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Paper Session II-A - ISSA Concept of Operation and Utilization

Dennis K. Anderson
The Boeing Company

ISSA Concept of Operation and Utilization

Dennis K. Anderson
The Boeing Company
M/S HS-30
PO Box 58747
Houston, TX 77258-8747

Abstract

At the time that NASA decided to redesign the Space Station and identified Boeing as the Prime Integration Contractor, a new approach oriented toward operations and science utilization was introduced into the process of defining and documenting the design of what would become the International Space Station Alpha (ISSA). This paper provides a brief history of studies that contributed to the evolution of the operation and utilization concept of the Space Station Freedom Program to the current ISSA concept. Emphasis is placed on the importance of defining and documenting a concise concept of operation for the ISSA prior to the design phase. This paper focuses on the use of that documented Concept of Operation and Utilization as the most significant driver for ISSA design specifications. An example is presented of a payload-related need documented in the Concept of Operation and Utilization and subsequently developed into a program detailed design. A brief view of future challenges concludes the operations and utilization perspective of ISSA.

History

Several significant studies occurred during 1992 and 1993 that greatly influenced what would become the ISSA Concept of Operation and Utilization (COU). The first of these began when the Operations Phase Assessment Team (OPAT), chaired by Eugene F. Kranz, the Johnson Space Center Director of Mission Operations, was chartered with developing an effective and sustainable operations plan for the Space Station Freedom Program (SSFP). The OPAT Final Report dated September 1992 provided an operations concept for mature SSFP operations. Changes across the program to support this new concept began during the winter of 1992.

With the mandated redesign of the Space Station, the Space Station Redesign Team requested that the OPAT reconvene to further reduce operations costs consistent with the Administration mandate that operations costs be reduced by half. OPAT II, chaired by Larry S. Bourgeois, the Johnson Space Center Assistant Director for Space Station Program, convened on April 5, 1993, and presented its report to the redesign team on April 23, 1993. This brief but substantial effort included all operations organizations of SSFP and the International Partners. The recommendations contained in the "Operations Phase Assessment Team II Space Station Redesign Support, Basic Report" would greatly influence the ISSA design. For example, the requirement for 24-hour autonomous operation of the on-orbit station represented a new design requirement that would allow large reductions in ground based real-time staffing costs.

The redesign team, led by Bryan O'Connor, published in the first week of June 1993 "The Space Station Redesign Team Final Report to the Advisory Committee on the Redesign of the Space Station." This report provided hardware Options A, B, or C and their associated range of costs for the Administration to choose from, and incorporated substantially all of the OPAT II recommendations for more efficient and less costly operations that would apply to whichever hardware design was chosen. This report provided the most directly applicable source for ideas and concepts to be expanded upon and detailed in what would become the ISSA COU.

The Advisory Committee on the Redesign of the Space Station (Vest Committee) presented the results of its work to the Administration on June 10, 1993. On June 24, 1993, the President of the United States directed NASA to develop a Program Implementation Plan by September 7, 1993, to support a restructured Space Station based on modular Option A described in the Redesign Team final report. NASA Administrator Daniel Golden and Yuri Koptev, Director of the Russian Space Agency, initiated a joint study to proceed in concert with the team developing the final definition of Option A. The results of merging modular Option A with Russian involvement were captured in the "Alpha Station, Program Implementation Plan," dated September 1993 and an associated Addendum dated November 1, 1993. These reports describe a Station configuration with a substantial increase in Russian involvement, including a Phase I Shuttle/Mir joint participation period preceding Phase II and Phase III efforts directed at launching and assembling a complete Alpha Station. The report addressed to some extent the science and utilization capability of the proposed Space Station Alpha; however, little was written about operations.

In August 1994, Boeing was selected by NASA to serve as the Prime Integration Contractor for the redesigned Space Station. In this role, Boeing initiated an effort to define and document the redesigned Space Station. It was imperative that this effort proceed rapidly to minimize ongoing SSFP expenditures on tasks that might not be required to implement the redesigned Space Station. The top-level definition and documentation of the redesigned Space Station were proceeding in parallel with and were impacted to varying degrees by decisions resulting from the studies described in the preceding paragraphs.

