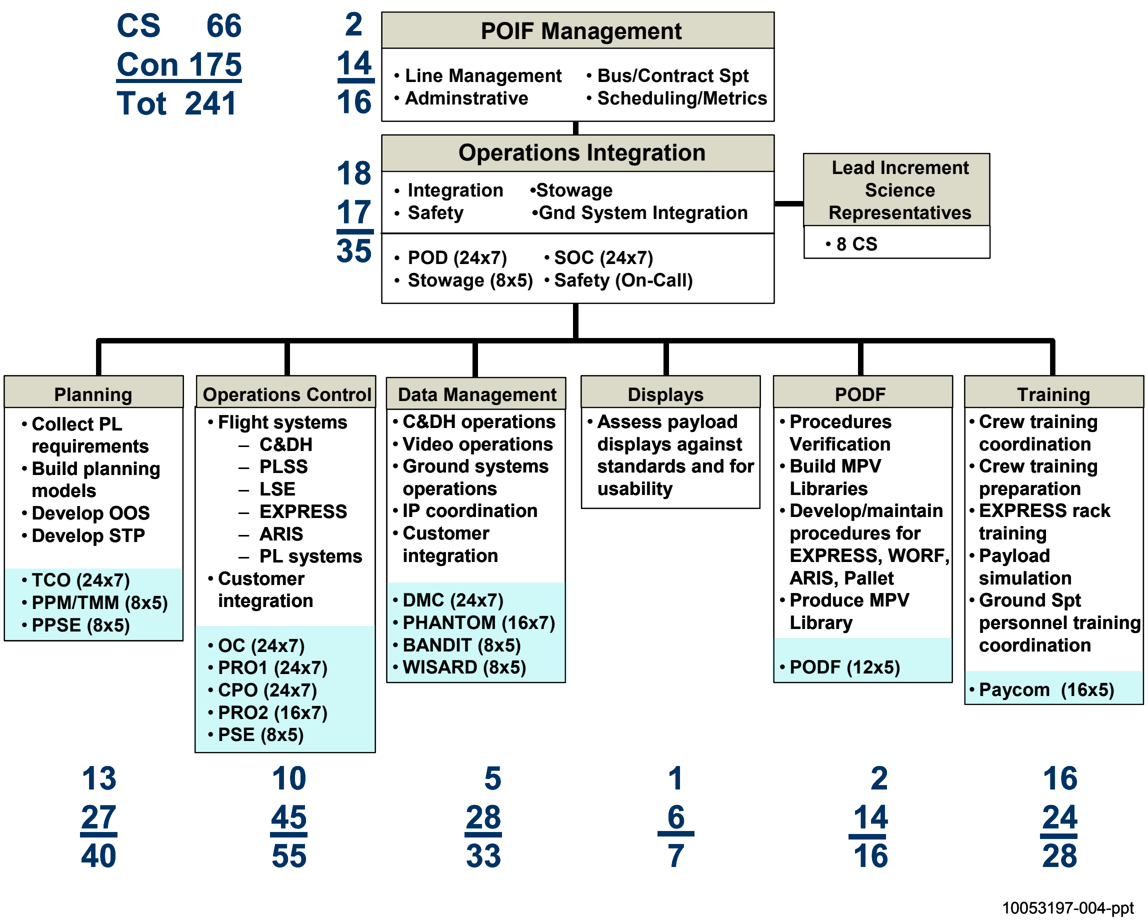


Although some activities begin as early as 36 months before the increment, the majority of the work occurs within the 12 months prior to the increment. Early activities include, importantly, consulting with PIs to establish with them the requirements and strategy for operations preparation. Ground system communications requirements and training preparation are also long-lead items.

4.1.1.2 POIF Labor Resources

The POIF is a labor-intensive activity, assisted by tools created internally to the POIF or provided by the POIC. The current POIF labor staffing is shown in Exhibit 4-4.

Exhibit 4-4. Current POIF Functions and Staff



The current distribution of POIF manpower against categories of activities is shown in Exhibit 4-5.

The distribution of labor is shown further in Exhibit 4-6, converted to LOE.

The current manning of real-time POIC positions is shown in Figure 4-7.

Exhibit 4-5. FY 2002 POIF Manpower

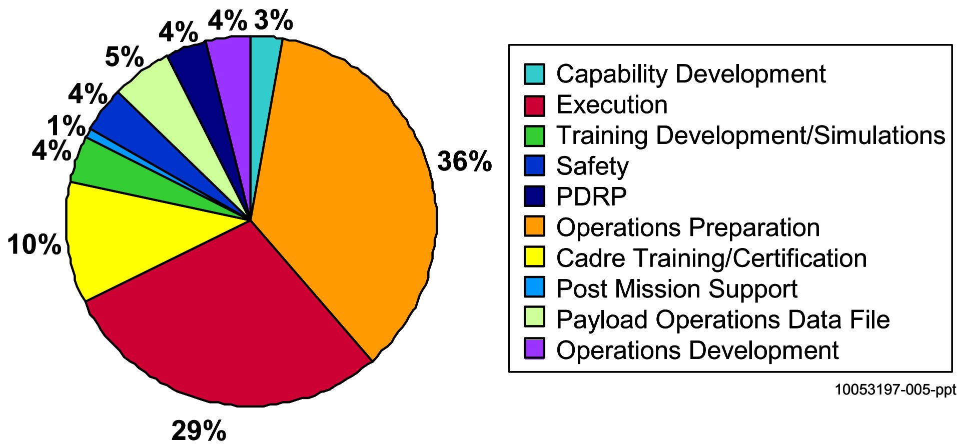


Exhibit 4-6. FY02 Manpower Distribution

	Percentage	FTE
Operations Preparation	36	87
Operations Execution	29	70
Capability Development	3	7
Training Development/Simulation	4	10
Safety	4	10
Payload Display Review Panel	4	10
Cadre Training/Certification	10	24
Post Mission Support	1	2
Payload Operations Data File	5	12
Operations Development	4	10
Total	**100**	**241**

Exhibit 4-7. POIF Real-Time Positions

Position	Sun			Mon			Tue			Wed			Thur			Fri			Sat		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Payload Opns Director (POD)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P/L Comm Manager (PayCom)				X	X		X	X		X	X		X	X		X	X				
Operations Controller (OC)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Payload Rack Officer 1 (PRO1)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Command P/L MDM Officer (CPO)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Payload Rack Officer 2 (PRO2)	X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Payload Systems Engineer (PSE)				X			X			X			X			X					
Data Mgt Coordinator (DMC)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Photo & TV Opns Mgr (PHANTOM)	X	X		X	X		X	X		X	X		X	X		X	X		X	X	
B/W Integration Timeliner (BANDIT)				X			X			X			X			X					
Wkly Data Sys/Resources (WISARD)				X			X			X			X			X					
Timeline Change Officer (TCO)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Payload Planning Mgr (PPM)				X			X			X			X			X					
Timeline Maint Mgr (TMM)				X			X			X			X			X					
P/L Plan/Sched Engineer (PPSE)				X			X			X			X			X					
PODF Support (PODF)				X	X		X	X		X	X		X	X		X	X				
Shuttle Opns Coord (SOC)	When Shuttle is On-Orbit																				
POIC Stowage				X			X			X			X			X					
Safety (On-Call)																					

4.1.2 General POIF Findings

Provides Essential Functions. The Study Team assesses that the POIF is providing essential payload operations functions, not otherwise performed, which include the following:

- Integrating ISS payload operations
- Facilitating the performance of experiments by PIs and crew, and managing shared resources
- Controlling the PLSS (KuBand data, MCOR/HCOR, PL MDM)
- Controlling assigned onboard research facilities (8 EXPRESS Racks, MELFI, ARIS, and WORF)
- Ensuring the safety of payload safety-critical operations

Steep Learning Curve. Current POIF implementation is successfully enabling the manifested research in parallel with assembly operations and has achieved a steep learning curve and cost reduction in the first year of operations.

- Preliminary OOS has been eliminated (12 to 18 months before increment)
- Real-time positions have been reduced
- PODF staff now formats crew procedures, rather than PDs (PODF staff reduced 33 percent)
- PDRT now works with PDs earlier to familiarize and guide display development (PDRT staff reduced 57 percent)

- Training, PODF, and PDRP functions have been integrated
- Training and simulation requirements have been reduced (training/simulation staff reduced 27 percent)
- Increment preparation schedule template has been shortened
- Payload Operations Integration Working Group (POIWG) was established to increase face-to-face interaction with PDs, shorten time templates, and increase process flexibility for payloads

The POIF Team is pursuing additional areas for savings:

- Continuous assessment of cadre positions to develop efficiencies and reduce real-time staffing
- Reductions in travel by locating personnel at JSC and KSC
- Better allocation of payload time, enabling staffing of positions only when needed
- Scaling back the CoFR process to include only safety and interface items

Workload Factors. The Study Team recognizes that current workload is significantly driven by operations workarounds and frequent changes due to assembly configurations, constraints, and manifest. Also, the initiation of IP payload operations in 2004 will create a workload to define and verify the interfacing procedures beginning in 2003. An added learning curve must be expected with associated workload as IP operations begin.

PI/PD User Community Observations. The current PI/PD user community evaluates current payload operations as too complex and too cumbersome. This response occurred consistently in the POCAAS survey of researchers (see Section 2.4). Some relevant observations included the following:

Some of the researchers evaluate their effort required for ISS payload operations as two to four times greater than for the same or similar Shuttle/Spacelab payloads:

- "Differing standards, competing committee structures, changing requirements"
- "….requirements can be trimmed…."
- "…verification for non-critical requirements is ridiculous…."
- "…current ISS document burden is greater than for Spacelab….multiple documents or databases…requests for identical data in multiple places…then not used in real time…"
- "…not so much the number of approval levels as the number of points of contact…"

Need for Reengineering. The Study Team believes that the ISS Program, including POIF, needs an increased focus on finding new, simpler, less expensive processes, rather than just improving current processes. This means reduced requirements and documentation, better coordination and less overlap among functions, and greater reliance on competent but fewer people operating with less formality. The Team believes *strongly* that the necessary process and documentation reform must be accomplished at the payload integration level, not just within payload operations.

4.1.3 POIF Cost-Reduction Options

The POCAAS was established primarily to seek ways of reducing the cost of payload operations, from the perspective of an experienced Team external to NASA. The Team was also charged at the beginning of the study to seek innovative changes in architecture and concepts, as opposed to a detailed audit of current processes.

The Team, in assessing POIF, considered two approaches:

1. Conduct a detailed review of current requirements, processes, and standards to seek efficiency improvements. Incremental cost reductions would be identified against specific program changes.
2. Perform a bottoms-up estimate for a minimum, technically acceptable level of POIF, based on the assumption of basic operations principles and methodology, but assuming reasonable reduction of current program requirements and streamlining of current processes.

The Team selected Approach 2 as the most effective way to address the POCAAS charge. The Team believed that this approach would present the most innovative result and identify a minimum level at which, in the judgment of the Team, POIF could be successfully performed. This approach is consistent with the NASA direction at the beginning of the study to focus on concepts, not a detailed audit of current operations.

Approach 2 identifies the results potentially achievable by reengineering the POIF, as opposed to continuous improvement. The Team recognizes the ongoing continuous improvement efforts of the POIF team, as well as the ISS Program, and did not wish to duplicate those efforts. Within the time and resources available for the POCAAS, the Team does not believe they could acquire the detailed knowledge of the current performing organizations and better their continuous improvement results. However, the Team does believe that they present in this report a different perspective on POIF with potential cost reduction.

Caveat. Budget reduction based on this study must be accompanied by real changes in ISS Program requirements, processes, and standards, or ineffective payload operations will result.

The cost reduction option presented in the following analysis requires significant changes in requirements, processes, standards, and policies. Some of these changes are within Code U authority, some within ISS Program authority, and some require changes to policies that are institutional in nature.

The changes identified may result in increased but reasonable risk of crew and ground error with the result of a limited reduction in utilization efficiency. The Study Team believes that the increase in researcher satisfaction and reduction in cost greatly outweighs this risk. Some of the changes in reducing POIF cost could result in increased PI/PD workload and, therefore, should be subject to tradeoff to achieve reduction in total cost. In this regard, some may be applicable to classes of payloads, but not all payloads.

Some of these changes have been proposed individually during previous budget reduction exercises, and rejected as inappropriate within the prevailing program framework. That does not negate their reconsideration in the POCAAS, nor their acceptability in a different framework.

Recommendation. Budget reduction should be preceded by a definitive program action, working with the research community, to identify and define specific changes to reduce requirements, reduce complexity, increase flexibility, and reduce cost.

4.1.3.1 Concepts for POIF Cost Reduction

The Study Team began its assessment of POIF with the identification of a number of concepts for improvement in cost effectiveness.

- Consolidate payload operations requirements and standards, to the maximum extent possible, into one reference document. The composite set of requirements can then be managed more effectively than in multiple separate documents with separate approval channels. Requirements and standards should also recognize the diversity of payloads and offer flexibility for different classes of payloads.
- Focus the review of compliance with requirements and standards on the intent of the specification, and trade rework to meet requirements against the cost of strict adherence. Use standards as guidelines, rather than mandatory criteria. So long as safety of operation is not affected, delegate the interpretation and decision authority for acceptable compliance to the working level.
- Reexamine historical operations policies, which are largely based on sortie-mode operations (Shuttle and Spacelab), for applicability to ISS as a continuous research facility. Relax nonsafety criteria, optimizations, and constraints.
- Accept lower efficiency of payloads operations if necessary to reduce cost, while still working to improve efficiency over time. Accept increased risk to individual payload success on a given increment, while using continuing operation and reflight to increase research success in the longer run.
- Limit changes and recognize the cost of changes in allowing them (e.g., late changes in manifest, crew preferences).
- Reduce nominal POIF service levels to PIs/PDs. This may result in an increased burden on the PIs/PDs that increases total cost; therefore, provision should be made for exceptions, on an added cost basis, where PIs/PDs request assistance. Reduced service levels during real-time operations may result in a slower than desired response to payload problems or changes.
- Reduce lead times for products and activities as much as possible to reduce rework. Later lead times can allow more mature products from PIs/PDs in consideration of their development schedules, as well as minimizing impacts of late manifest changes.

