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.

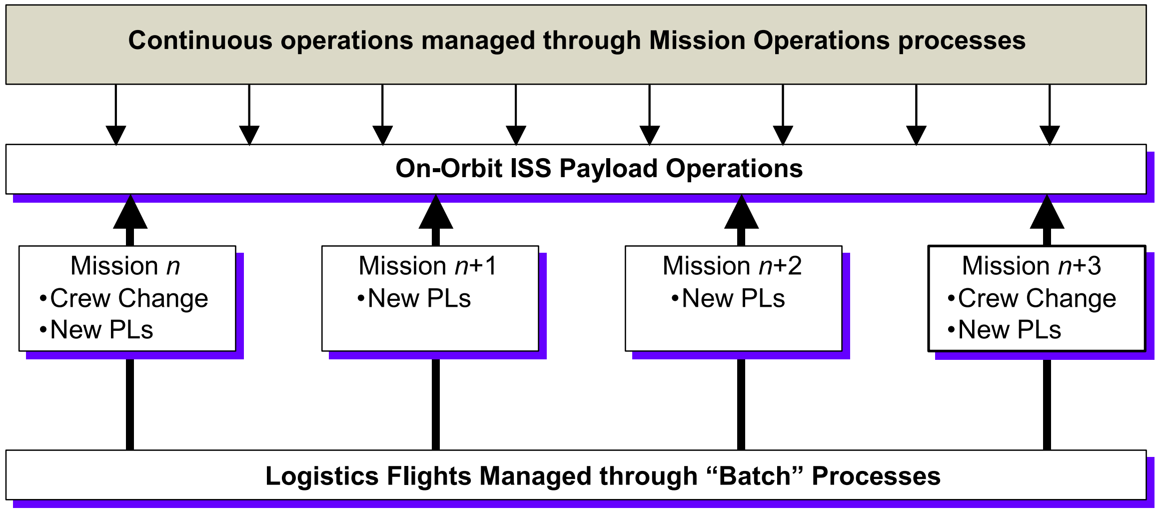
ES-5. ISS operations today are being largely conducted in "sortie" mode; an alternative concept for long-term payload operations is "continuous flow".

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.

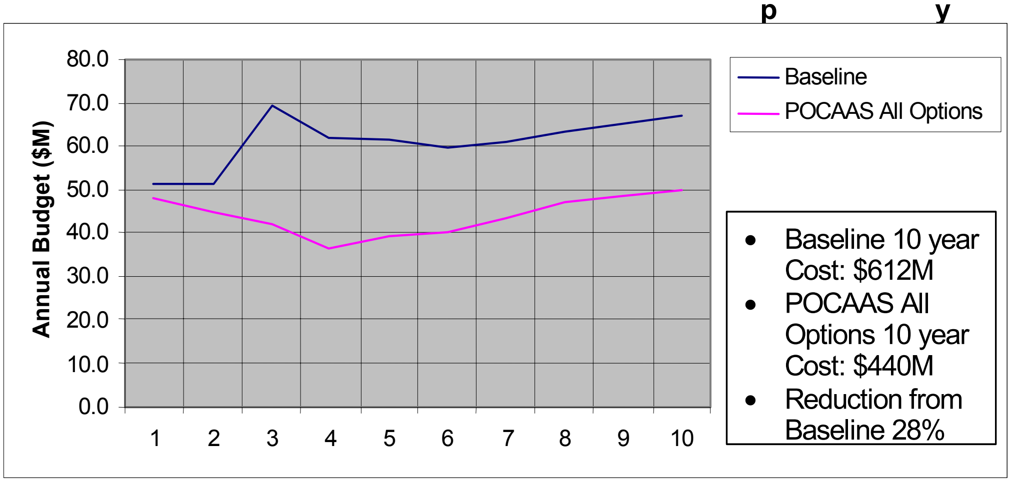
Recommendation. Defer the requirement for distribution of ISS onboard video to the TSCs and RPIs (approximately $780,000 per year). (This recommendation does not affect experiments with video data embedded in the experiment data stream.) Any experiments needing ISS video in their operations should be 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.

