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SPACEHAB I MAINTENANCE EXPERIMENT

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Abstract

The SpaceHab I flight on STS-57 served as a test platform for evaluation of two space station payloads. The first payload evaluated a space station maintenance concept using a sweep signal generator and a 48-channel logic analyzer to perform fault detection and isolation. Crew procedures files, test setup diagram files, and software to configure the test equipment were created on the ground and uplinked on the astronauts' voice communication circuit to perform tests in flight. In order to use these files, the portable computer was operated in a multi-window configuration. The test data was transmitted to the ground allowing the ground staff to identify the cause of the fault and provide the crew with the repair procedures and diagrams. The crew successfully repaired the system under test.

The second payload investigated hand soldering and de-soldering of standard components on printed circuit (PC) boards in zero gravity. It also used a new type of intra-vehicular foot restraints which uses the neutral body posture in zero-g to provide retention of the crew without their conscious attention.

As initially conceived, Space Station Freedom was to be a highly automated, highly productive port in space. All the main systems would contain automated fault detection and isolation capability to aid in maintenance. Failed units would identify themselves and be replaced by the crews using a limited list of tools. Equipment meeting a group of approximately 30 attributes like these were designated orbital replacement units (ORU's). These requirements were in the program requirements documents of the space station.

As the program developed, costs grew, problems were identified, and it was subjected to numerous revisions. The universal automated fault detection and isolation capability requirement was removed during the revision in the summer of 1990. The effect of this decision was to increase the probability that more systems, as compared to components, would have to be changed on orbit. The increase in up and down mass for maintenance would have an adverse impact on normal operations and payloads.

This impact prompted an effort by the Tools and Diagnostic Equipment Subsystem of the Manned Systems to provide common test equipment in addition to the common tools in its charter. This test equipment was to give the crew the ability to actively test the various systems and isolate the faults to as low a level as possible. The intent was to allow changing of a component, such as a transformer, instead of a black box.

In a parallel effort, the Marshall Space Flight Center (MSFC) was developing plans to support the users of the space station with special test equipment. The lab support equipment included a battery charger, a logic analyzer/oscilloscope, and a multimeter. When MSFC started to implement their plan, the duplications became obvious and the program elected joint development of the common equipment to reduce costs.

The equipment selected to meet the maintenance needs and the lab support equipment needs were the Tektronics 1230B logic analyzer/oscilloscope and the Hewlett Packard 8116A sweep signal generator. The logic analyzer/oscilloscope is a 48 digital channel test instrument capable of testing PC boards and a dual channel analog oscilloscope. It is computer controllable through a RS-232 interface, and is triggered to store the data array by relationships among the active channels. This data may be displayed or stored in a DOS file which can be transferred over the

RS-232 interface. This transfer capability allows the data to be downlinked to the ground and displayed on instruments there.

The sweep signal generator can produce standard test signals, i.e., sine, square, triangular, and ramp waves and dc voltages.

Selection of the equipment had been completed and materials and electromagnetic interference characteristics were being investigated when an opportunity arose.

SpaceHab, Inc., was formed to take advantage of the Space Transportation System's capabilities to carry diverse payloads. By providing an integration function and a vehicle, the SpaceHab module, the company will provide an important service to small payloads. SpaceHab contracted with Alenia Spazio, an Italian aerospace organization, to build the modules. The contract to perform the integration of the payloads into the vehicle was given to McDonnell Douglas Space Systems Division (MDSSC), Huntsville, Alabama.

On the first flight of the module on STS-57, some of the volume and weight capability was not taken by customers. This available resource was acquired by NASA and offered to internal offices having a need to perform flight testing.

The development of the maintenance diagnostic equipment for the space station had advanced to the point at which a flight test was feasible, and the offer of resources was accepted. Weight and volume were reserved for the Space Station Tools and Diagnostics System (TDS). Initially, this area included three experiments: the Diagnostic Equipment (DE) experiment, the Soldering Equipment (SE) experiment, and the Battery Charger (BC) experiment. As the design of the experiments matured, the weight limitation caused the BC experiment to be dropped.

One goal of the TDS-DE was to operate the space station maintenance diagnostic equipment in the zero-g environment. A scenario was developed to simulate the proposed maintenance concept of the space station. In this concept, when an equipment failure is discovered, the failure is analyzed by the flight and ground crews and any descriptive information is given to the system engineers. The system engineers develop a test to isolate the fault based on using the programmable test equipment on board. The test procedures, appropriate schematics and diagrams, and the program to configure the test equipment are uplinked to the flight vehicle. The crew uses the program to configure their equipment and the procedure to setup and perform the test, aided by the schematics and diagrams.