4.1.3.2 Continuous Flow Concept

The Study Team observes that the ISS Program currently plans and executes operations as *increments* and *flights*, which are both essentially sortie modes. The crew is exchanged on an increment basis, and some planning and preparation takes place on that basis (e.g., the OOS, manifest selection, crew training). However, increments vary in length, and may be extended in length over time.

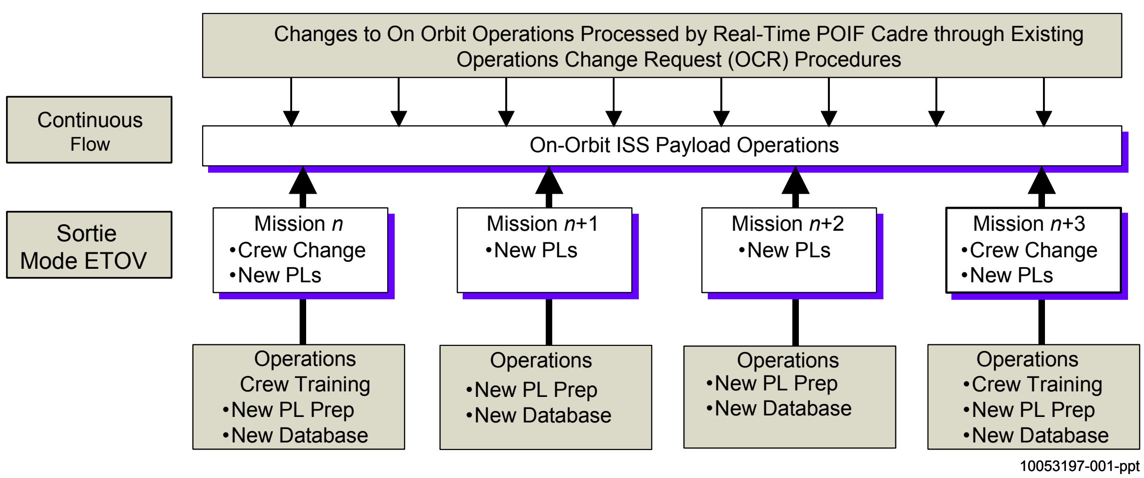
Payloads are manifested on ETOV flights, but some payloads continue operation across flight and increment boundaries. Telemetry and command databases change on a flight basis, requiring changes in onboard and ground displays and systems. Flight readiness review is accomplished on a flight basis. Because operations preparation is driven by the payload manifest, it is driven primarily by flights.

The Study Team observes that existing ISS processes and standards incorporate sortie mode policies. For example, the Payload Integration Process Improvements briefing to the ISS Independent Review (IIR) noted the following:

- "The PIA Addendum for each increment contains ascent and descent requirements and on-orbit resource requirements"
- "Because the ISS will use many aspects of the data collected for multiple increments, detailed standards have been established to ensure the usability of the products from one flight and crew to the next"
- "Flight products in the past have been tailored to the specific crew and reworked for the next flight"
- "Compared to Shuttle there are additional requirements and some that have become more strict…..driven in part…by the need to optimize the crew interface…."
- "The ISS integration template is driven by the ISS crew training template…the ISS template is longer by about three to six months"

The Study Team adopted the concept of *continuous flow*, as illustrated in Exhibit 4-8.

Exhibit 4-8. Continuous Flow Concept



Under the continuous flow concept, on-orbit operations are managed to the maximum extent possible as a continuous flow, using existing real-time staff and operations change request procedures in lieu of separate readiness reviews, control boards, and documentation. All changes in procedures and plans for payloads already on-orbit are managed through the OCR process. This will maximize productivity of the staff required to be on duty to manage real-time activities. The real-time staff can be supplemented during peak periods of change activity as needed.

Planning and preparations for logistics flights continue as a batch process, using off-line POIF staff. These preparations include procedures, displays, training, and PODF for new payloads which have not flown before, and for reflight payloads which have changed significantly since their previous flight. Long lead planning for new payloads and activities necessary to assess manifest compatibility are also conducted in this manner.

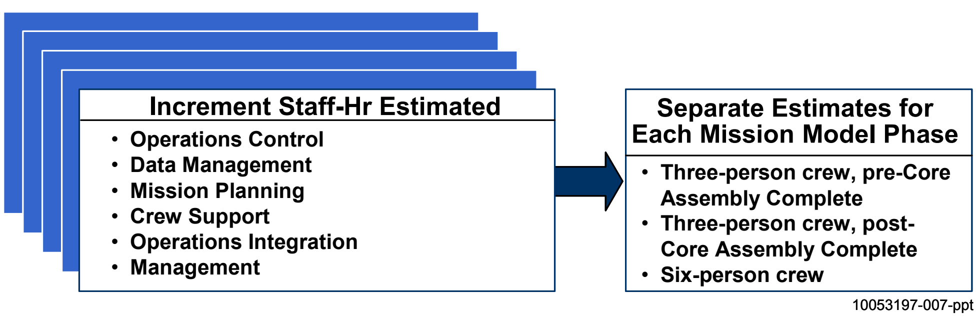
POIF staff members continue to be rotated between on-console shift duty in the POIC and off-line office support to maintain continuity and consistency in operations, and (importantly) to reduce the impact of shift work on the staff.

4.1.3.3 POIF Independent Cost Estimate Methodology and Assumptions

Applying the concepts identified in Sections 4.1.3.1 and 4.1.3.2, the Study Team performed a bottoms-up, minimum-service-level cost estimate. The cost estimate assumed the Mission Model described in Section 3.2.1, and that the minimum service level was appropriate for simple and average payloads, under the definitions in Section 3.2.1. The estimate assumed that optional additional POIF assistance could be made available at added cost. The PD would negotiate and fund added cost services at the time the planning for a payload began. Added cost services would be required for complex payloads and as optional assistance at PI/PD request.

Labor staff-hours for each of the basic POIF functions was estimated by week for a single 3-month increment as illustrated in Exhibit 4-9, time phased over 24 months, and assuming the payload complexity mix defined in the Mission Model.

Exhibit 4-9. Cost Estimate



Overlapping Increment Preparations Summed

This process was repeated to provide separate estimates for each of the program phases defined in the Mission Model:

- Three-person crew, pre-Core Assembly Complete
- Three-person crew, post-Core Assembly Complete
- Six-person crew

For each of the program phases, the individual increment estimates were then overlaid and summed to account for overlapping increment preparations. Level-of-effort estimates were also included for continuing activities in each POIF function that are required independent of increment activities.

The estimates made no distinction between Federal Government and contractor personnel, but only estimated labor hours required to perform work. The Study Team acknowledges that some additional overhead may be associated with the division of work between Government and contractor, but expects all staff to work as an integrated team.

Subteams of the POCAAS Study Team were established as shown below to perform the cost estimation.

- Planning – Jerry Weiler and Ed Pavelka
- Management, Operations Integration, and Operations Control/Data Management – Tom Recio and Fletcher Kurtz
- Crew Support – Chuck Lewis, Bob Holkan, and Ron Parise

The subteams based their estimates on the review of ISS Program presentations and documentation, the POCAAS Mission Model (Section 3.2.1), the concepts described in Sections 4.1.3.1 and 4.1.3.2, discussions with MSFC and JSC operations personnel, and their own expertise. Each subteam member has had years of prior experience in planning, performing, and managing the same functions for ISS and predecessor programs.

The entire Study Team reviewed and endorsed the subteam estimates.

Key factors in the basis of estimate for each functional area are summarized in the following paragraphs.

Operations Control/Data Management

Assumptions:

- Three increments in preparation and one increment in real-time support continuously (3-month increments)
- Data collection and preparation for an increment begins about 12 months before the increment, with majority of work performed during the last 6 months
- Systems and process development rework, when needed, begins 18 months prior to increment
- PLSS configuration stable after Core Assembly Complete
- KuBand communications coverage increased and stabilized after 2003
- Processes are stable and documented for three-person crew pre-assembly complete
- Use of on-the-job training is maximized using real-time slack time
- Reduced requirements, reviews, control boards, and documentation

The analysis found the workload to be not directly a function of the number of payloads or the complexity of the experiments. The magnitude and complexity of the ground support OC/DMC tasks is primarily a function of the composite payload increment integrated tasks, including OC/DMC requirements for PLSS support, television downlink/real-time support required during AOS, television scene setup and execution, command loads and verification and uplink sizes, recorder management and data distribution, integration of crew/telescience, and most importantly, the iteration of the above tasks during preincrement preparation and real-time. The labor estimate was assessed task by task based on the integrated payload compliment, and a separate payload data-gathering, maintenance, and consolidation preparation task (customer integration) was assessed experiment by experiment and summed with the integrated tasks described previously.

The estimate includes 10 percent of the operations preparation work done more than 12 months prior to increment, 30 percent done between 6 and 12 prior to increment, and 60 percent done within that last 6 months prior to increment.

The following risks are associated with the estimate:

- Limited service levels may impact smooth integration of IP payload operations during the transition
- Lengthened response to problem correction may result in loss of research efficiency

Planning

Assumptions:

- Increments are 3 months in duration, which implies that four increments are always in work simultaneously.
- Data collection for an increment begins 12 months prior
- Only one OOS is produced for an increment. This is delivered 2 months prior to the increment. The OOS planning level (complexity) is reduced wherever possible.
- Use of a typical (as opposed to specific) increment template for payload analytical integration analyses for assessing manifest compatibility.
- No special timeline development or planning for cadre, payload analytical integration, training, or simulations; prior operational or generic timelines used
- Manifest fixed at I-12 months; minor changes accepted at I-6 months
- Late manifest changes accepted on nonoptimized activity insertion basis only.
- Planning procedures stable after 2004.
- Reduction of program requirements and process flow documentation
- Training is accomplished on the job.
- A continuous operations flow concept is implemented.

In the analysis, the payloads in the Mission Model, including the continuing and reflight portion drove the Payload Activity Requirements Collection (PARC) and the pre-increment planning (OOS development) manpower. The lead-time and manpower were reduced due to the assumption of a single OOS. The Mission Model (both the number and complexity of payloads) also drove the number of pre-increment planners required. When the IPs where added, additional planning manpower was added to account for the integration of their payload timelines into the overall integrated station payload timeline.

The TCO position was reduced to 16 hours a day from 24 hours a day, seven days a week, under the philosophy of addressing problems on the day shift, as opposed to before the next crew awake shift.

The risk identified with the estimate is that the less optimized planning may result in a less timely research efficiency/accomplishment, but over time, with the continuous flow concept, the research will be accomplished.

Crew Support

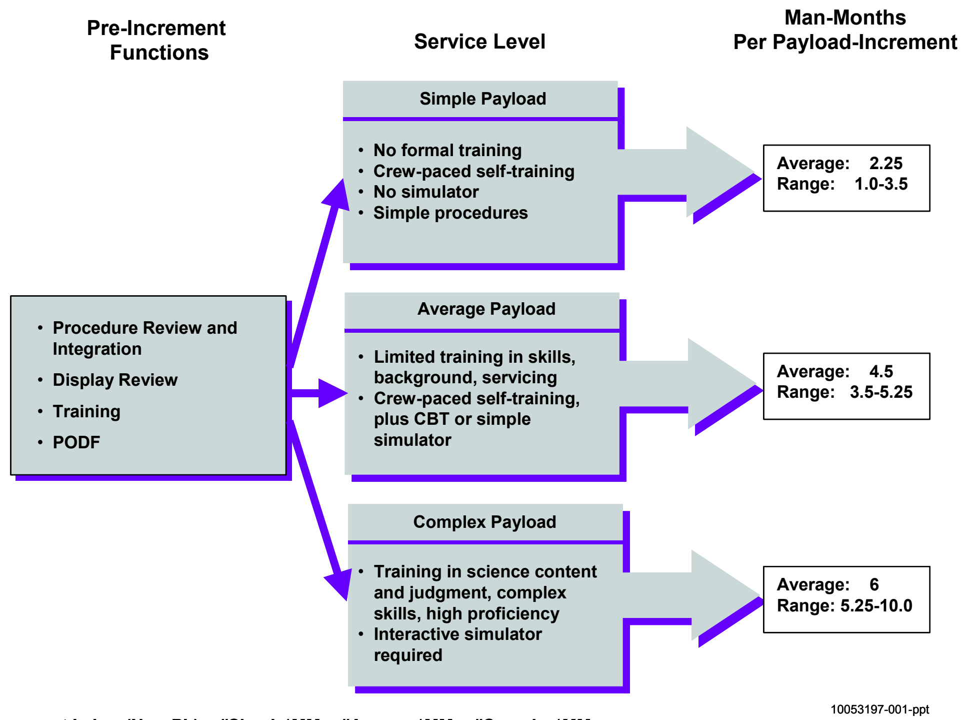
Assumptions:

- All functions described by MSFC in the Payload Operations Presentation to the POCAAS, November 13, 2001, for the Training Team, Payload Operations Data File Team, and Procedures/Display Review Panel must be performed
- Crew training is performed at the Payload Training Complex at JSC
- Manpower required to perform the POIF preparation functions (planning, coordination, facilitation, evaluation, training delivery) is directly proportional to required crew involvement for each payload, as reflected in complexity classifications
- A small amount of manpower is used to identify and categorize payloads early in the process flow; simple payloads then require little involvement later, and thus little or no manpower for some functions
- A fixed level of manpower is required for administration, coordination, and instructors located at JSC
- Reflight of a payload requires less manpower than the first flight; procedure and display changes are made only to fix operational problems (no personal preference changes)
- PD writes procedures to ensure proper operation and assumes risk for poorly written procedures
- PD designs displays to operate the experiment efficiently and assumes risk of poorly designed displays
- The exact same “look and feel” of procedures and displays among different experiments are not required; PD accepts risk of any inefficient experiment operations that may result from not fully meeting standards
- PD provides training to first-time crew; subsequent training is delivered by POIF staff

Crew support, more than other functional areas, is driven by the number of payloads and payload complexity. A time-phased crew support preparation estimate was performed for a “typical” payload in each of the three complexity levels (simple, average, and complex) defined in Section 3.2.1. A number of current payloads were evaluated in formulating the typical estimate. The resulting “typical” simple, average, and complex labor profiles were then summed for an assumed increment payload complement, based on the POCAAS Mission Model. Overlapping increment labor profiles were then summed to generate labor estimates for the three mission phases (three-person crew pre-AC, three-person crew post-AC, and six-person crew). A fixed LOE was added for management, administrative support, and other sustaining functions. The LOE crew support tasks that are not driven by the payload model were assumed to be stable after 2003.

