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ATR-76(7362)-1, VOL. I

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STS Users Study (Study 2.2) Final Report

Volume I: Executive Summary

Prepared by ADVANCED MISSION ANALYSIS DIRECTORATE
Advanced Orbital Systems Division

1 November 1975

Prepared for
OFFICE OF SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW-2727

Systems Engineering Operations
THE AEROSPACE CORPORATION

Report No.
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STS USERS STUDY (STUDY 2.2)
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STS USERS STUDY
(STUDY 2.2) FINAL REPORT

Volume I: Executive Summary

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FOREWORD

The STS Users Study (Study 2.2) Final Report is comprised of three volumes titled as follows:

Volume I	-	Executive Summary
Volume II	-	STS User Plan (User Data Requirements) Study
Volume III	-	Ancillary Equipment Study

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Mr. William F. Moore, STS Operations Office, Office of Spaceflight, NASA Headquarters, managed the STS Users Study. Assistance was also given by Messrs. John Twigg and Charles Hart (NASA KSC); Wilbur Thompson and Robert Mixon (NASA MSFC); and Joseph Loftus, Max Krchnak, and Ed Dupnick (NASA JSC).

The Aerospace Corporation effort on the studies was accomplished by the following Members of the Technical Staff:

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CONTENTS

TABLES

1. INTRODUCTION

The STS User Study includes:

1. The STS User Plan (User Data Requirements) Study
2. The Ancillary Equipment Study.

NASA needed to find out which STS user required data are not being furnished and have them described. In addition, the NASA Headquarters Office of Space Flight (OSF) Missions and Payloads Office is interested in working toward a document constructed to fit the needs of potential STS users (i.e., users working in the study phases of payload and space systems).

For the STS User Plan Study, over 100 STS and payload documents were surveyed to find which user data are missing. The user data required for each phase of the user activity are formalized in a matrix, related to the documented data, and the missing users' data are identified. If further investigation shows no plan or provision for acquiring and documenting it, the missing data are defined and described in a statement in Research Technology Operating Plan (RTOP) format. The study results therefore mesh with the RTOP system and are directly useful to NASA.

NASA is considering definition and development of Multi-Mission Support Equipment (MMSE). NASA needs to understand which support equipments under consideration are potentially useful for DoD STS payloads. In the Ancillary Equipment Study the ancillary equipment needs for DoD payloads were examined. Many of the NASA MMSE correspond to the types of equipment needed by DoD. Fifteen on-line MMSE are potentially applicable to one or more of the DoD payloads in the near term.

2. STUDY OBJECTIVES

The objectives of the STS User Plan (User Data Requirements) Study are to:

1. Prepare an overall estimate of data and planning requirements needed by the STS user
2. Determine where the NASA and USAF studies related to STS users fit into the estimated Matrix of planning requirements
3. Provide NASA with the contractors' estimates of additional user required data not currently covered by study activity which, if carried out, would satisfy the requirements of the Matrix and planning requirements.

The objective of the STS Ancillary Equipment Study was to describe, from NASA's point of view, the potential for common usage of Multi-Mission Support Equipment (MMSE) by DoD in addition to NASA users.

3. RELATIONSHIP TO OTHER STUDIES

In Study 2.2, the STS user analysis made use of a long list of NASA and DoD study reports, as well as documentation for NASA and DoD payload projects and NASA and Rockwell International documentation on the STS. For a complete list of studies used, please refer to Sections 9.1 and 9.0 of Volumes II and III, respectively, of this report.

The STS User Plan (User Data Requirements) Study is related to the SAMSO-sponsored STS Users' Guide activity. Wherever possible, the same Aerospace Corporation personnel supported both these activities. Thus, when documentated data was reviewed for application to one activity, little additional effort was required to assess the applicability of the same information to the other study.

The Ancillary Equipment Study is primarily related to the Multi-Mission Support Equipment (MMSE) Study accomplished by the Martin Marietta Corporation, Denver Division. This FY 75 study was sponsored by NASA Marshall Space Flight Center and NASA Kennedy Spacecraft Center. Other primary references for the Ancillary Equipment Study are the DoD STS Payload Interface Study accomplished in fiscal years 1973, 1974, and 1975 by McDonnell Douglas, and Rockwell International Payload Interface Studies carried out in FY 75. These latter studies were sponsored by the USAF Space and Missile Systems Organization (SAMSO).