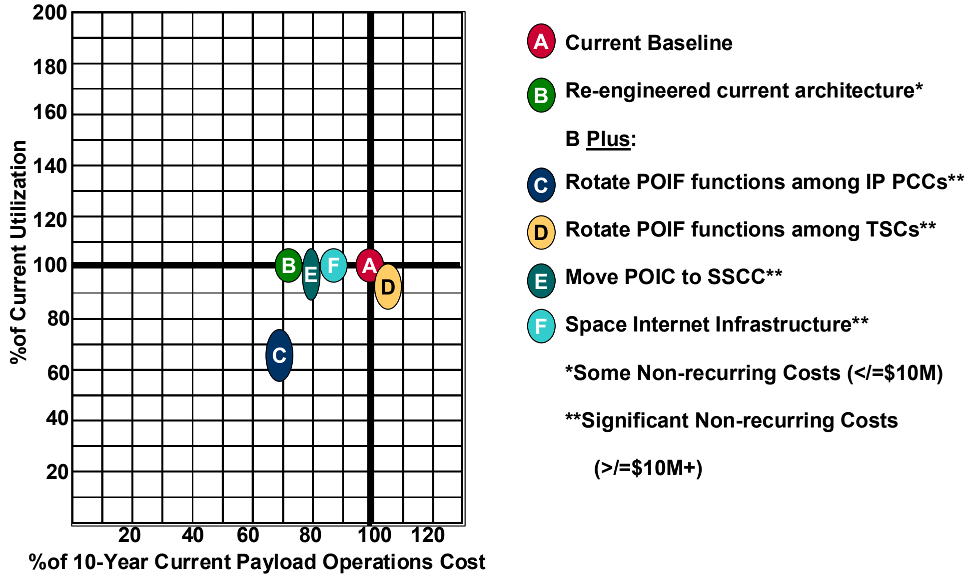
Exhibit ES-5. Baseline Architecture Cost Option Summary



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.

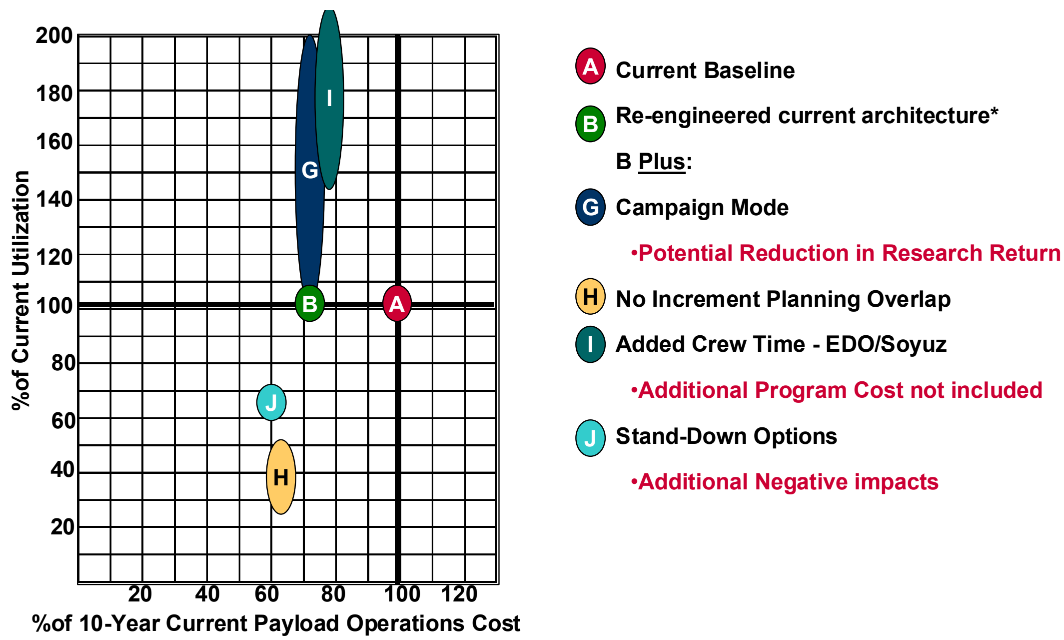
The alternative architectures studied have higher recurring costs than the reengineered current architecture, and each alternative has additional operating disadvantages. The alternative architectures have large nonrecurring costs associated with their implementation. None of the alternatives was found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