The bottoms-up estimates were also used to generate the summary crew support parametric model illustrated in Exhibit 4-10.

Exhibit 4-10. Crew Support Parametric Labor/Payload Model



Increment Labor (New PL) = #Simple*MM + #Average*MM + #Complex*MM
Increment Labor (Reflight) = 0.4*(New PL)
Fixed LOE = 9

The risk associated with the reduced crew training model under this estimate is operations delay or crew error, which may reduce research efficiency.

Operations Integration

Assumptions:

- Procedures are stabilized after Core Assembly Complete
- Specialists (safety, stowage) provide support across all increments
- A payload operations director leads the preparation for each increment
- Flight-qualified PODs lead multi-increment integration tasks and reviews
- Payload operations directors lead real-time support on a 24-hours-a-day, 7-days-a-week basis

- Workload will move rapidly toward continuous process, rather than batch (increment) process
- Reduction in program requirements, reviews, and control boards

The operations integration workload was judged relatively insensitive to the number of payloads supported per increment but is driven by the number of interfaces and ongoing activities requiring coordination. The estimate requires the following:

- Five payload operations directors for real-time 24-hours-a-day, 7-days-a-week operations
- Four shuttle operations coordinators (SOC) for 24-hours-a-day, 7-days-a-week real-time support while the Shuttle is on-orbit, SOCs also perform premission planning and preparation for flights
- Three PODs for coordination of pre-increment preparations
- Two PODs for coordination of IP activities, plus one operations engineer
- Five safety engineers
- Three stowage engineers
- Two scheduling/integration and two ground support engineers
- Two project management and PCB/MCICB support engineers

The estimate assumes that Operations Integration staff are rotated among the on-console POD positions and other integration tasks, both to promote continuity and integration of activities, and to provide relief to shift work. The labor estimate is based on estimated work, not on the number of staff having the title "Payload Operations Director."

The principal risk in the estimate is that IP interface procedures and reviews are not yet fully defined, resulting in workload uncertainty.

Management

Assumptions:

- Line management is estimated within functional areas
- Scheduling is performed in operations integration
- Industry norms for management of 100 to 150 LOE services contract

The analysis estimates the following:

- Two senior managers (one Government and one contractor)
- Two LOE of administrative support
- One contractor LOE of business/contract support, based on industry norm for approximately 150 LOE services contract
- Two staff LOE for reporting and management support

4.1.3.4 Summary of Minimum Service Level Cost Options

POIF Cost Option 1. The results of the POCAAS independent cost estimate for a minimum acceptable level of POIF support are summarized in Exhibit 4-11.

Exhibit 4-11. Minimum Service Level Cost Option (LOE/year)

Function	Current	POCAAS Bottoms-Up Estimate		
	3 Crew, Pre-AC	3 Crew, Pre-AC	3 Crew, Post-AC	6 Crew
POIF Management	16	7	7	7
Operations Integration – RT	10	9	9	9
Operations Integration – Prep	25	19	20	20
Planning – RT	10	7	8	9
Planning – Prep	30	16	20	21
OC/DMC – RT	28	28	35	35
OC/DMC – Prep	60	36	43	46
Crew Support – RT	9	9	9	9
Crew Support – Prep	53	27	31	55
Total	**241**	**158**	**182**	**211**

The labor estimate is total LOE, including both Government and contractor. The estimate assumes the POCAAS Mission Model, the concepts discussed in Sections 4.1.3.1 and 4.1.3.2, and the further assumptions described in Section 4.1.3.3.

It is essential to recognize that the concepts included require an ISS Program-wide streamlining of requirements, processes, standards, and documentation to be successfully accomplished. POIF will not be able to achieve this level of operation independent of change in other program functions. Achievement of POIF cost reduction under this model is directly dependent upon ISS Program determination and decisions to accept performance risk and accomplish changes in current requirements, policies, and practices.

POIF Cost Option 2 – Elimination of SFOC Training Instructors. Current crew training plans require the POIF to integrate the training products and their initial delivery, but for repeating payloads, plans required the POIF to hand the delivery over to the SFOC contractor in the Payload Training Facility. This handover has not yet taken place. POIF Cost Option 2 eliminates this SFOC function and continues with the current practice of POIF and PI/PD staff delivering the training. The POIF Cost Option 1 estimate includes the total labor required.

POIF Cost Option 3 – PI/PD Assistance. The PIs/PDs vary in their experience level with human space operations, especially if they are first-time users. POIF assistance to inexperienced PIs/PDs in the past has reduced development time, reduced overall cost, and resulted in better operations products.

This cost option would provide a staff of 10 to 15 operations interface engineers in the POIF to work with PIs/PDs on an as-requested basis to assist them. (The number of staff should be based on current payloads in process and their needs). This approach can allow the PIs/PDs to focus on their core competencies of science research and experiment development, while using experienced operations personnel to translate experiment data into operations products and formats.

The operations interface engineers, if maintained in a separate pool within the POIF, can provide an added role of advocacy for continuous improvement of the researcher interface within the POIF.

POIF Cost Option 4 – IP Operations Interface Preparation. Limited process and procedural definition has been accomplished to date for IP payload operations interfaces. A dedicated team of 5 to 6 operations personnel is needed in 2003–2004 (or beginning approximately 2 years prior to Columbus/JEM on-orbit delivery) to work with the PCCs to develop interfaces. Some additional resources may be required in 2004 (or beginning approximately 1 year prior to Columbus/JEM on-orbit delivery) for joint simulations to validate procedures and train IP personnel. The resource level needed is dependent upon SSCC simulation plans.

Implementation Considerations

A balance should be maintained between Government and contractor staff. The Government component is essential because of NASA's responsibility and to maintain a core skill base. The POIF Contract (NASA-50000) ends in FY 2005, and a recompete is assumed to take place in FY 2004.

Capability must be kept to rotate staff between on-console real-time shifts and preparation work performed in the normal office work environment. This rotation is essential for staff retention and maintenance of skills.

A phase-in of the POCAAS minimum service level model is required to accomplish changes in current requirements, documentation, and operating practices, and to avoid disruption to ongoing payload operations. A recommended phase-in profile is shown in Exhibit 4-12. The profile reflects a transition in FY 2002–2003 to the Minimum Service Level Model. A transition from the three-person crew, Pre-Core Assembly Complete payload traffic model (30 payloads/increment) to the higher three-person crew, Post-Core Assembly Complete payload traffic model (40 payloads/increment) begins in FY 2005, based on the POCAAS Mission Model. Although IP payload operations may begin in FY 2005, the total payload workload does not change until FY 2006. The additional initial effort required for integration of the IPs into payload operations is separately accounted for in Option 4. The transition to the six-person crew payload traffic model (70 payloads/increment) begins in F2008.

The assumed Government staff level in FY 2003 and subsequent is an arbitrary fraction of the total staff.

4.1.3.5 POIF Recommendations

POIF Recommendation 1 – Minimum Service Level. The Study Team recommends that POIF Cost Option 1 be adopted, with an appropriate phase-in, and conditional upon similar ISS Program changes in payload integration that are necessary for the success of this option.

Exhibit 4-12. LOE Phasing for POIF Cost Options

FY	02	03	04	05	06	07	08		10	11
Cost Option 1										
Government	66	58	50	50	50	50	50	50	50	50
Contractor	175	142	108	120	132	132	147	161	161	161
Cost Option 3										
Contractor		15	15	15	15	15	15	15	15	15
Cost Option 4										
Contractor		5	5							
Total	**241**	**220**	**178**	**185**	**197**	**197**	**212**	**226**	**226**	**226**

POIF Recommendation 2 – Elimination of SFOC Training Instructors. The Study Team recommends that this option be adopted. A level of SFOC funding must be maintained for PTC maintenance support.

POIF Recommendation 3 – PI/PD Assistance. The Study Team recommends that POIF Cost Option 2 be also adopted, subject to a review of the planned payload manifest and the needs of manifested PIs/PDs.

POIF Recommendation 4 – IP Operations Preparation. The Study Team recommends that POIF Cost Option 3 be reviewed with respect to IP agreements, processes, and timing. Timely preparations for IP payload operations are essential to avoid disruption and loss of science return.

4.2 Payload Operations Integration Center

4.2.1 Current POIC Description

The POIC is the facility located at MSFC that houses the central information technology infrastructure for payload operations, and hosts the POIF and the U.S. Operations Center (USOC).

The USOC is a portion of the POIC that provides floor space with access to POIC services for PIs who may wish to operate their ISS payloads from that location.

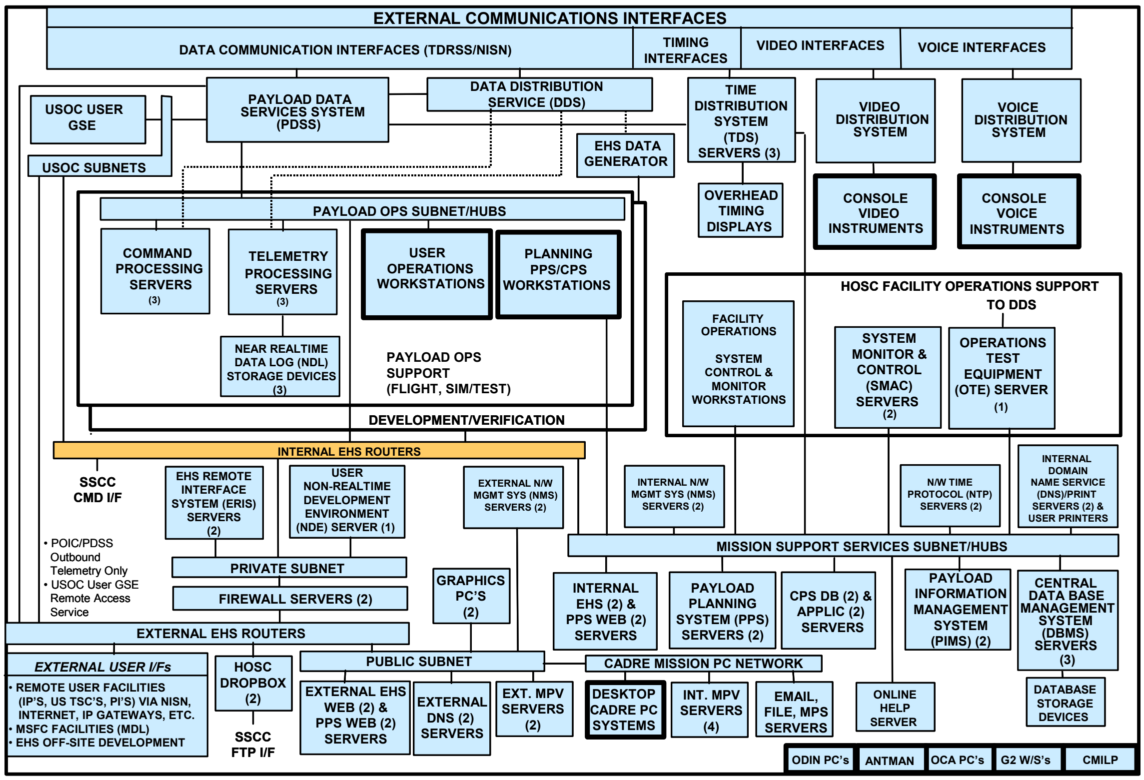
The POIC performs the following functions:

- Real-time (RT) and near-real-time (NRT) telemetry processing
- Command processing
- POIC and remote command and display processing
- KuBand data distribution via the Payload Data Service System (PDSS) to the Internet
- Local and remote voice communications (HVoDS/IVoDS)
- Local video distribution

- Hosting of operations tools
  - Payload Planning System (PPS)
  - Payload Information Management System (PIMS)

A schematic of the POIC information systems is shown in Exhibit 4-13.

Exhibit 4-13. POIC Schematic



10053197-009-ppt

The system is relatively complex, due to the multitude of services provided. The system is also highly distributed, due to its design in the early 1990s based on Unix server technology prevalent at the time. The system is highly capable and flexible, providing a variety of services and features.

The system includes about 150 workstations that are used principally by POIF operations personnel. The system also supports remote users at the TSCs and at RPI locations. Portions of the system are designed to support up to 300 simultaneous remote users.