4. STS USER PLAN STUDY

4.1 METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

When the STS User Plan Study was planned and initiated in the September 1974 time period, SAMSO/Aerospace had a large STS data bank, consisting of NASA, DoD, and contractor documents related to the various elements of the Space Transportation System and its potential payloads. The Aerospace Corporation's Advanced Mission Analysis Directorate also had acquired data on many NASA payload projects over the previous three or four years for use on NASA studies. Early in the study, an activity was initiated for the purpose of surveying the data available and acquiring data not already in house but needed for these studies. This study shared in the NASA studies data bank effort in order to acquire NASA and DoD historical payload data needed but not available at Aerospace. Other primary users of these data were Studies 2.3 and 2.4 (Ref. 1).

On the basis of the information in the payload data banks, a list of STS user data requirements is made. The requirements include data shown to be needed by payload project phase for past or current payload projects. STS payload study data was also used to determine payload data requirements. In addition, several brainstorming meetings were held for the purpose of generating user data requirements which might not be evident from the documentation.

The user data requirements list was related through a matrix format to a typical payload project activity by program phase. The full matrix listing the user data requirements is 39 pages and is presented in Volume II. A sample page is shown in Table 4-1. The data requirements are listed in the left-hand column and payload program phases

Table 4-1. Sample Page from User Data Requirements Matrix

DATA REQUIRED RELATIVE TO THE STS SYSTEM BY STS PAYLOAD PROJECTS
PAYLOAD/SHUTTLE INTEGRATED FLIGHT
(Interface Specifications, Vehicle Data, System Capabilities, Software, Policies and Procedures, NASA Contact)

Payload Program Phases / Data Requirements For:	Potential User			Committed User					
	Pre-Phase A	Phase A	Phase B	Develop (Phase C/D)	Mission & Flight Planning	Ground Operation	Orbital Operation	Data Management	L/V Transition Phase*
• Shuttle Payload Attachments and Structural Support Provisions									
/ Changes from Ground Config.		f, ②	①	①					①
/ Flight Loads Accepted		f, ②	①	①					①
• Shuttle Power									
/ Locations		f, ①	①	①			①		①
/ Quality and Schedule		f, ①	①	①			①		①
/ Kitting Provisions		f, ①	①	①			①		①
• Remote Manipulator									
/ Functions		f, ①	①	①			①		①
/ Limitations		f, ①	①	①			①		①
/ End Effectors		f, ②	①	①			①		①

* For payload transition from expendable launch vehicles to the STS with "minimum modification" to the payload.

are listed across the top of the page. Pre-Phase A and Phase A are conceptual study phases; while Phase B is a system definition phase. The remaining Development and Operational Phases are self-explanatory. These phases represent typical steps which a user's payload project may go through (Ref. 2). The notation "f" in a column denotes that that particular phase is the first one of the sequence where the data is needed. Where a (1) appears in a column, the data is required in order to carry out a normal study in that phase of payload activity. Where a (2) appears, it denotes that it is desirable to have the information or data available for that phase of the study, but the study could normally be carried out using assumed or estimated data. These user data requirements were reviewed in house, with NASA Headquarters, and with representatives from KSC, MSFC, and JSC.

The next task in the STS User Plan Study was to read through documents which could contain STS user data. The information in each of the documents is summarized and related to the matrix when appropriate. A sample of a Document Summary Sheet is shown in Table 4-2. The key for this reference if F-1. Wherever it is applicable to the data requirements, the key F-1 appears in the matrix. For instance, the data are applicable to seven of the data requirements in Phase A shown in Table 4-3. This table repeats the "f", (1) , and (2) information and lists by key each of the references with data applicable to each of the user data requirements. If evidence is found in a document that data will be made available in the future, it is noted in parentheses after that key, e.g., EP-15('75) indicates that document EP-15 plans to make the data available to the user and the estimate is by the end of 1975. Data for items 7 a and c to support Phase B are provided in detail commensurate with the development phase requirements. Thus the data are available to cover these areas, although the user would have to select and filter the data to obtain data appropriate for Phase B activity.