The data from this test is then downlinked to the system engineers who either develop a repair procedure or develop a further test. The repair files, containing procedures, schematics, and diagrams, are uplinked to the crew who then restore the equipment. Testing, where appropriate, would be done in a similar manner. Demonstration of this uplink and downlink capability was also a goal of the TDS-DE experiment.

Since the multiple files would have to be operated or referenced at arbitrary intervals, the normal DOS environment was replaced by using a Microsoft product that allowed several applications to be active. Evaluation of this technique was a third goal of the TDS-DE experiment.

Because the TDS-DE was considered to be a payload on the SpaceHab module, specific resource usage was required by MDSSC, the payload integrator. This requirement skewed the test somewhat, in that a timeline for the crew was needed before the failure would normally have been discovered. This timeline and the procedures and data were developed around a test assembly, used to simulate the system under test. The test assembly was a frequency counter with a jumper wire across two pins on a terminal strip. It contained test points to provide signal tracking through the circuitry and power status and connectors for the signal generator and logic analyzer. The repair consisted of relocating the jumper wire.

The soldering test was an outgrowth of a soldering test which had been flown on the KC-135. As conceived, the test used battery-powered soldering tools. In practice, the number of solder connections was too high for the battery-powered tools and it was necessary to use commercially available DC powered tools. The tasks required soldering and de-soldering wires to 44 test points on two PC boards. These test points included various types of connectors (turret, pad, etc.). Wicking material was selected to remove the solder during the de-solder process.

Concern that soldering was a hazardous process led to the requirement for containment of any particulate matter generated during the soldering process. The containment device developed consisted of a shroud over the MDSSC-supplied work bench.

Special foot restraints to react to small forces generated during labor intensive tasks were developed. Normally, an acclimated crew prefers to float freely in the vicinity of the work. Exertions of small forces are adequate for them to remain in the desired position. For extended work in one area, foot loops are available. Some muscular exertion is required to maintain the foot in the restraint, which is a cause of hot spots and cramps. The engineer involved in the TDS-SE had been a test subject for evaluation of the space station foot loops on the zero-g aircraft. On the basis of his experience there and his knowledge of the soldering restraint requirements, he developed IVA foot restraints using the same principle as the old "golden slippers" EVA foot restraints. These foot restraints are open in the center with bars behind the heels and over the instep. They mounted to the handrails of the single SpaceHab rack below the MDSSC-provided work bench. They were installed for launch.

As an aside, this was my first experience as a payload provider. The other equipment I have provided was as part of the vehicle and was supported by the internal resources in the provisioning of the safety material. This was not the case for the SpaceHab I flight. It was necessary for me and my staff to prepare the data needed for the safety review process. I did not anticipate the type of data needed to satisfy this requirement. Once the requirements were understood, the required data was provided.

The result of the experiments was proof of the maintenance concept. The TDS-DE procedures were uplinked as planned, the data was downlinked, the repair procedure was performed by the crew inflight, and the equipment was tested successfully after the repair.

The crew was able to display the procedures and diagrams simultaneously.

The TDS-SE was highly successful. More than the one solder and de-solder board were completed. Analysis of the solder joints shows results consistent with preflight training. The foot restraints were well received and have been requested for future SpaceHab flights.

A STANDARD SET OF INTERFACES FOR SERVICEABLE SPACECRAFT BY THE NASA SPACE ASSEMBLY AND SERVICING WORKING GROUP

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Abstract

One key element required for effective space logistics activity is the development of standard spacecraft interfaces. To this end, the NASA Space Assembly and Servicing Working Group has created the Interface Standards Committees composed of mechanical, electrical, fluid, thermal, and optical committees. The objective of the ISC is to create international spacecraft standards to support space maintenance and servicing. Recently, ISC panel discussions have described the need for a "Standard Set" of interface hardware standards for satellites and platforms and to develop international standards for each of these critical interfaces. The set is to include: Navigation Aids; Grasping, Berthing, and Docking Interfaces; and Utility Connectors.

1.0 INTRODUCTION

The Space Assembly and Servicing Working Group (SASWG) is a NASA organization with over 700 individual members from government, industry, and academia dedicated to the study of enabling technologies for spacecraft maintenance and servicing. To this end, the SASWG has created the Interface Standards Committees (ISC) composed of mechanical, electrical, fluid, thermal, and optical committees with approximately 60 voluntary members from NASA, U.S. Space Command, U.S. Air Force, U.S. Navy, and industry personnel. It is the objective of the ISC to create international spacecraft standards to support space maintenance and servicing.

The SASWG ISC is currently engaged in 10 standards projects. Draft documents have been referred to professional standards organizations to become standards, guidelines, or recommended practices. To date, the American Institute of Aeronautics and Astronautics (AIAA), the Electronic Industry Association (EIA), and the Society of Automotive Engineers (SAE) have accepted SASWG ISC interface standards projects. The ISC provide these standards organizations with the technical expertise required to prepare standards, guideline, and recommended practices. After review by the professional standards organization, documents are adopted and referred to the ANSI for referral to international standards organizations.