4.2.2 POIC Cost Elements

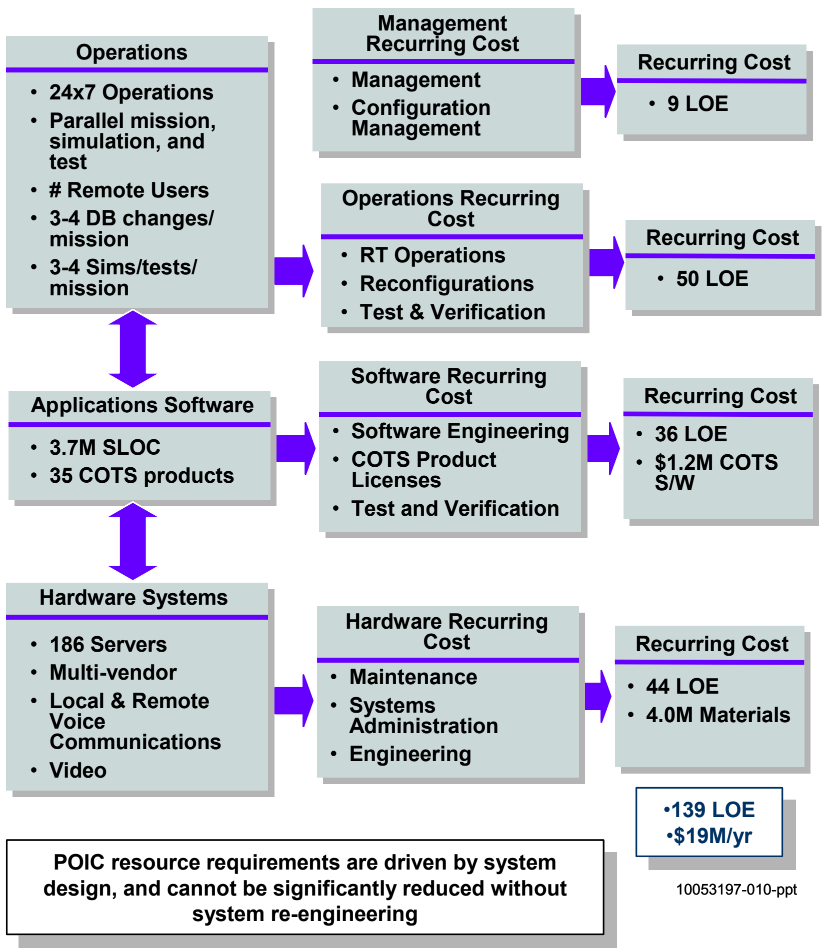
The POIC cost elements are shown in Exhibit 4-14.

The Hardware Systems hosts 3.7 million source lines of code (SLOC) of custom applications software, which perform the functions shown above. The software was designed to reduce custom code through the use of commercial off-the-shelf (COTS) products and contains 35 commercial software products.

The operations staff is responsible for conducting 24-hours-a-day, 7-days-a-week operations of the systems and supporting in parallel the real-time ISS mission, including Shuttle data processing; mission simulation; and information systems test, both internal and with external locations.

The recurring costs are driven largely by the system design—the large number of servers that must be maintained and configured, the quantity of COTS software licenses, the amount of custom code that must be maintained, and the resulting operational complexity. The operations staff is also driven by the operational workload, i.e., the number of parallel simulations and tests.

Exhibit 4-14. Current POIC Cost Elements (Pre-FY 2002 Budget)



4.2.3 General Findings

POIC Status. The POIC development was essentially completed within the past year, although the last developmental software delivery is scheduled for second quarter of CY 2002.

In parallel with completion of development, the POIC has undergone a staff reduction from 250 LOE in March 2001 to about 140 at the time of the POCAAS study, with a further planned reduction to 125 in March 2002.

The Study Team observes that systems of this type typically require approximately a year to stabilize their configuration, software, and operation after development is complete. The POIC is still in this shakeout period.

Need for Technology Refreshment. The Study Team observes that technology refreshment is essential to reducing POIC recurring cost as well as maintaining system effectiveness. Some POIC equipment (e.g., SGI Indy workstations, SGI Challenge Servers) are at or nearing end-of-life and/or economical operation. Newer technology would allow system consolidation and lower maintenance and operating cost. Simplification of the system and increased automation of operations is also essential to reduce labor cost. However, the necessary reengineering, software migration, and hardware replacement requires an investment to accomplish.

FY 2002 Budget. The FY 2002 POIC budget guidelines require an immediate and continuing 10 percent reduction in annual operating cost. MSFC responded to these guidelines with a request for an increase of $3.5 million in FY 2002–2003 funding to enable reengineering to achieve the 10 percent reduction in the out-years. MSFC proposed four initiatives to achieve this reduction:

- Consolidation of the command, telemetry, and database server functions onto new SGI clustered servers, with an FY 2002 hardware buy
- Migration of the workstation command and display functions from the current SGI Indy workstations to PCs
- Reengineering of the PDSS to consolidate servers and replace the custom CCSDS packet processing hardware with a general purpose system
- Simplification of PIMS and removal of the expensive In-Concert COTS software

MSFC also provided a budget alternative that would meet the FY 2002 budget guidelines without over-guidelines in FY 2002–2003, but with significant impacts and risk. Measures proposed to allow this would include operating without vendor maintenance for several years and a moratorium on any functional software changes, until the resources thus freed could be used to reengineer the system and migrate the software to Intel-based servers with a Linux operating system.

MSFC did not address means of further cost reduction beyond the FY 2002 guidelines.

4.2.4 POIC Cost Reduction Option

The Study Team reviewed and updated the POIC Ground Data Systems Independent Assessment previously performed by Fletcher Kurtz in support of the MSFC Ground System Department. This updated assessment identifies a variety of actions to reduce POIC recurring cost.

- Consolidate server functions on new technology systems that afford significantly greater performance at reduced acquisition and operating cost
- Provide sufficient robustness and reserve capacity to allow maintenance on a nominal 8-hours-a-day, 5-days-a-week basis
- Migrate display functions from Unix workstations to PCs
- Perform software migration in a way that provides future portability across platforms

- Adopt a software productivity improvement program in accord with the Software Engineering Institute standards. This methodology has been shown to achieve a 15- to 21-percent reduction in effort for a one-increment change in the Software Process Maturity Level. The POIC contractor does not currently have such a program.
- Reengineer PDSS to consolidate servers and replace the custom CCSDS packet processing hardware with a general purpose system.
- Simplify PIMS and remove the expensive In-Concert COTS software
- Reengineer PPS to simplify operation, provide better integration with CPS, and eliminate at least the DEC server currently in use for data management timelining.
- Reengineer operations processes to take advantage of the system consolidations, and to provide increased automation
- Evaluate use of leasing of major hardware systems over a 3- to 4-year period to reduce the need for capital investment in hardware refreshment. The rapid progress in information technology requires that systems of this nature should be replaced every 3 to 4 years to maintain cost effectiveness.

The reengineering, hardware upgrades, software migration, and systems verification required to achieve these actions require a substantial investment. However, the investment can result in an 18 percent reduction the 10-year cost of the POIC.

- Invest approximately $6 million in FY 2002–2004 above the FY 2002 budget guidelines
- Reduce the operating budget in FY 2005–2011 to approximately $13 million per year (FY 2002 dollars)
- Achieve a reduction of $36 million (18 percent) from the FY 2002 budget over the 10-year period (FY 2002–2011).

4.2.5 POIC Recommendations

Recommendation 1. Develop a long-term plan for POIC evolution that provides for regular technology refreshment that will leverage technology progress, as well as anticipate future PI requirements.

Recommendation 2. Reengineer the POIC system in FY 2002–2004 to introduce current market technology and reduce operating cost, in accordance with the cost-reduction option described in Section 4.2.4.

4.3 Telescience Support Centers

In assessing the TSCs, the Study Team requested the Program Office to provide the following information on each TSC:

- A description (provided in the form of a user's guide for each TSC)
- Answers to several specific questions:
  - What are the functions and capabilities of the TSC?

- What payloads are supported by the TSC?
- What capabilities and functions does the TSC provide that are not provided by the POIC/POIF?
- What capability does the TSC have to process payload timeline planning, data, and commands independent of the POIC?
- What augmentation would be required to the TSC for it to conduct science operations without the POIC/POIF?
- What are the recurring operations costs for the TSC?

The responses to these questions were given in presentations by each TSC at the second meeting of the Study Team.

The assessments in this section are based on the material provided.

4.3.1 Description of Current TSCs

Currently, the four TSCs are located at ARC, GRC, JSC, and MSFC. The TSCs are generally multipurpose facilities that perform multiple services, payload operations representing only one area of services.

All of the TSCs provide host facility and information technology services for PI teams in a locale; these services typically include operational voice communications, local video processing and distribution, and data communications.

The ARC, GRC, and JSC TSCs also importantly provide facility class payload integration and timeline planning. Facility class payloads are generally ISS racks that contain equipment custom-designed to support the unique need of a single discipline, and within which multiple experiments can be operated. Current examples are the Biological Research Project (BRP) at ARC, the Fluids Integrated Rack (FIR) and Combustion Integrated Rack (CIR) at GRC, and the Human Research Facility (HRF) at JSC. Each TSC is responsible for the pre-increment integration and planning for research to be conducted in their facility rack, and on-orbit integration of payload operation as well as real-time control of the facility rack itself.

The MSFC TSC offers similar services for EXPRESS rack payloads but has delegated the responsibility for real-time control of the EXPRESS racks to the POIF.

All TSCs host and obtain synergy from related Research Project Office functions, such as scientific data archiving and flight facility and/or experiment development laboratories.

From the viewpoint of the payload operations architecture, TSCs can be regarded in function and capability as super-RPI sites. They are intended to perform functions similar to any RPI site, but for multiple payloads, or for a dedicated research facility-class rack.

Some characteristics of the individual TSCs are discussed below.

4.3.1.1 ARC TSC

Specialized functions:

- Facility class payload integration and timeline planning

- Monitoring and control of control group for biology experiments
- Science data processing
- Biology data archiving
- Hardware acceptance test and bio-compatibility testing
- Ten Mb/sec interface to Biology Research Project hardware at integration sites, launch sites, and onboard ISS
- Custom communications and data system for BRP data

Experiments currently supported:

- ADF (8A/UF-1/UF-2)
- BPS (8A/UF-1/UF-2)

Dependency on POIC:

- Voice and raw telemetry delivery
- Payload Planning System access

Resources:

- Operating budget: $1.1M/year
- Maintenance and sustaining engineering manpower: 3.5 FTEs
- Mission-dependent manpower: 3 FTEs + 7 EP/4 months

4.3.1.2 GRC TSC

Specialized functions:

- Facility class payload integration and timeline planning
- Science data processing and temporary storage

Experiments currently supported:

- SAMS
- FIR – late 2005
- CIR – no earlier than late 2005. Development uncertainties.

Dependency on POIC:

- Voice and processed telemetry delivery
- Trek workstations for command and control processing
- Payload Planning System access

Resources:

- Budget: $1.2M/year
- Nine FTEs for facility engineering, maintenance, training, and operations

4.3.1.3 JSC TSC

Specialized functions:

- Facility class payload integration and timeline planning
- Data transfer to life sciences data archive
- Shared for MCC software testing, ISS simulations, and flight controller training

Experiments currently supported:

- Human Research Facility (HRF)
- Biotechnology (BSTC and BTR)
- ARIS-ICE
- Earth Observations
- EARTHKAM

Dependency on POIC:

- Voice and raw telemetry delivery
- Payload Planning System access

Resources:

- Budget: $2.4M/year ($0.2M/yr in ISS utilization budget; remainder RPO)
- TSC operations: 6.6 FTE
- TSC Data Systems: 12.9 FTE

4.3.1.4 MSFC TSC

Specialized functions:

- Hardware development and test

Experiments currently supported:

- Material Science and Biotechnology Glovebox experiments
- Protein Crystal Growth (PCG)

Dependency on POIC:

- Voice and processes telemetry delivery
- Trek

- Payload Planning System access

Resources:

- Budget: $0.36 M/yr
- 2.5 FTEs

4.3.2 TSC Findings

The Study Team evaluated the TSCs only against their ISS operations and utilization budgets. The POCAAS scope does not include other RPO-funded functions.

The Study Team observed that the ARC and GRC TSCs were principally designed for operation of dedicated facility racks. However, at ARC, the flight of space biology payloads will be limited by three-person crew time. At GRC, the FIR and CIR are planned no earlier than late 2005. Furthermore, the current mission model supports only one payload insert per dedicated facility rack per increment, as compared to the original plan for multiple inserts per increment. The payloads currently supported by the ARC and GRC TSCs require only RPI level support, which is typically provided at lower cost than the ARC and GRC budgets.

The JSC TSC is currently supporting HRF, other payloads, and other RPO functions, and is largely funded from other RPO sources.

The MSFC TSC is currently supporting EXPRESS rack payloads and MSG at a nominal cost.

Recommendation 1. Defer development and operating costs for the ARC and GRC TSCs until needed for dedicated facility rack operation, no earlier than 2005.

Recommendation 2. Transfer TSC responsibility from payload operations budget to RPO budgets. Do not consider TSCs as common-use payload operations services, but treat them as any other RPI site, with cost justified as part of the cost of payloads.

4.4 NASA Integrated Services Network

The current NISN budget will be discussed first, followed by a discussion of the Enhanced Communications for Payloads budget line item in FY 2004–2006.

4.4.1 NISN Budget and Services

The current NISN budget of $4.1 million in FY02 can be decomposed as shown in Exhibit 4-15.

The SSCC-POIC services and the POIC-TSC services consist primarily of T1 channels provided through the NISN network.

The POIC-WSC 50 Mb/sec data circuit is a satellite link that carries the KuBand data to both the POIC (for payload data distribution) and to the SSCC (for onboard video processing and recorded core system data). The cost of the satellite link is shared, and only the payload's 50 percent cost is shown here. This satellite service is under a contract which expires in 2 years.

The A/G video to the ARC and GRC TSCs is via a leased satellite channel, while the A/G video distribution to the RPIs is planned via mpeg over the Internet. The cost is for Internet 2 access

Exhibit 4-15. FY 2002 NISN Budget

Services	Budget ($k)
SSCC-POIC – voice, S-Band data, A/G video	935
POIC-WSC – voice and 50 Mb/sec KuBand data	1051
POIC-TSCs – voice and data	571
A/G Video to ARC and GRC TSCs	240
A/G Video to RPIs	540
IVoDS (begins March 2002)	205
HVoDS to 10 RPIs (temporary until IVoDS)	196
Data to RPIs via Internet	250
Miscellaneous	120
Total	**4108**

services. The A/G video is currently converted to mpeg format at the SSCC, and transmitted to the POIC as part of the SSCC-POIC data stream.