Sample Document Summary Sheet

REFERENCE F-1

TITLE: DoD Space Shuttle System Summary

REPORT NO: None

DATE: 1 August 1974, Updated 4 December 1974

AUTHOR(S): Report is complied and maintained by the Reusable Launch Vehicles System Program Office (SAMSO/LVRE), with Capt. Paul H. Kruppenbacher editing the 1 August issue and the update.

SUBJECT: Report summarizes the characteristics of the Space Transportation System with emphasis on DoD aspects.

BASIS FOR INFORMATION: Report is a compilation of annotated briefing charts prepared with the assistance of Rockwell International and The Aerospace Corporation

STATUS OF INFORMATION: Current as of 4 December 1974 but made partly obsolete by subsequent STS development; planned to be updated to include Orbiter 102 Preliminary Design Review data in Spring, 1975; not an official Air Force publication.

COVERAGE OR CONTENT: General description of Space Transportation System, its capabilities, development milestones, and elements of operations and support systems.

COMMENTS: Good document for an overall view of the Space Transportation System; does not provide a great deal of depth; the same material, including identical figures, can be found in other documents.

APPLICABLE TO DATA REQUIREMENT: Sections 2.1.1; 2.1.6.j; 4.1.1; 4.1.6.j; 5.3; 5.4.a, c; 5.7.b; 5.8; 5.9; 5.10.a, d, e; 5.11; 5.12.b; 5.14.a, b; 5.15; 5.16.d; 5.19.d; 5.27; 5.28; 5.30; 5.32.a.

Table 4-3. Sample Page from Data Available Matrix

STS POTENTIAL USER DATA REQUIRED RELATIVE TO THE STS SYSTEM

5.0 PAYLOAD/SHUTTLE INTEGRATED FLIGHT

(Interface Specifications, Vehicle Data, System Capabilities, Software, Policies and Procedures)

Data Requirements For / Payload Program Phases	Pre-Phase A	Phase A	Phase B
• Shuttle Payload Attachments and Structural Support Provisions			
/ Changes from Ground Config.		f, ② EP-4;EBM-6, 11; F-7	① (1)
/ Flight Loads Accepted		f, ② EP-4;EBM-6, 11; F-7	① JP-1; EBM-11
• Shuttle Power			
/ Locations		f, ① EBM-11; F-1, 2, 7, 8; JP-12; EP-4, 14, 15(A'75)	① EP-15(A'75); JP-1; EBM-11
/ Quality and Schedule		f, ① EP-4, 14; F-1, 2, 7, 8; EBM-6, 11; JP-1	① JP-1, 12; EBM-11
/ Kitting Provisions		f, ① EP-4, 14; EBM-6; F-1, 2, 7, 8; JP-1, 5	① (1)
• Remote Manipulator			
/ Functions		f, ① EBM-6, 11; F-1, 7; JP-16	① JP-12, 16; EBM-11
/ Limitations		f, ① EBM-6, 11; F-1, 7; JP-1, 16	① JP-1, 16; EBM-11
/ End Effectors		f, ② EBM-6, 11; F-1; JP-12(2), 16(2)	① EBM-11

(1) Some data applicable to committed user is available, see Section 8.0, Volume II

(2) Partial coverage.

After the User Data Requirements Matrix is filled out, it is inspected to determine areas where data are missing or inadequate. The data are missing from several areas because the STS definition was inadequate to support the user data requirements. Work on these areas is postponed until the data are expected to be ready. For other missing data areas, study tasks were initiated in order to define the data, describe the data, and justify the requirement for the data. Nine study tasks are accomplished. Where justified, statements of user data requirements are prepared for each area in RTOP format and transmitted to NASA.

It is assumed in this study that studies developing interface analysis techniques, plans for testing to obtain interface data, and plans to furnish data described in the documents as "to be determined" or "TBD" would be carried out. It is also assumed in assessing the documented data for applicability to the users' needs that NASA, DoD, or NASA/DoD contractor documents covering any of the user data requirement areas were furnishing credible information.

4. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

In this study it was found that the STS user required information related to flight scheduling and flight manifests was not available. The user needs to understand organizationally at NASA where the management and responsibility for these areas lay; the current schedule and projections for available flight accommodations; and rules, requirements, policies, and procedures relative to flight scheduling and sharing. The user also needs to understand and be provided methods for estimating weights charged to the payloads for shared and unshared flights.

Another finding in this study resulted from the survey of the data available to the user on dynamic loads on the Shuttle payload. Recent technical studies simulating the dynamic payload orbiter combination have shown that dynamic loads during landing can be as high as 5 to 9 gs. These loading conditions designed some elements of the payload structure. The uncertainty in these loads at this stage of the orbiter development and the weight constraints on some payloads can result in critical design problems late in the development program. Load alleviation devices can be added to the payload installation, design, and testing program. The user needs data on STS dynamic load alleviation concepts which could be potentially applied to the interface between the payload and the orbiter.

The STS user has the option to use orbiter power, communications, cooling, and other services, as well as orbiter attachments, the remote manipulator, and attitude and navigation handoff data. Each of the services is supplied through orbiter and orbiter/payload interface equipment. The user needs failure mode, effects, and frequency of occurrance data covering each of the equipments.

During the study it was found that the acoustic environment to which the payload would be subjected at liftoff was being predicted on the basis of analytical studies and model testing. The uncertainty in the predicted acoustic environment is relatively large and it was recommended that a 3-sigma, worst-case type environment prediction be made for use by payloads interested in a low risk development program.

In the study it was found that some of the payloads would want to consider mounting the payload in the payload bay with five attach points. In order to reduce the attach point loads to acceptable levels, the fifth attach point requires that loads induced by the orbiter deflection be added to the payload attachment loads. In order to accomplish this analysis, the STS user will need orbiter payload bay deflection data.

A Spacelab user will need interface data for both the pressurized module and the unpressurized pallet. Some of the data supplied, but the following information is missing at this time:

1. Administrative (data related to scheduling, flight manifests, proprietary rights, user costs, and experiment/Spacelab interface control)
2. Equipment environments (contamination data)
3. Ground support facilities and services (ETR and WTR)
4. Spacelab services, instruments, standard support equipments on data management, power supplies, pointing and navigation data, and crew support (including EVA)
5. Provisions for experimenters onboard the STS
6. Spacelab experimenter training and qualification
7. Physical constraints and mechanical interfaces
8. Physical characteristics of payloads permitted (e.g., weight and dimensions)
9. Integration procedures, requirements, and instructions for Levels I, II, and III integration
10. Ground operations and flight operations.

In order to relate the user's payload design with STS performance, a payload chargeable sequential weight statement will be required. The user will also need to understand the weight margins available to him and Shuttle load factors. The derivation of these sequential weights is a part of the user's mission analysis. It must be relatable to the STS operator's flight plan. In order to accomplish this, a set of standard definitions for payload chargeable weights; load factors; and weight, propellant, and payload c. g. margins need to be developed. An example analysis is used to illustrate the problem.

It was found during the study that certain data would not be finalized until needed [illegible] STS users scheduled for flight early in the Shuttle era. For instance, the dynamic loads to which a payload may be subjected are expected to be much better defined after the Shuttle flight test program. The acoustic overpressure to which the payload is subjected will also be much better understood after the flight test program. The need for the data on load alleviation devices and worst-case acoustic environment result from this gap in the user required data. Both these user data requirements supply data enabling the payload designer and Shuttle user to work around the temporarily unavailable data.

The STS capability in several areas is currently being defined but is in such a state of change or incomplete definition that the user data requirements cannot be currently quantified. Among these are: (1) the capability of the remote manipulator system expected to assist in the deployment of payloads, (2) the procedures and sequence for docking payloads to the orbiter, (3) the potential electromagnetic interference between orbiter and payload due to orbiter radiation, and (4) the orbiter/payload avionics capability. It is recommended that these areas be monitored in the future for STS user data requirements. It is recommended that the STS user data requirements in the avionics area be studied in the next fiscal year. The avionics system definition is maturing rapidly.