Design Focus on Operations

Boeing's approach to ensuring that operational and user needs are driving the design is to document a concept of operation which then drives the system specifications and lower level specifications. Ralph Light, a Boeing Senior Systems Engineer from Seattle, laid the groundwork for the ISSA COU and nurtured its initial development.

Space Station Freedom Program did not have a documented concept of operation, and this left many people in the user community concerned that Space Station Freedom was not designed to meet their needs. Without a concise statement of what the users needed that could be baselined by program management prior to establishing a design, it could be debated whether the design satisfied user needs. Likewise, the operations community was concerned that the Space Station Freedom was not designed to meet operational needs. For example, questions arose during the Space Station Freedom Program as to whether required extravehicular activity (EVA) maintenance hours would exceed the total EVA hours available. Bringing the operations and user communities in at the front end of the process also made them players in the many trade-offs required to establish a Space Station concept based on a reduced and fixed amount of funding.

To ensure that the COU drives the design, it is tied to ISSA System Specification, SSP 41000, through the use of a workstation-based tool called Requirements & Traceability Management (RTM™). One application of RTM is to logically tie COU principles and utilization needs to the resulting system specification and from there to the segment specifications and lower level requirements documents. While not every operation or utilization principle may be tied to a system specification requirement, every system specification requirement must have a parent principle or user need.

Concept of Operation and Utilization

The COU, SSP 50011, is divided into three volumes: I - Principles, II - Mission Profiles and Scenarios, and III - Processes. Since the system design specification traces only to Volume I, it is through this document that operations and utilization needs are translated into requirements. For purposes of this paper, the acronym COU will refer to Volume I - Principles.

The COU is written in the present tense to provide a perspective of an assembled and operational ISSA. The principles apply to the point in time that the ISSA is fully assembled in the year 2002. Additional or revised principles may be applicable to the assembly and development of the ISSA on a flight-by-flight basis. No attempt was made to include these intermediate operational principles in the COU.

The COU, released December 22, 1993, as Boeing document D684-10001-1, was the first document approved by NASA on the ISSA program. Each of the International Partners has contributed to the document and has either signed the document or is in the process of resolving final differences. Russian operating principles are expected to be included in the COU during the second quarter of calendar year 1995.

Operations Principles

Operations principles are organized into the three areas. A partial list of principles from each of the three areas is provided.

Orbital Operations

- The US is responsible for overall program coordination and direction of the Station.
- A single central operational command and control authority leads mission operations.
- English is the language for all documentation and operational communications on board the Station, between the Station and any ground center or orbiting vehicle, and between ground centers.
- The Station (or individual components thereof) will be safely disposed of or returned to Earth at the end of its operational life.
- The Station operates as an integrated vehicle with an integrated crew.
- All nominal onboard activities are scheduled and executed consistent with a single integrated plan.
- The capability to return the crew to Earth independent of the scheduled activities is always available.

Launch Processing

- All acceptance testing of the elements is done prior to delivery to the launch site.
- Postdelivery checkout is conducted to verify the integrity of the elements after shipment.
- All elements can be powered up in a stand-alone configuration.
- Requirements for Station time-critical stowage in the Shuttle middeck must not extend beyond launch minus 14 hours.

- Development-center-provided ground support equipment must meet program and launch site requirements.

- Unique support equipment for element-unique processing requirements is provided to the launch site by the element provider.

Integrated Logistics Support

- Spares procurement is prioritized with Station/crew survival, criticality, and sufficiency as key criteria.

Utilization Principles

The COU captures both utilization principles that may drive the Station design and specific user needs that drive end item design. Examples of each follow.

Station Design

- Payload activities must be consistent with an integrated operations plan.

- The Station is capable of supporting on-orbit payload installation, checkout, reconfiguration, and removal.

- Payload plans and procedures can be displayed on board.

- The Station can record payload data during periods of communications outage for later transmission to the ground.

End Item Design

- Annual average (30 kW) and minimum (26 kW) continuous power will be available to users during periods of microgravity and standard Station modes.

- Station atmospheric pressure will remain at 14.7 (+ 0.2, -0.8) psia during all operational research phases.

- The Station will have at least four external payload attach points in addition to the International Partner element attach points.

- Payload and core system command formats will adhere to a common command format standard.