Voice distribution to the RPIs is currently provided via HVoDS instruments, which operate over leased circuits to the POIC voice system. RPI operational voice requirements include the ability to monitor as many as eight different voice loops simultaneously, while talking on one. The IVoDS development enables voice transmission over the Internet, using voice-over-IP (VOIP) technology, and using PC software at the RPI to control the voice loops.

The FY 2002 budget level is essentially continued through FY 2006, with 10 percent increases each year.

4.4.1.1 NISN Budget Findings

The priority of delivering onboard video to all TSCs and RPIs for operation of payloads is unclear. Some payloads requiring video for operation have embedded payload-unique video into their KuBand data streams. Although general distribution of video is good public relations, its value should be balanced against cost. If only a few payloads require onboard video for payload operation, not all at the same time, less expensive alternatives may exist. Potential alternatives include call-up satellite transmission service, as used by local television stations, or use of NASA TV for limited periods. NASA TV was used throughout the Spacelab Program for general dissemination of onboard video transmissions.

HVoDS can satisfy RPI requirements (10 sites) through 2003 for equal or less cost than IVoDS. Longer term cost savings with IVoDS, as RPI requirements increase, are dependent upon resolution of technical issues, primarily the bandwidth requirements for satisfactory operations (up to 300 Kb/sec per remote instrument). Another factor is the anticipated technology refreshment of the HVoDS system in the 2005 time frame, and what capabilities a replacement system may offer for remote voice distribution. VOIP technology is developing very rapidly, and commercial products may become available at lower cost.

The cost for the POIC-WSC circuit is locked in by contract through 2003; however, the current marketplace offers equivalent service for less cost. A 50 percent or greater cost reduction is possible in 2004.

Similarly, the NISN costs for the T1 channels used for transmission of voice and data between the SSCC and POIC, and POIC and TSCs, are a multiple of current commercial T1 costs.

Observation. NISN budget projects increases of 10 percent per year over the next 3 years, while commercial data communications costs are dropping by 40 percent per year.

4.4.1.2 NISN Recommendations

Recommendation. Pursue alternative means of providing needed communications services at lower cost.

Recommendation and Cost Option 1. Defer the requirement for general video distribution to the TSCs and RPIs, with a cost reduction of $780K/year. Address specific payload operations requirements on a case-by-case basis, and budget as an optional service to the payload. Reevaluate the use of NASA-TV for limited payload requirements.

Recommendation and Cost Option 2. Reevaluate implementation of IVoDS, and consider deferral of implementation until payload requirements and technical status justify the move from HVoDS. The reevaluation should include commercial alternatives to the current custom solution.

4.4.2 Enhanced Communications for Payloads

The FY 2004–2006 budgets contain $24.9 million for enhanced communications for payloads. The origin of this item is a projected requirement for 150Mb/sec data downlink via the KuBand system, an upgrade from the 50Mb/sec capability currently provided.

4.4.2.1 Background

The ISS KuBand communications subsystem was designed to provide 150Mb/sec service on the return link for payload data. The ground network, however, can currently support only 50 Mb/sec. This includes the circuits from WSC to MSFC and JSC, and the front-end processors at MSFC and JSC. The plan was that, when user bandwidth requirements exceeded the current 50Mb/sec capability, the ground network could be upgraded to accommodate the higher rate already available from the vehicle.

A plan for implementing this upgrade was built into the CSOC contract in the form of the so-called “Option 6”. This contract option is intended to provide 150Mb/sec circuits from WSC to MSFC and JSC as well as provide for the development of new front-end processors to handle the higher rate from the ISS. However, no provisions exist for any upgrades to the on-board data system in CSOC Option 6. The current estimate for exercising Option 6 is in the neighborhood of $34 million.

In 2000, NASA entered into an agreement with Dreamtime, Inc., to provide a significant amount of high-definition television (HDTV) from the ISS. This project immediately drove the bandwidth requirements above the 50Mb/sec level. CSOC was asked to investigate ways to implement HDTV on the ISS KuBand return link.

Dave Beering (now the CSOC chief engineer) developed a concept that would replace the end-to-end KuBand system (space and ground segments) with commercial data communications technology. This concept, called "Enhanced Option 6", is based on the asynchronous transfer mode (ATM) link layer and would provide transparent connectivity between the on-board systems and the ground network at the standard ATM rate of 155Mb/sec. Enhanced Option 6 is estimated to cost about $28 million.

The original Option 6 has the disadvantage of requiring the investment of a sizeable amount of money in developing new 1980's technology hardware. The commercial telecommunications industry has evolved very rapidly over the past 20 years and now has many solutions that far exceed the requirements of the ISS. Many advantages exists to upgrading to commercial telecommunications technology both in terms of cost and of performance:

- Some components of the current KuBand space segment, such as the high-rate frame mux (HRFM) and video baseband signal processor (VBSP), have only one spare. Loss of either of these components will create single points of failure that will be difficult to recover from should another failure occur. The upgrade to commercial technology will eliminate the need for these components.
- Technology upgrade paths are continuously being developed and are available from multiple vendors.
- Maintenance and operation of commercial equipment is less expensive
- Software products are commercially available to provide services over commercial network interfaces.
- Network security solutions are readily available and need not be custom developed

4.4.2.2 Findings

The Study Team was unable to identify any driving requirement in the near term greater than the 50 Mb/sec data rate. However, as the number and variety of payloads increase, additional requirements will likely arise.

Several options are available to increase the current 50 Mb/sec bandwidth, recognizing that the ISS onboard system can currently support 150Mb/sec, but that the ground systems cannot:

- **Option 1.** Use the existing WSC-POIC/PDSS architecture, and increase the WSC-POIC circuit bandwidth to 75 Mb/sec. The approximate circuit cost, if implemented after 2003 when the current circuit commitment expires, would be less than $750K, which is less than the current 50Mb/sec circuit cost. (This option does not consider circuit cost to the SSCC associated with this upgrade.)
- **Option 2.** Use the existing WSC-POIC/PDSS architecture, but implement the POIC FY 2002 initiative (see Section 4.2.4) to reduce PDSS operating cost. This initiative also will increase the PDSS capacity to allow 150Mb/sec service. Increase the WSC-POIC circuit bandwidth to 150Mb/sec. The approximate circuit cost (after 2003, as for Option 1) would be approximately $1.5M/year.
- **Option 3.** Implement a variant of CSOC Enhanced Option 6, which would enable industry-standard data communications from an ISS payload direct to an RPI via the

Internet (see Section 5.1, Option F, for further discussion). This option shifts the PDSS function to WSC and could significantly increase the ability of PIs to communicate transparently with their payloads. The approximate development cost is approximately $25 million; annual operating cost would be similar to the other options.

The upgrade to 150 Mbs should be accomplished when the requirements mandate the additional bandwidth. When the requirement does exist and in consideration of obsolete systems that need replacement, it would be the appropriate time to implement the CSOC Enhanced Option 6 that would replace and upgrade technology both on ISS and in the ground system.

4.4.2.3 Recommendations

Recommendation and Cost Option 1. Defer the requirement for an increase in the current 50Mb/sec capability until a justified payload requirement, or requirement to replace the onboard ISS system, is defined. When a requirement is defined, evaluate the alternative ISS onboard and ground implementation alternatives to meet the requirement.

Recommendation 2. In the longer term, the Study Team recommends migration to the use of industry-standard data communications directly from an ISS payload to an RPI via the Internet. This option could significantly increase the ability of PIs to communicate transparently with their payloads.

4.5 Cost Reduction Options Summary

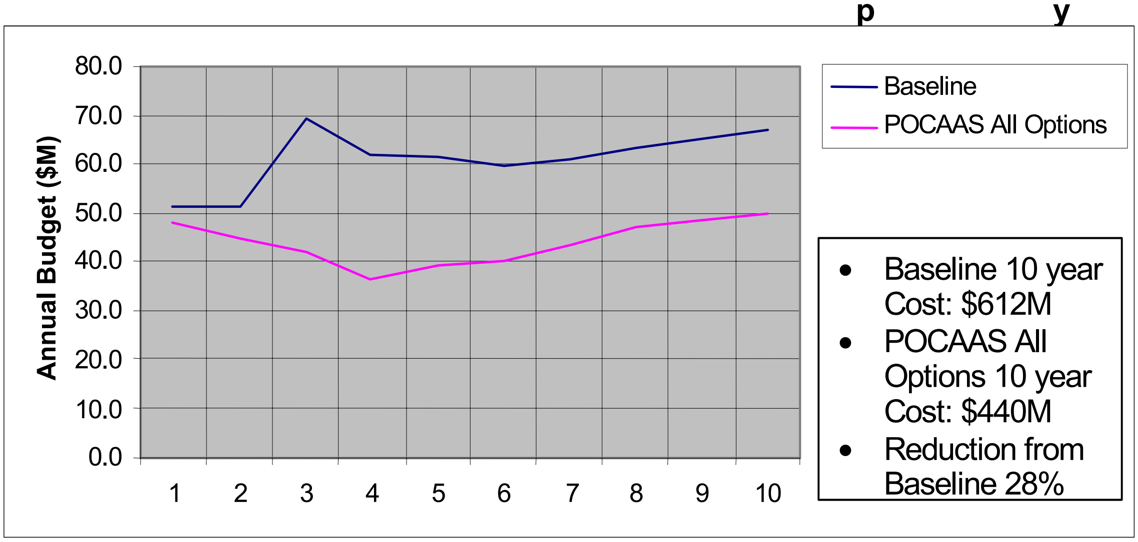
A comparison of the current payload operations budget incorporating all cost options recommended by the Study Team is shown in Exhibit 4-16. The current budgets provided to the Team have been projected beyond 2006 using a 3-percent escalation factor. The same escalation factor has been applied in constructing the POCAAS minimum service cost. For POIF, a labor cost of $125,000 per person-year has been assumed, derived from the FY 2002 budget of $22 million and contractor LOE of 175.

Exhibit 4-16. FY 2002 vs. Minimum Service Cost

UPN		ITEM	02	03	04	05	06	07	08	09	10	11	01-11
~~FROM 39X RESEARCH PROGRAMS~~													
		TSCs	3.2	2.7	2.6	3.5	2.7	2.8	2.9	3.0	3.1	3.2	29.7
		POCAAS	0	0	0	0	0	0	0	0	0	0	0
~~FROM 479 PAYLOAD OPERATIONS AND INTEGRATION~~													
479-20	JSC	NISN (SOMO)	4.1	4.5	5.0	5.5	5.7	5.9	6.0	6.2	6.4	6.6	55.9
		POCAAS	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	34.5
479-41	JSC	ENHANCED COM			16.0	5.3	3.6						24.9
		POCAAS	0	0	0	0	0	0	0	0	0	0	0
479-42	JSC	P/L TRNG-TSC (PTC)	1.0	0.4	0.4	0.3							2.1
		POCAAS	1.0	0.4	0.4	0.3							2.1
479-42	JSC	P/L TRNG-SFOC (PTC)	1.1	1.9	1.9	2.1	2.3	2.4	2.5	2.6	2.7	2.8	22.3
		POCAAS	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	3.4
478-43	JSC	PPS	0.3										0.3
		POCAAS	0.3										0.3
479-22	MSF	POIF (+65 CS)	22.0	23.9	25.1	26.0	26.9	27.7	28.5	29.4	30.3	31.2	271.0
		POCAAS (+50 CS)	22.0	20.9	17.1	18.5	20.8	21.4	24.2	27.2	28.0	28.9	229.1
479-XX	MSF	POIC & PDSS	18.4	17.1	17.8	18.2	19.1	19.7	20.3	20.9	21.5	22.1	195.0
		POCAAS	20.4	19.1	19.8	13.0	13.4	13.8	14.2	14.6	15.1	15.5	158.9
479-43	MSF	PPS	1.1	0.8	0.8	1.1	1.1	1.1	1.2	1.2	1.2	1.3	10.9
		POCAAS	1.1	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	11.3
		BASELINE TOTAL	51.2	51.3	69.6	62.0	61.4	59.6	61.4	63.3	65.2	67.2	612.2
		POCAAS	48.1	44.8	41.8	36.5	39.0	40.2	43.6	47.1	48.5	49.9	439.6

The total cost comparison is shown graphically in Exhibit 4-17.

Exhibit 4-17. Baseline Architecture Cost Option Summary



4.6 Organization and Contractor Findings

In the course of the POCAAS, the Study Team noted instances of a lack of common purpose and integrated approach to achieving enhanced research results and a more effective total organization.

Organization Recommendation. To achieve the efficiencies reflected in the POCAAS cost options, technical integration must be strengthened both among the payload operations elements (POIF, POIC, and NISN), and between the payload operations and engineering integration elements of the program.

The Study Team also recognizes that the POIC is planned to transition from the UMS contract to the CSOC contract at the end of FY 2003. However, the reengineering of the POIC to reduce cost will require several years to complete, and a transition during the reengineering process could result in schedule delay and increased cost. The POIF contract (NASA 50000) expires near the end of 2005, coinciding with scheduled commencement of IP payload operations.

Contract Recommendation. NASA should evaluate the phasing of contract transitions in view of ISS phasing and cost-reduction goals.

5. Alternative Architectures and Mission Concepts

The Study Team evaluated six alternative payload operations architectures and six alternative mission concepts.

5.1 Evaluation of Alternative Payload Operations Architectures

The Study Team defined *architecture* to mean a distribution of functions among payload operations elements. The elements in the architecture were those described in Section 3.3 (SSCC, PCCs, POIF, POIC, TSCs, NISN). The Study Team found no reason to define additional architectural elements. The Team considered that the basic functions of the POIF, and POIC must be provided in some way within a valid architecture.