5. ANCILLARY EQUIPMENT STUDY

5.1 METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

When the study was initiated, the on-line Multi-Mission Support Equipment (MMSE) list contained 76 items and 56 additional items were listed as launch site MMSE. In the Ancillary Equipment Study, 35[1] airborne and 19 launch site equipment items, studied by Martin Marietta and accepted by NASA KSC or MSFC for further definition and study, were identified and listed as MMSE to be considered. Descriptions of most of the selected equipments are contained in the Martin Marietta catalogs for launch site and airborne (or on-line) MMSE (Refs. 3 and 4). The catalogs, modifications in the catalog descriptions, and description of items not in the catalogs were furnished to this study by Wilbur Thompson of NASA MSFC.

Revision 4 of the DoD STS Mission Model was used in this study. It was found that the payload and interface data (Refs. 5 through 10) are available in sufficient depth to identify airborne ancillary equipment needs for six DoD payloads. Most of the launch site MMSE could be studied for applicability without the detailed payload data required for the airborne MMSE. The launch site MMSE application analysis was not limited to the six payloads. DoD airborne ancillary equipment needs are extracted from the information and data in References 5 through 10. Payload data are also extracted from the same references on the six payloads studied.

(1) Thirty-four automated spacecraft MMSE and one sortie MMSE.

The DoD ancillary equipment needs were then compared to the MMSE list to identify candidate MMSE for application to the DoD mission model. Thirty-one of the 35 items of airborne MMSE were identified as candidates for DoD ancillary equipment. The application of each equipment to each of the DoD satellites was studied by specialists. These equipment studies are discussed and the results are provided in Volume III of this final report.

This study was a first cut at identifying potential applications of MMSE. It is assumed that the study will continue in FY 76 so that when better definitions of payload/STS interfaces evolve, the potential utility of MMSE can be further assessed and compared with alternative approaches to support equipment.

5.2 BASIC DATA GENERATED AND SIGNIFICANT RESULTS

In the Ancillary Equipment Study the basic data generated are the potential applications of MMSE defined for DoD payloads. These basic data are presented on the Multi-Use Mission Support Equipment Data Sheets contained in Section 5 of Volume III of this report. In the near-term STS era, 15 on-line MMSE items were found to have one or more potential users among the DoD payload projects. Thirteen launch site MMSE items were found to have potential users in the DoD mission model. Several equipment items were recommended for addition to the NASA MMSE candidate list as another result of the Ancillary Equipment Study.

Eight of the 15 MMSE items which would be used by DoD payload projects are associated with the IUS/payload structural interface.

1. Payload Mounting Beam for Side-By-Side Payloads (XPMB-1)
2. Payload Mounting Beam for Single Payloads (XPMB-2)

3. Payload Interface Adapters Suitable for DoD Payloads (PIA-2 and PIA-3)

4. Payload Spacer for Small Diameter Multiple Payloads (PLS-2)

5. Payload Spacer for Medium Diameter Multiple Payloads (XPLS-3)(1)

6. Payload Service Plates (PSP-1, -2)

7. Separation Latch and Push-Off Assembly (SLP-1)

The General Purpose Platform (GPP-2) could be used to mount any one of three DoD payloads piggyback in the orbiter bay over the Spacelab tunnel.

A payload shroud may be needed by at least one DoD payload and MMSE item 06-02 is large enough to accommodate the IUS payload (DSP). In addition, the low earth altitude orbit payloads SOSS and DMSP may need shrouds. Recommendations are made for NASA's consideration for modification to accommodate these payloads.

The RTG Cooling Unit (06-01) satisfies DoD cooling capacity requirements and could be a common MMSE item for DoD and NASA.

The Orbiter/Payload Servicing Cable (IUS Deployed) MMSE item (05-03) is potentially useful to at least ten DoD payloads and some multiple payloads on the IUS. The Payload Umbilical Cabling (05-04) which mates with the servicing cable could also be used. Another MMSE item labeled Orbiter/Payload Service Cable and J-Box (05-01) would be applicable to multiple payload configurations in the payload bay if some weight reduction modifications to the approach could be incorporated.

---

(1) XPLS-3 design diameter increased to accommodate DoD payloads (see Volume III, Section 5.2, of this report).