Each professional standards organization is accredited by American National Standards Institute (ANSI) to develop American National Standards. Only the ANSI serves as the U.S. member of international standards organizations such as the International Standards Organization (ISO), the International Electrotechnical Commission (IEC), and the Pacific Standards Congress (PASC).

While the SASWG has set an objective to create international spacecraft standards to support space maintenance and servicing, it should be noted that there are other compelling reasons to support international spacecraft standards. Joint U.S. Government and industry activity is needed to support private sector interests in government-to-government standards negotiations, since it is unlikely that industry alone will provide the necessary financial support for U.S. representation. Also, industry cannot perform a adequate role of negotiator to assure a means for U.S. manufacturers to meet international standards and continue to have access to international markets.

Recently SASWG spacecraft standards panel discussions have described the need for a "Standard Set" of interface hardware standards for satellites and platforms. The set is to include: Navigation Aids; Grasping, Berthing, and Docking Interfaces; and Utility Connectors (electrical power, data, and fluid connectors, as required by spacecraft for on-orbit maintenance). It is the objective of the SASWG to develop international standards for these critical interfaces.

2.0 DISCUSSION

2.1 Current SASWG Interface Standards Projects

Documents have been referred to professional standards organizations for review and approval.

American Institute of Aeronautics and Astronautics

1) Guideline for Grasping / Berthing / Docking Interfaces - Approved by AIAA Serviceable Spacecraft Committee on Standards (AIAA SS COS) (AIAA G-056-1992)
2) Standard Interface for Remote Manipulator System Payload Deployment and Retrieval Grapple Fixture - Proposed to AIAA SS COS
3) Standard Interface for Magnetic End Effectors - Proposed to AIAA SS COS
4) Guideline for Serviceable Spacecraft Utility Connectors - Proposed to AIAA SS COS

Electronic Industry Association

5) Electrical Connector - Sub-Miniature - Approved by EIA Standard Committee CE 2.0
6) Electrical Connector - Large - Approved by EIA Standard Committee CE 2.0
7) Fiber Optic Connector - SASWG ISC Project

Society of Automotive Engineers

8) Preparation of Specifications for Metric Fluid Couplings for Spacecraft Servicing - Approved by SAE Committee G-3 (MAP2261)
9) Standard Interface for Hex Head Bolt and Wrench - Proposed to SAE Committee E-25
10) Guideline for Replaceable Thermal Insulation Interfaces - SASWG ISC Project

2.2 SASWG Interface Document Preparation Methodology

The SASWG ISC standardization process is performed in six steps:

1) Identify and discuss key standards issues during face-to-face meetings and report in SASWG ISC Minutes.
2) Prioritize candidate hardware interfaces projects by consensus vote.
3) Identify committee members from industry and government and elect a project leader.
4) Prepare draft standards, guidelines, and recommended practices (mostly performed with communication by facsimile and telecon).
5) Refer draft documents to professional standards organizations for review and approval.
6) Attend professional standards organizations committee meetings and provide consultation, especially for technical requirements unique to spacecraft design and operations.

3.0 DOCUMENTS PROPOSED TO THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS (AIAA)

3.1 Grasping / Berthing / Docking Interfaces

This guideline provides technical information for the design of three mechanical interfaces required for spacecraft servicing --- grasping by telerobotic or visual manipulation, berthing of payloads or spacecraft, and docking of spacecraft. Achieving a degree of commonalty individually and collectively for this general class of interface will simplify the servicing of a variety of orbital replaceable units (ORU's), Attached payloads, platforms, Space Station Freedom, satellites, and other passive and mobile spacecraft. The invaluable experience of past missions from Gemini to the Shuttle Orbiter provides the basis for the information contained in this document.

3.2 Remote Manipulator System Payload Deployment and Retrieval Grapple Fixture Interfaces

This standard establishes the interface design requirements for three standard grapple fixtures - Flight Releasable Grapple Fixture (FRGF), Rigidized Sensing Grapple Fixture (RSGF), and Electrical Flight Grapple Fixture (EFGF). Design requirements are provided for the Grapple Fixture interface and Extravehicular Activity (EVA) release interface. It should be noted that there are three new non-standard grapple fixtures models - Flight Releasable Light Weight Grapple Fixture (LWGF), Auxiliary Grapple Fixture (AGF), and Electrical Light Weight Grapple Fixture (ELWGF). The light weight grapple fixtures are a solution to the weight / budget problems of payloads.