- A nitrogen supply flow rate of at least 0.5 lbm per minute and pressure range of 90 to 110 psia will be provided to every international standard payload rack (ISPR) location (e.g., furnaces, combustion facilities, etc.).

Functional Decomposition

Describing the systems engineering methods and associated computer tools used on the ISSA to derive design requirements from the COU principles is beyond the scope of this paper. "Functional

Decomposition Document Revision A," D684-10200-1, describes functional decomposition, functional modeling, and functional allocation as employed on the ISSA.

Note that each specification document will have a section 3.2 subparagraph which describes a capability and decomposes into one or more section 3.7 subparagraphs. The section 3.7 subparagraphs are then allocated to lower level specifications and appear in the corresponding documents 3.2 subparagraphs and so on until the end item specification is reached. Figure 1 (taken from the functional decomposition document) depicts the flow of system analysis that supports this process. This process of functional decomposition is now a standard system engineering methodology, and is, together with the electronic traceability of the requirements, a necessity for a large complex project such as ISSA.

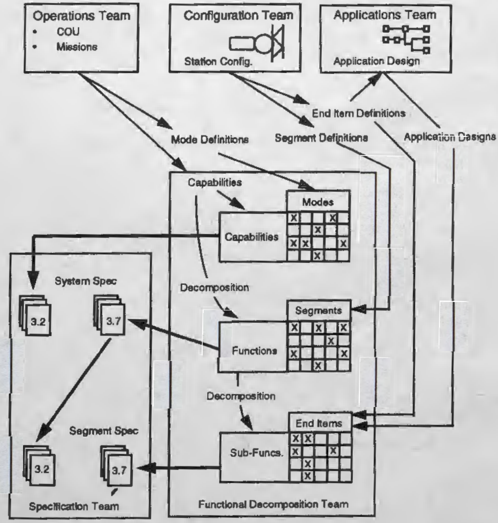

Figure 1. Functional Allocation Process.

Utilization Example

A specific example is provided for the following utilization need documented in COU Volume I, Appendix C (Science and Utilization Research Requirements), Paragraph C.9 (Resources and Support), Subparagraph B. The requirement states a nitrogen supply with flow rate of at least 0.5 lbm per minute and pressure range of 90 to 110 psia will be provided to every ISPR location.

Table 1. Trace of COU Requirement to End Item Specification

Level of Functional Decomposition	*Specification Flowdown*		
1. Support user payloads.	System Spec 3.2.1.1.1.9		
2. The US oxygen system (USOS) shall distribute gases to user payloads as shown in Table V.	System Spec 3.7.1.3.9.4	*3.7.4.3.9.4*	*3.7.3.3.8.4*
	USOS Spec 3.2.1.1.1.32	*JEM Spec 3.2.1.1.1.26*	*APM Spec 3.2.1.1.1.22*
3. The US Lab shall provide nitrogen at between 63 degrees F and 85 degrees F, 80 psia to 120 psia pressure at flowrates of up to 0.5 lbm/minute to payloads.	USOS Spec 3.7.1.3.53		
The US Lab shall distribute nitrogen to ISPR in accordance with SSP 41152, Gaseous Nitrogen Interface.	US Lab Spec 3.2.1.66		

To further explore this example, one might follow the path to the "Interface Requirements Document - International Standard Payload Rack," SSP 41152, or follow the "distribute gases to user payloads" trace into the Japanese Experiment Module (JEM) segment specification or the European Space Agency's attached pressurized module (APM) segment specification as indicated by the paragraph numbers appearing in italics in Table 1.

Future Challenges

Within the current ongoing program, some disconnects between the COU principles and the specifications requirements still exist. The RTM reports allow tracing paths rapidly and identifying problems. These disconnects are then documented as issues to be resolved by either modifying the principle/user need or revising the appropriate specification. In the international arena, the Russians are currently reviewing the COU and have yet to provide comments.

Perhaps the greatest challenge to maintaining a concise set of principles and user needs that drive design specifications will come from the evolving concept of distributing command and control for operations within an International Partner's segment to the respective International Partners. Accommodating new launch vehicles, new transfer vehicles, new on-orbit modules (e.g., centrifuge module), and perhaps even new International Partners will require either the development of new principles or the revision of previous principles that appear in the ISSA baseline COU.

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