In addition to the alternate architectures presented here, the Study Team discussed variants to this set, but found none that were practical, distinctly different, or offered significant advantages over those presented.

5.1.1 Definition of Alternative Payload Operations Architectures

The Team evaluated six alternative architectures:

- Current architecture
- Reengineered current architecture (see Section 4)
- Rotate POIF functions among the POIC and IP PCCs
- Rotate POIF and POIC functions among the TSCs
- Move POIF/POIC to SSCC
- Space Internet infrastructure

The Study Team evaluated the alternative architectures to determine their relative effect on ISS research utilization, the 10-year cost of payload operations, and other significant factors. Ten-year cost was used rather than annual recurring cost to account for investments required in some alternatives.

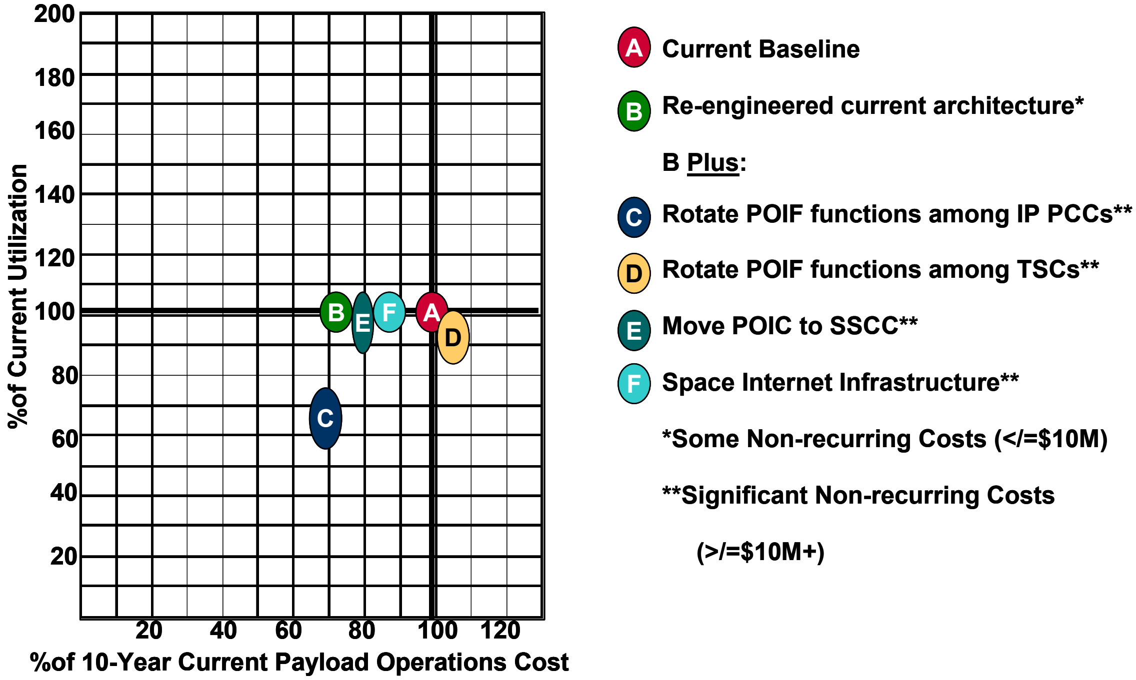
In evaluating the recurring cost, the Team assumed that all architectures except Alternative A (the current architecture) adopted the efficiencies projected in the minimum service level principles used in Alternative B (the reengineered current architecture).

The relative comparison of each alternative against research utilization and recurring cost is shown graphically in Exhibit 5-1, with a qualitative statement as to the significance of other advantages and disadvantages. Each alternate architecture is then discussed in turn.

A. Current Architecture

The current architecture is described in Section 3.3. In Exhibit 5-1, it represents the origin of the coordinate system against which the other architectures are compared.

Exhibit 5-1. Notional Research/Cost Evaluation of Alternative Architectures



B. Reengineered Current Architecture

This architecture incorporates the reengineering of requirements, processes, and functions as discussed in Sections 2.4.5 and 4.1.3.1. The reengineered architecture has lower cost than the current architecture (Alternative A) and provides an improved environment for research. This alternative has no disadvantages to Alternative A.

C. Rotate POIF Functions Among the POIC and IP PCCs

In this architecture, the ESA PCC, NASDA PCC, and the POIF/POIC would each assume control of ISS payload operations for one shift per day.

The IP PCCs would be required to develop the capability to use the U.S. C&DH, and to develop capability to operate the U.S. PLSS. Each PCC would be required to operate the Payload Planning System, to acquire and train staff to integrate all U.S. and IP payload operations, and to interface with U.S. remote PIs, TSCs, and the SSCC. It was assumed that the U.S. POIF would continue to perform the crew support functions of display review, procedure integration, and training coordination. However, the IP PCCs would have to become familiar with crew procedures for U.S. payloads to provide real-time support, and to be able to provide the ground-to-air payload communications interface during on-orbit operations, and to manage and implement on-orbit PODF changes.

The SSCC would be required to interface with multiple PCCs. Shift handovers would require not only a payload handover from the previous shift PCC, but also an SSCC handover between PCCs.

Each PCC would incur one-time cost for modification of its IT infrastructure to operate with the U.S. C&DH, and to acquire and train staff for the POIF functions. Each PCC would incur recurring cost for POIF staff and the modified IT infrastructure.

It was assumed that the U.S. would not provide monetary compensation to the IPs for their increased cost but, rather, would barter payload resources as compensation. (The U.S. is obligated under the terms of the international MOUs to provide the POIF.) It was estimated that the amount of compensation would be in the range of 25 to 45 percent of the U.S. payload resources.

U.S. POIF costs would be reduced by two shifts of real-time support, or about 20 percent of total POIF labor. This reduction in POIF labor amounts to a 7-percent reduction in U.S. payload operations cost. However, this cost reduction would be offset by (1) increased SSCC labor, due to the multiple interfaces created, (2) one-time cost to the U.S. POIF to transfer knowledge and procedures to the IP PCCs, and (3) recurring cost to the U.S. POIF for continuing transfer of information on U.S. payloads to the IP PCCs.

The rotation of responsibility for safety assurance of payload operations would increase the scope of safety-critical operator certifications required, and potentially increase safety risk due to the additional interfaces and divided responsibility.

The net effect of this architecture would be a more complex operation with increased interfaces, an uncertain but possible small reduction in U.S. payload operations cost, and a large reduction in U.S. research resources. This option was judged by the Study Team to be unacceptable.

D. Rotate POIF/POIC Functions Among the TSCs

In this architecture, each TSC would in turn provide the POIF function for an increment. Each increment would be operated in a campaign mode, where the discipline focus of the responsible TSC would be given priority in research conduct. (The campaign mode itself is evaluated in Section 5.2 as an alternate mission concept.)

Each TSC would be required to develop the information infrastructure to provide POIC-like capabilities, with associated communications. The PDSS was assumed not to be duplicated. However, each TSC would require the control rooms to accommodate POIF staff, full capability for command and telemetry processing, and full capability for the POIF tools (such as PPS). Each TSC would be required to interface with the SSCC information systems, and the SSCC would be required to interface with four TSCs rather than one POIC. The one-time cost to duplicate POIC is conservatively estimated at $20 million. This assumes transfering the POIC system design without modification and sustaining engineering provided by the staff at the current POIC.

POIC operating cost would be reduced by limited operation 75 percent of the time. This savings would be offset by increased IT operating staff at the TSCs.

Each TSC would develop duplicate capability to control the U.S. PLSS, to operate EXPRESS racks, to interface with other TSCs, to interface with the SSCC, and to interface with IP PCCs. Each TSC would be responsible for full pre-increment planning and preparation, including crew support. The added labor for four TSCs is estimated at four times 50 percent of reengineered POIF labor, while the one times 100 percent of re-engineered POIF cost would be saved.

RPIs would be assigned to a TSC for support, but because not all TSCs would support every increment, RPIs would potentially have to interface with multiple TSCs or not be able to operate during certain increments.

SSCC and IP PCC operating cost would be increased by an increased number of interfaces.

The Team estimated that a 10-percent reduction in ISS resource utilization would result due to the increased complexity of operations and limitations on manifesting likely to result from this architecture. It would be very difficult to maintain consistent and effective interfaces among the multiple architectural elements involved.

The rotated responsibility for safety assurance of payload operations would increase the scope of safety-critical operator certifications required, and potentially result in increased safety risk due to the divided safety responsibility.

The net effect of this architecture was judged by the Study Team to be a much more complex operation with increased cost. Research resource efficiency would probably be reduced. The Team judged this architecture to be unacceptable.

E. Move the POIF/POIC to the SSCC

In this architecture, the SSCC would be augmented to provide the POIF and POIC functions, including support to the TSCs and RPIs.

The assessment of this option was performed based on a briefing to the Study Team provided through the ISS Program Office, which identified the functional differences between SSCC information systems and POIC information systems. However, JSC declined to present an assessment of potential impacts associated with this option. Therefore, the analysis presented is that of the Study Team.

The Study Team considered two options for SSCC augmentation to provide POIC payload data services.

In Option 1, the existing POIC information systems would be moved to empty space in the SSCC. Assuming that facilities were available, 1 to 2 years of POIC downtime would be required for the move, resulting in an equivalent ISS stand-down from payload operations. During the course of the move, POIC cost would continue until an equivalent staff was reconstituted at JSC. Because it is unlikely that the current POIC staff would transfer intact, increased cost would be expected during this period for overlap and training of the new staff. The POIC recurring cost would not be reduced.

In Option 2, the existing SSCC information systems would be modified to provide POIC functionality. While this option would offer the greatest synergism, the magnitude of the reengineering effort was estimated at $20 million. The SSCC effort would require 1 to 2 years, and would require care to avoid impact to ongoing SSCC operations. After the SSCC began payload operations, the POIC recurring cost would be eliminated, but an increase in SSCC recurring cost would occur due to the added functionality and TSC/RPI interfaces.

The POIC was assumed to continue operating while the SSCC is being reengineered, so that payload operations would continue.

In addition to the POIC, the POIF staff would be reconstituted at the SSCC. Because it is unlikely that the current POIF staff would transfer intact, 1 to 2 years would be required to recruit and train POIF staff at the SSCC. Assuming that payload operations were continued during this period at the POIC, additional POIF cost equal to 1 to 1.5 years would be incurred, or $14 million to $21 million.

During the changeover between the POIC and SSCC, some limited stand-down time might be expected. (A separate analysis of the merits of a stand-down from all ISS payload operations is discussed in Section 5.2 as an alternate mission concept). The stand-down time would result in a loss of ISS research resources.

The potential synergistic advantage gained through integration of payload operations into the SSCC are undefined and argumentative, given the differing responsibilities and criteria of the SSCC for safe core systems operations and the POIC for facilitating research. The SSCC responsibilities require tight control and minimum risk, while the POIC responsibilities require flexibility while payload mission risk is traded against research innovation and cost. In the Spacelab Program, these factors led to relocation of the Payload Operations Control Center from the MCC to MSFC.

Currently, crew training is performed at the SSTF at JSC by both POIF personnel and SFOC instructors. It is advantageous for crew accessibility to conduct payload crew training at the SSTF. However, two sets of instructors are not necessary. Cost Options 1 and 2 recommend using MSFC POIF instructors co-located at JSC and eliminating SFOC payload training instructors.

A further negative factor in this architecture is the resultant loss of the institutional knowledge and skill base in manned payload operations that currently resides at MSFC. This base represents the experience of 20 years of operation during the Spacelab, Shuttle, and ISS programs, and a recognized leadership in payload advocacy.

The Study Team judged the known impact of this architecture to be a 1- to 2-year period of increased cost (approximately $40 million to $80 million), no significant reduction in operating cost, a potential loss of research resources utilization, and no clear advantages. The Study Team does not recommend this architecture.

F. Space Internet Infrastructure

This architecture assumes the extension of commercial communications standards, compatible with the Internet, into the ISS onboard and ground communications systems.

A logical evolution of space communications includes the use of commercial standards and equipment in space. Exhibit 5-2 illustrates the resulting architecture, which has been successfully demonstrated in a pilot freeflyer program.

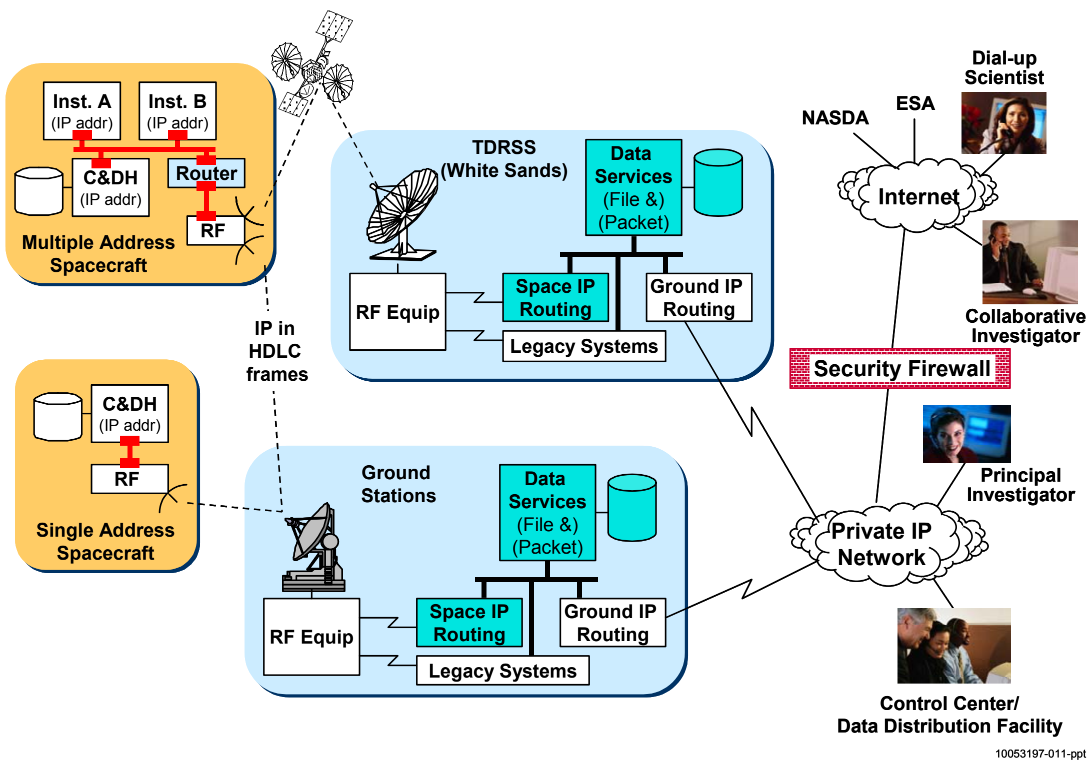
This architecture has been previously proposed for the ISS Program as “CSOC Enhanced Option 6.” It offers the advantages of using commercial technology rather than custom hardware and protocols. It would enable researchers to communicate directly with their space experiments across the Internet. Its application could in the long-term significantly enhance research capabilities, reduce the payload operations infrastructure, and reduce recurring costs.