3.3 Magnetic End Effector Interface

This standard provides interface requirements for use by robotic arms with a magnetic end effector for grappling ORUs, satellites, structures, tools, and other serviceable spacecraft payloads during space operations. The interface aspects are mechanical (dimensional), structural, performance, thermal, electrical, and operational. A Magnetic End Effector has been developed to provide a dexterous end effector for the Shuttle Remote Manipulator System (RMS), and will be tested in space during a flight demonstration in 1994.

3.4 Utility Connector Interfaces

This guideline reviews the development of utility connectors for spacecraft servicing systems. Utility connectors are designed for fully automated remote operation, separate from and independent of any docking mechanism, operation after a docking mechanism is rigidized, and are compatible with both single point and three point docking mechanisms. Technical information is provided for the development of standard interface design of utility connectors intended to be for a variety of applications where multiple utilities are required in a single connector. The connector may include electrical power, data, and fluid ports. This system is considered vital for the development of serviceable spacecraft.

4.0 DOCUMENTS PROPOSED TO THE ELECTRONIC INDUSTRY ASSOCIATION (EIA)

4.1 Electrical Connectors, Rectangular, Blind-Mate, Scoop-Proof

This standard provides terminology, description and requirements of a blind-mate, scoop-proof, rectangular shell series of electrical connectors for serviceable spacecraft for use during space and ground support activities. Aspects such as size, alignment, mating force, material requirements, reliability, durability, weight, electrical and physical characteristics, and temperature range are covered. This standard is intended to assist project managers, designers, and others concerned with electrical connectors in aerospace technology toward standardizing usage with respect to serviceable spacecraft.

4.2 Electrical Connectors, Rectangular, Blind-Mate, Scoop-Proof, Low-Force, Sub-Miniature

This standard is for a rectangular electrical connector is similar to the document above, except for the size and locking mechanism. This connector is smaller, and may utilize release levers.

5.0 DOCUMENTS PROPOSED TO THE SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

5.1 Preparation of Specification for Metric Fluid Couplings for Spacecraft Servicing

This approved SAE Metric Aerospace Recommended Practice (MAP) establishes the requirements for preparing a specification for fluid couplings for spacecraft servicing. The objective of this document is to provide design, development, verification, storage, and delivery requirement guidelines for the preparation of specifications for fluid couplings and ancillary hardware for use with serviceable spacecraft designed for use in the space environment. The couplings shall be capable of re-supplying storable propellants, cryogenic liquids, and gases to a variety of spacecraft.

5.2 Hex Head Bolt and Wrench Interfaces

This standard provides design and materials requirements for a 8 and 12 millimeter hex head bolt to spacecraft fastener. Dimensions and clearances were determined to assure bolt and wrench compatibility over the temperature extremes of space as part of a Special Project prior to the preparation of a draft standard for spacecraft fasteners.

6.0 CONCLUSIONS

The purpose of the NASA Space Assembly and Servicing Working Group Interface Standards Committee is to prioritize spacecraft mechanical, electrical, fluid, thermal, and optical interface projects selected by member consensus; prepare draft standards, guidelines, and recommended practices; refer to professional standards organizations; and assist with document review, approval, and referral to international standards organizations. A "Standard Set" is needed for serviceable spacecraft. The set will consist of (1) navigation Aids, (2) grasping, berthing, and docking Interfaces, and (3) utility connectors (electrical power, data, and fluid connectors). Standardization of interfaces has been proven effective for aircraft manufacturing, servicing, and maintenance. Internationally recognized standard interfaces are a driver to the development of serviceable spacecraft and the establishment of a global spacecraft maintenance infrastructure. Interface standards have to be imposed to force cost savings from on-orbit maintenance.

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13. ABSTRACT *(Maximum 200 words)*

This document contains papers presented at the Space Operations, Applications and Research Symposium (SOAR) Symposium hosted by NASA/Johnson Space Center (JSC) on August 3-5, 1993, and held at JSC Gilruth Recreation Center. The symposium was cosponsored by NASA/JSC and U.S. Air Force Materiel Command. SOAR included NASA and USAF programmatic overviews, plenary session, panel discussions, panel sessions, and exhibits. It invited technical papers in support of U.S. Army, U.S. Navy, Department of Energy, NASA, and USAF programs in the following areas: robotics and telepresence, automation and intelligent systems, human factors, life support, and space maintenance and servicing. SOAR was concerned with Government-sponsored research and development relevant to aerospace operations. More than 100 technical papers, 17 exhibits, a plenary session, several panel discussions, and several keynote speeches were included in SOAR '93. These proceedings, along with comments and suggestions made by panelists and keynote speakers, will be used to assess progress made in joint USAF/NASA projects and activities to identify future collaborative/joint programs. SOAR '93 was the responsibility of the USAF NASA Space Technology Interdependency Group Operations Committee. Symposium proceedings include papers presented by experts from NASA, the USAF, USA, and USN, U.S. Department of Energy, universities, and industry.

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