The MMSE Purge System (06-03) could be used by the DoD payload DMSP to satisfy purging and cooling requirements.

Although a justification task was not a part of this study, it is expected that DDT&E costs would be lowered for both DoD and NASA by sponsoring common interface equipments (MMSE). In addition, there are potential advantages for system operators. Orbiter turnaround costs and payload installation time could be saved by the use of common on-line interface equipment. The use of a standard interface between the IUS and the NASA and DoD payloads would greatly facilitate the IUS operation with multiple payloads on the IUS.

Most of the DoD payloads for the early STS time frame will be transitioning from expendable launch vehicles. These transitioning payloads are expected to have the option of using previously applied GSE or launch site MMSE. The applicability of the previously used GSE to the STS supported payloads needs to be studied. However, six launch site MMSE items needed by DoD payloads are new to the STS and are recommended for consideration by NASA as common NASA/DoD equipments. These include payload containers, container transporters, and interface verification equipment.

6. STUDY LIMITATIONS

6.1 STS USER PLAN STUDY

It became apparent during the study that some STS elements were either in a state of being defined or the definitions were in a state of change. The user required data for the initial upper stage, avionics interface, and remote manipulator system were not available since it was too early to obtain firm definitions of the interfaces. Follow-up study is recommended (see Section 8).

6.2 ANCILLARY EQUIPMENT STUDY

The emphasis in the Ancillary Equipment Study was on the use of support equipment early in the Shuttle era; therefore, emphasis was on the IUS-related equipment rather than Tug-related equipment.

Initially Payload Specialist Station (PSS) and Mission Specialist Station (MSS) equipments were included in the study. It was found, however, that the scenario for use of these stations and their interface with the payload was under study by NASA, DoD, and their contractors; thus subject to considerable change. Therefore, these areas were deleted from this study and recommended for further effort in the future.

During this study, Aerospace was directed to apply MMSE defined by NASA and their contractors and not to define additional equipment, even though it might be identified as needed by DoD.

The DoD STS/payload interface data used in these studies were the best available (see Refs. 5 through 10). The interface studies are continuing and the DoD needs for support equipment are subject to change.

7. IMPLICATIONS FOR RESEARCH

As these studies progressed, it was noted that there is a great deal of concern about the possibilities of airborne and surface particles dirtying the payload while it is in the orbiter payload bay. Possible contamination from the orbiter reaction control system and orbiter vents, exhausts, and dump lines is also of concern. Research is needed on techniques for countering dirt and contamination on vital payload surfaces. The ability to clean payloads on orbit would be very desirable. Removing particles orbiting in the vicinity of the payload may also be desirable. It is suggested that cryogenic "vacuum" techniques, electrostatic techniques, and other approaches for accomplishing these types of cleaning be investigated with the objective of eventually developing payload cleaning tools (hand tools, RMS end effectors, etc.).

8. SUGGESTED ADDITIONAL EFFORT

User data requirements in some areas are related to hardware and STS capabilities which are in a state of development and change, making detailed user plan study at this time inappropriate. Areas expected to mature in the coming year and suggested for study include the orbiter avionics system and the NASA Mission Control support capability for payloads. In addition, it is recommended that the following areas be reviewed again since the study assumes that rapid progress will be made in obtaining user required data: (1) remote manipulator system, (2) rendezvous and docking to the orbiter, (3) electromagnetic compatibility and interface, (4) integrated payload/orbiter dynamic loads, (5) STS simulators for orbiter/payload interface, (6) Shuttle operational data book, and (7) reentry and terminal flight phase constraints affecting return opportunities.

In the coming year, Martin Marietta is under contract to NASA to study MMSE in the following areas which may be applicable to DoD: (1) attitude reference sensor, (2) electrical cabling, (3) RTG cooling unit, (4) payload shroud, (5) purge system, (6) IUS to payload interface structure, (7) orbiter to payload interface structure, and (8) deployment mechanisms.

In addition, McDonnell Douglas and Rockwell International are under contract to SAMSO to continue definition of STS/payload interface equipment needs. It is recommended that the Ancillary Equipment Study be continued in order to assess the applicability of the redefined MMSE to DoD and investigate potential advantages of common ancillary equipment between the two agencies.

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