However, this architecture requires a significant modification to onboard ISS systems, space-hardening of commercial ground communications products, and modifications to the ground communications and data processing systems. Use of direct uplink capability also introduces security issues. While these issues can be mitigated with current technology, resolution of the issues require policy decisions as well as technical consensus.

The ideal time to implement a new onboard architecture is when requirements increase which require onboard system modification, or when obsolete or failed systems onboard the ISS have to be replaced for those reasons.

The Study Team believes this architecture represents a desirable evolution in space communications and, therefore, merits long-term consideration in the ISS Program.

Exhibit 5-2. Space Internet Architecture



5.1.2 Alternate Architecture Summary

The information systems of the POIC are the enabling resource for telescience. The POIC was specifically designed to support payload telescience requirements.

The POIC represents a major program investment in time and dollars. The POIC capabilities are not easily duplicated or moved.

Most POIF functions are more cost-effectively centralized rather than duplicated in multiple locations. Duplication of personnel and skills in multiple locations results and increased cost and increased complexity of interfaces. The only existing capability is at the POIC.

Centralization of the POIF function of ensuring the safety of payload operations improves consistency and reliability in this critical area.

Each current TSC is dependent upon POIC information system services.

Each TSC currently provides capability equivalent to a super-RPI site but not equivalent to the POIF or POIC. Each current TSC does not have the resources or skills to perform POIF integration functions.

Alternate Architecture Recommendation. The best path to cost reduction is through reengineering and continuous improvement of the current architecture and processes.

5.2 Alternate Mission Concepts

The Study Team defined a mission concept as a principal way of operating the ISS to accomplish its goal of enabling world-class research.

In addition to the alternate concepts presented here, the Study Team discussed other concepts and variants on the concepts presented. No other concept was found that was practical, distinctly different, or offered significant advantages over those presented here.

5.2.1 Definition of Alternate Mission Concepts

The Study Team evaluated six alternate mission concepts

A. Current Baseline

B. Reengineered Current Baseline

G. Campaign Mode

H. No Increment Planning Overlap

I. Added crew Time — EDO/Soyuz

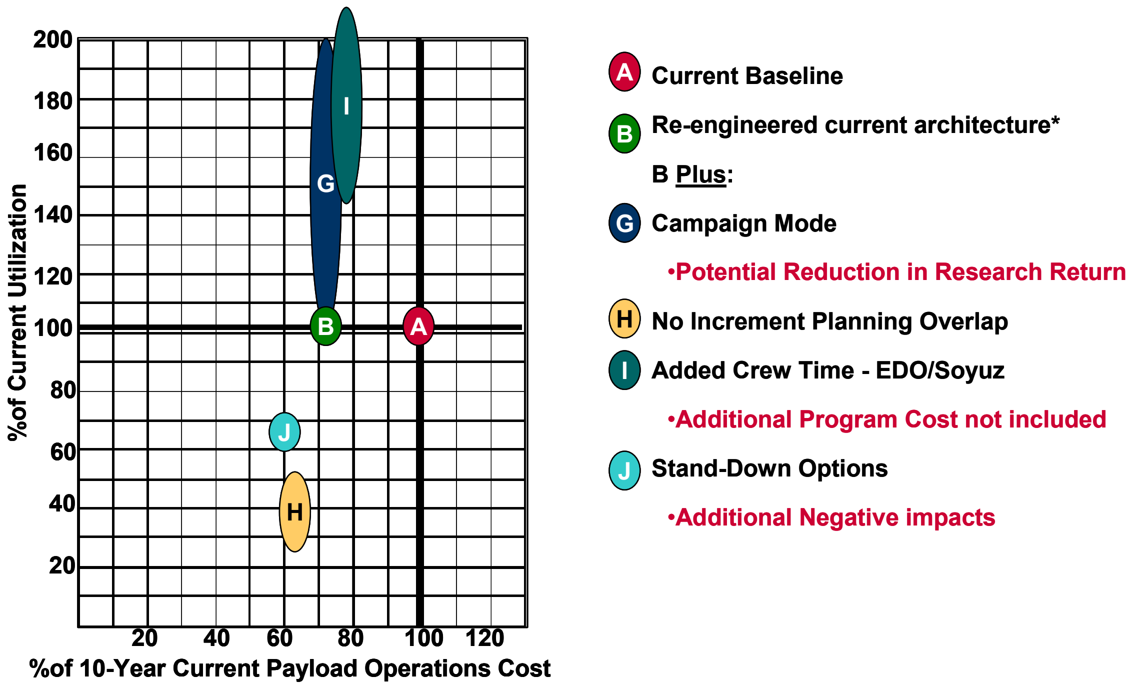
J. Stand-down Options

The Study Team evaluated the alternative mission concepts to determine their relative effect on ISS research utilization, the 10-year cost of payload operations, and other significant factors. Ten-year cost was used rather than annual recurring cost to account for investments required in some alternatives.

In evaluating the recurring cost, the Team assumed that all mission concepts except Concept A (the current architecture) adopted the efficiencies projected in the minimum service level principles used in Concept B (the reengineered current architecture).

The relative comparison of each alternative concept against utilization and recurring cost is show graphically in Exhibit 5-3, with a qualitative statement as to the significance of other advantages and disadvantages. Each alternate concept is then discussed in turn.

Exhibit 5-3. Notional Research/Cost Evaluation of Alternative Mission Concepts



A. The current architecture

The current architecture is described in Section 3.3. In Exhibit 5-1, it represents the origin of the coordinate system against which the other architectures are compared.

B. Reengineered Current Architecture

This architecture incorporates the Minimum Service Level Model described in Section 4.1.3. The reengineered architecture has lower cost than the current architecture (Concept A), but does not imply any change in ISS manifesting or research utilization. This alternative has no other significant advantages or disadvantages over Concept A.

G. Campaign Mode

The campaign mode assumes each increment research discipline area (life sciences, microgravity sciences, and space products) is sequentially assigned an increment in which it is allocated all of the available resources it requires.

The ISS Payloads Office analyzed this mode for the three-person crew mission phase using their payload utilization modeler (PLUM). The research resource requirements were provided by the RPOs. The human research discipline was assigned 80 percent of its required crew time, which is all that is available with a three-person crew. Other disciplines were selected randomly to use any resources remaining after the primary discipline was scheduled. The analysis results are shown in Exhibit 5-4.

Exhibit 5-4. Campaign Mode Analysis

Discipline Resources Achieved (% of Discipline Requirement)

Discipline	Allocated Discipline Campaigns, Augmented*				No Campaign (Random)	Efficiency Ratio**
	Life Sciences	Micro-gravity	Space Product	Avg		
Life Sciences	52.5	2.9	4.1	19.8	12.3	1.61
Micro-gravity	4.5	38.9	4.7	16.0	15.7	1.02
Space Product	2.8	6.6	100.0	36.5	16.5	2.21
Average				24.1	14.8	1.63

Life Sciences:	**Human Research** **Fundamental Biology -** **Cell Culture Research**
Microgravity:	**Materials Science** **Fluids & Combustion** **BioTechnology**

* **Equal campaign opportunities provided to Life Sciences, Microgravity, and Space Product Development (SPD) according to the 30-30-30-10 allocation. Non-prime discipline research augments each campaign where resources allow.**

** **Average Discipline Campaign ÷ No Campaign**

Assumptions

- **U.S. Racks Only**
- **Pre-CAM**
- **3 Crew**
- **Reduced HRF capabilities (80%)**
- **U.S. Crew time: 13.5 hrs/wk**
- **Crew Training: 473.4 hrs**
- **Upmass: 3467 kg**
- **Middecks: 10 MDLs**
- **Power: 32.43 kW**
- **Keep-Alive Power: 14.21 kW**

10053197-012-ppt

Exhibit 5-4 illustrates that the use of campaign mode increases achievement of discipline resource objectives, averaged over multiple increments. However, campaign mode results in very low resources for disciplines that are not prime during an increment. The no campaign mode provides a lower but continuous level of resources to all disciplines.

The effect on research productivity depends upon the value of continuity in access to space (no campaign mode) versus the value of increased resource availability (campaign mode). Commercial users need timely, frequent, and repeated access to the ISS, while other disciplines may favor other strategies.

A partial campaign mode that provides an emphasis to one discipline at a level less than their full requirement may offer the best compromise, given the present research priorities.

The use of campaign mode was judged to have no effect on payload operations costs.

H. No Increment Planning Overlap

This mission concept assumes that a reduced POIF staff plans, prepares, and then executes one increment at a time (no overlapping planning activities).

With a 6-month planning and preparation cycle, this results in payload operations being conducted on one increment in three. Alternatively, six-month increments could be used, with payload operations being conducted on one increment in two. No payload operations are conducted on the intermediate increments, so that research resource utilization is between 33 percent and 50 percent.

POIF staff would be reduced by an estimated 30 to 50 percent due to reduced real-time and operations preparation workload. This reduction in staff would result in a total payload operations cost reduction of approximately 8 percent relative to mission Concept B.

I. Added Crew Time – EDO/Soyuz

This mission concept provides additional crew time for research by using the Shuttle EDO capability during ETOV visits.

A six-person crew is needed to achieve the full benefits of human conduct of research onboard the ISS. Some career scientist crew members are also required, either within the career astronaut corps or as payload specialists from the research community.

In the interim, until a continuous six-person crew can be supported, use of the EDO and extended Soyuz missions can increase the crew time available for research. This option was discussed in the ICE Report of the IMCE Task Force, and is further discussed in Appendix E.

Estimates of the increased research utilization vary depending upon assumptions as to the number of Shuttle flights, overlap times, and mid-deck locker space available. Differing options also exist for the use of the increased crew available during the overlaps. (The EDO crew could be used to perform ISS maintenance, freeing ISS crew time over the remaining increment for more research. Or the EDO crew could concentrate on research itself, in a campaign mode.) The range shown in Exhibit 5-4 represents this variation.

The Study Team assesses some increase in recurring payload operations costs due to increased crew training, timeline planning, and real-time coordination with this concept. The magnitude of the increase is dependent upon utilization option selected.

The full program cost effect of implementing EDO/Soyuz missions was not assessed in the POCAAS.

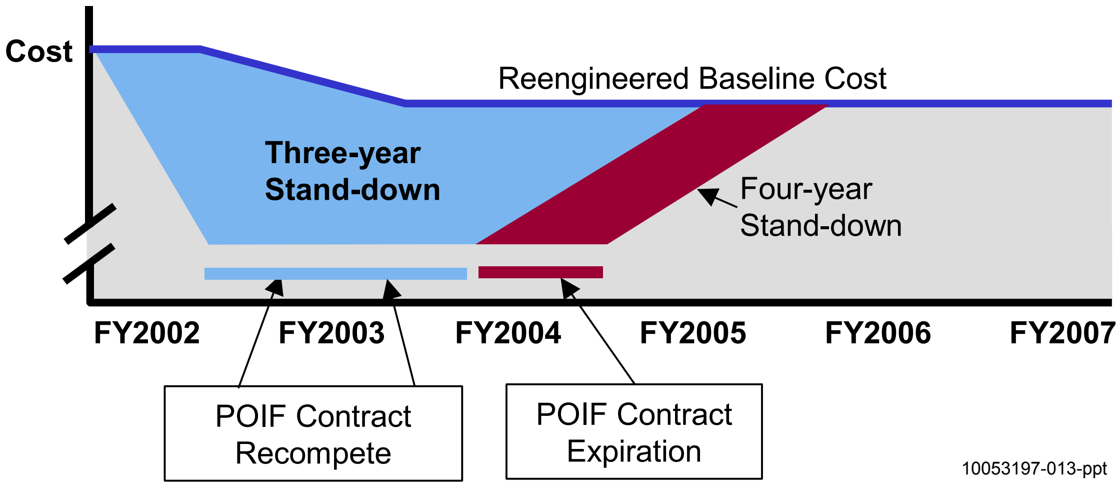
J. Stand-Down Option

This concept assumes a complete stand-down from payload operations for an extended period of 3 to 4 years, in order to reduce cost.

Cost savings from a stand-down results from reduction in POIF and POIC staff during the stand-down, as well as reduction in communications costs. The costs savings during a stand-down could be used to reengineer payload operations to reduce out-year recurring cost, payload development, or other research activities.

A notional stand-down time profile is shown in Exhibit 5-5.

Exhibit 5-5. Notional Stand-Down Time Profile



Payload operations staff would be reduced over the period of 1 year, as increments already in preparation and their PI commitments are completed. At the bottom of the stand-down, POIF staff would be reduced to a minimum level for retention of skills. POIC operations staff would be similarly reduced, but sustaining engineering and maintenance activities would necessarily be kept to maintain integrity of systems and software.

The return to operations after a full stand-down is estimated to require 2 years for rehiring and retraining POIF and POIC staff, system reverification, and increment preparation.

If return to operations requires 2 years, a stand-down of at least 3 years is required to achieve cost savings. The estimated savings is $27 million for a 3-year stand-down, and $44 million for a 4-year stand-down.

A stand-down of 3 to 4 years out of 10 results in a 30 to 40 percent loss of research resources and commercial opportunities.

A return to operations is required to take place before 2005 so as not to delay IP payload operations, which would impact the international MOUs.

A stand-down before September 2004 incurs termination costs for the POIF contract, and requires immediate recompete to have a vehicle in place to enable rehiring.

The Study Team believes that a stand-down would result in severe loss of researcher support for the ISS, as well as loss of NASA credibility. It would also result in loss of payload operations expertise and loss of U.S. stature. The Study Team strongly recommends against this concept.

5.2.2 Alternate Mission Concept Summary

Recommendation. Continue analysis of the campaign mode to determine optimum manifesting to maximize achievement of research objectives, including resource utilization.

Recommendation. Pursue increased crew time for research, including EDO/Soyuz options, as possible within funding constraints.

6. Recommended Changes to User Requirements

The Study Team analyzed interim and permanent changes to current NASA user development requirements that could reduce payload operations costs.

The Team did not identify any specific instances where current user practices are over-driving payload operations requirements and costs. However, users can reduce payload operations workload and cost in several ways.

- Defer the need for RPI access to ISS downlink television, where not essential to experiment operation. Where television access is required, seek the lowest cost and available implementation, and treat the service as an optional service with added cost for that experiment.
- Deliver quality operations products on schedule. Late deliveries and poor quality products cause workload peaks and rework of operations products.
- Minimize C&DH database changes after baselining. Late changes cause workload peaks and rework of operations products. Currently, there are three to four database deliveries per mission segment.
- Keep data requirements within the current 50 Mb/sec downlink capability.
- Use telescience to minimize crew support costs. However, total experiment cost may be reduced by the use of crew time.
- Design payloads to satisfy multiple investigations and to maximize hardware remaining on-orbit, while minimizing upmass, downmass, and installation activities.
- Take advantage of operations experience and lessons learned by considering operations requirements and performing operations strategic planning from the beginning of payload design and development. Establish an early dialog with POIF staff.

7. Recommendations on Changes to the ISS Concept of Operations that Take Full Advantage of the Continuous Operations Environment Afforded by the ISS

The primary characteristic of the ISS that sets it apart as a world-class research facility is the capability to provide a laboratory in space with continuous access to the microgravity environment and vacuum of low-Earth orbit. Within crew time and resource constraints, continuous payload operations offer unlimited laboratory time on orbit for support of research. Inherent in this continuous operations environment is the ability to conduct extended uninterrupted research activity on a specific experiment.

Equally significant to quality scientific research is the potential contribution of a continuous operations environment to flexible, responsive opportunities for investigators and payload developers. This is critical because discovery cannot always be scheduled and unanticipated outcomes often lead to the most significant breakthroughs. The scientific benefits of the ISS research environment can be more fully realized if the concept of operations aggressively moves from the principles rooted in the limited duration human space flight missions of past programs to take full advantage of the potential of this international asset.

7.1 Case for Change Guided by a Long-Term Plan for Operations

The current ISS concept of operations, the requirements that govern the concept, and the processes and systems that support it are staffed, operated, and maintained by skilled and dedicated people adhering generally to well-established and proven practices and templates. A significant effort has gone into the development of this operations concept for ISS payloads and payloads have been supported very successfully during the Assembly Phase. While recognizing the accomplishments, the POCAAS Team believes there are changes that will make long-term payload operations more resource efficient and will move ISS closer to the concept desired by most researchers.

This study has conducted an intensive review of current ISS payload operations and makes recommendations for efficiency improvements and reductions in the costs of operations. Within the limits of the study objectives and the scope and duration of the study, these recommendations concentrate on the near-term and on cost savings. It was also clear in the course of the team discussions, that changes should be made in the ISS concept of operations to take full advantage of the continuous operations environment. Additionally, it became evident in reviewing the design reference missions and the probable technology replacements and upgrades that ISS payload operations will continue to evolve. Progress along the operations learning curves and successful research results will promote further evolution. A plan that will provide a living baseline for evaluating and implementing specific changes and continuous improvement would be extremely beneficial in guiding process, technology and staff skills development, and change.

The formulation of a long-term plan was not possible within the context of this study, but the areas where the change initiatives should be concentrated are discussed within this Section.

7.2 The Advantages of Continuous Operations

The basic advantages of the continuity available in ISS operations can best be seen in a comparison to the operational characteristics of the Space Shuttle, Spacelab, and SpaceHab sortie-type research missions. Long-duration missions also present operations planning and integration challenges as seen in Exhibit 7-1.

Exhibit 7-1. Key Operational Characteristics

Sortie (Increment)	Long-Duration Missions
Concept that all payloads are new for each increment	Concept that majority (75%) of payloads are continuing or reflights from previous increments
All payload hardware on increment must be certified for each increment	Payload hardware remaining on-orbit was certified when launched. Review integrity periodically
All payload hardware launched on a flight must be certified for flight	All payload hardware launched on a flight must be certified for flight
Payload crew procedures processed and certified for each increment	Payload crew procedures established when payload launched and maintained through RT operations
Payload displays reviewed and certified for each increment	Payload displays reviewed and certified when payload launched and maintained through RT operations
PODF new for each increment	PODF maintained through on-orbit configuration control
Crew change-out regarded as beginning new mission	Crew change-out regarded as shift handover for on-going payload operations
Payload documentation system based on separate documents for each increment	Payload documentation system based on one-time baselining with change control for reflight
In-depth planning on increment basis	Relaxed planning
Infrequent reflight opportunities	Ability to repeat payload operations
Training designed for specific flight crew	Training designed for generic flight crew

While time on orbit will always be an expensive and precious commodity, the less time constrained environment of the ISS offers the ability to conduct most space research without undue external pressure as to the time required to set up and conduct the experiment and then react to the immediate results or indications. Resolution of anomalies or reaction to unexpected results can proceed at a more deliberate pace. If reflight is indicated to improve processes or equipment, or if results prompt the researcher to pursue a variation or second-generation alternative based on results, the opportunities for reflight are greatly improved.

Human space flight payload operations have been marked by minute-by-minute intensive planning and timelines that are intended to maximize the return from the time available. Often these precise plans and procedures must be revised in real-time to adjust to the mission as it unfolds, to handle systems occurrences, or to take advantage of "discoveries". The resources that have gone into this intensive planning for sortie missions are significant. The processes have required a level of data specificity and detailed interaction with users that are a source of considerable concern when extrapolated to a large number of experiments flown over long durations. With the continuous operations environment of ISS, the researchers and the crew have the time and will benefit greatly from the opportunity to plan and adjust more of their detailed schedules and activities based on their evaluation of the situation and priorities. The preflight and real-time ground planning can be on a higher, more relaxed level.

In the continuous operations environment, a payload mission can span more than one increment and, therefore, be operated or serviced by more than one increment crew. Training must, therefore, shift from concentration on a specific flight crew or crew member to a generic crew approach that provides general preparation for multiple crews.

Along with the advantages inherent in the ability to repeat operations during flight, and to fly repeat or second-generation experiments promptly there are inherent challenges. The operations integration and planning processes must be adjusted to accommodate late manifesting when the decision is made to expeditiously fly repeat or second-generation payloads and planning must cope with the probable delay in other experiments when there is significant carry-over work for an ongoing payload.

7.3 The Payload Operations Vision in Practice

The three major elements of the operations vision for the ISS were described in Section 2.1. The operations concept features that are needed to make those vision elements a reality can be defined as follows:

- **Facilitate the pursuit of flight research and make the complex operation environment associated with the ISS transparent to the end-user.** There are two possible approaches. The first approach would be to use NASA resources to totally buffer the researcher and payload developer from the complexities of the current complex environment. The second approach, and the only affordable approach, is to reduce the complexity and streamline the processes wherever possible. Alternative operations service levels and processes should be provided so that a payload must deal with only those requirements that apply. Total transparency to the user is an unrealistic goal, but significant process improvement and limited but effective assistance when necessary can produce a user-friendly and more affordable environment.

- **Make the researcher fully responsible for the success of his/her experiment, and enable the researcher to interact with his/her experiment apparatus as nearly as possible in the same way that he/she would interact in a remote Earth laboratory.** Quite simply, for a given payload, this means removing as many as possible of the current tiers of requirements, people, and functions between the researcher and the onboard experiment. This will be difficult because the NASA program and operations personnel feel that they have always been held accountable for payload mission success in addition to their mandatory (and continuing) responsibility for safety. They will understandably be reluctant to dispense with the checks and balances of the current operations concept. But for ISS, it is time to recognize the researcher's mission success responsibility.

- **Facilitate the researcher's conduct of science at the minimum possible cost, consistent with the objectives of maintaining crew and ISS safety and protecting each payload from damage or interference from other payloads.** This statement captures the basic challenge of ISS payload operations support; i.e., provide the necessary services and support at the lowest possible cost consistent with protecting the crew, the

ISS, and the individual and collective integrity of payloads. This is the implementation test for process and concept restructuring proposals.

7.4 Recommended Changes for Continuous Operations

The POCAAS Team believes that ISS payload operations can be further streamlined resulting in a reduced workload for the researcher and the payload developer and, just as critical to overall program cost reduction, a reduction in the resource requirements for NASA operations support. Any significant process streamlining and cost reduction must be accompanied, in fact driven, by reevaluation, streamlining, and reduction of program requirements, standards, and payload integration activities. Changes that are recommended for implementation in continuous operations are as follows:

- **Relax resource utilization and preflight/real-time planning optimization.** The flexibility, the less time-constrained environment, and the ability to repeat operations inherent in continuous operations make intensive and optimized planning unnecessary and not sufficiently value-added to warrant the resource expenditure. It is recommended that the level of detail and the number of iterations in the planning process, particularly in the early portion of the payload template, be thoroughly scrubbed.

- **Increase the use of real-time operations versus preplanning.** The ISS payload operations do not require predetermined minute-by-minute plans that optimize the research that can be accomplished in a tightly time-constrained flight duration. That pace is not sustainable in a continuous operations environment and unrealistically constrains the researcher and crew in what is intended to be a true laboratory setting. More productive science will undoubtedly result from real-time flexibility on priorities and plans that respond to the situation.

- **Build and adapt operations concepts and practices incrementally during ongoing operations.** A hallmark of NASA mission operations has been the capability to respond to mission changes, anomalies, and emergencies. This has been the result of the skill, training, and team approach of the operators and support staff. As this level of expertise and operations know-how matures in the ISS payload operations, the confidence level and management change control processes can support continuous improvement in operations concepts and practices during ongoing mission activity. Obviously, any changes will now be occurring during ongoing operations. This recommendation is not primarily directed at changes that can be extensively modeled and simulated prior to first use during a future increment. This recommendation applies to the flying of payloads with sufficiently mature operations concepts and procedures to initiate operations but with the intention of further developing elements of the concept and making procedures improvements as the mission progresses. Taking advantage of real-time experience and results is a basic advantage of the ISS research environment.

- **Increase the use of self-paced, onboard crew training and Help facilities.** The possibility of an extended length of time between the crew's last training on a payload before launch and the in-flight execution of nominal or malfunctions procedures results in the need for a means of "refreshing" the crew's training. This makes the use of onboard training and payload operations Help facilities an important element of the program. Fortunately, the advances in computer-based training and video training delivery provide these capabilities and the program is taking advantage of them. Further advantages can be pursued by using these onboard capabilities to make the ground training more efficient and to replace all or portions of the ground training in some cases.

- **Accept less perfection in procedures and displays, because the additional risk of error is acceptable.** Considerable resources and critical personnel and template time can be saved if the present strict requirements are converted to reasonable guidelines on procedures and displays. Only safety-critical procedures and displays should be subject to absolute requirements and then the requirements should address the key functional aspects. The final decision as to the adequacy of the procedures and displays should be deferred to the POIF after appropriate coordination with PI/PD and crew. Reiterations based on individual preferences should be the exception and considered only in response to specific problems.

- **Accept the flight of experiments with operations that have not been fully defined and validated where justified by time criticality.** No experiment should be flown until the total operating envelope has been verified as safe for all nominal, off-nominal, and failure modes of the equipment. This includes all procedures that are necessary to safe the experiment and to protect the ISS and all other experiments. The probability remains that there will be experiments that are safe and have compelling reasons for manifesting on the next flight, but do not have the time to achieve fully defined and validated operations. In these cases, every consideration should be given to flying the experiment.

- **Eliminate the requirement for resubmitting documentation for reflights on successive increments.** It is believed that this is the program’s intention and has been put in practice in several instances. This should be a clear program guideline and, where the environments warrant, documentation and certification for other programs should be considered for potential application to ISS. Researchers would welcome this policy and the PI team and the program would save resources and time.

- **Create an incentive for designing modular experiment equipment that incorporates hardware with sample changeout capability.** In certain areas of research, it may be possible to develop experiment hardware that is designed to support continuous operations by allowing sample changeout. The hardware would remain on orbit, thereby reducing the launch and return logistics. Different samples, including samples from totally different researchers, could be installed by the crew and supported by the same equipment. The experiment equipment would be required to provide an increased scope of operating ranges and modes but the interested elements of the user communities could collaborate on the design. This concept has been applied to the larger facilities on the ISS but may increase research productivity without compromise of quality on a smaller scale.