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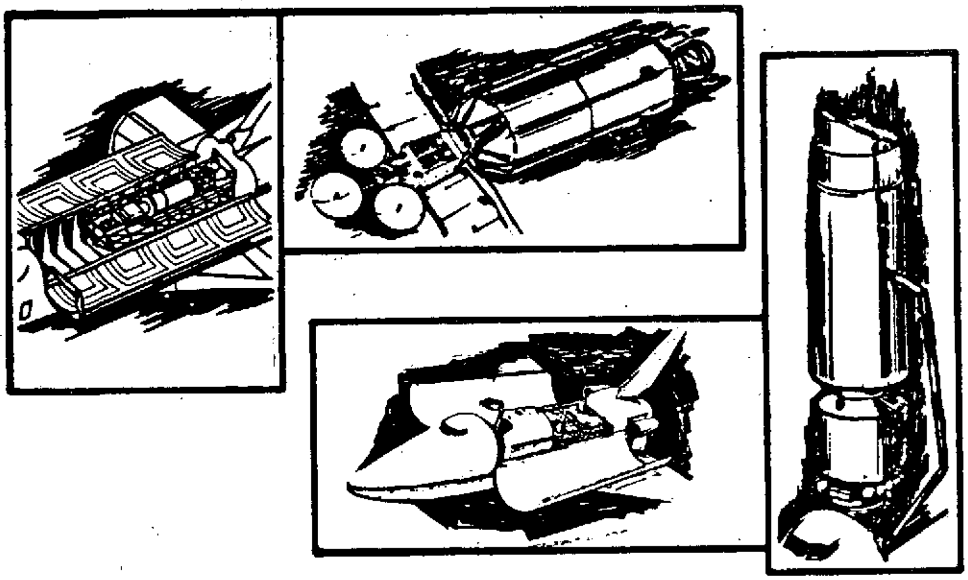

- SHUTTLE DELIVERED AUTOMATED SPACECRAFT
- SHUTTLE/TUG SPACECRAFT
- AUTOMATED SPACECRAFT
- SORTIE MISSIONS

CONTRACT NAS8-28583
MSFC-DRL 299/DR NO. MA-04

SHUTTLE ORBITAL APPLICATIONS AND REQUIREMENTS - SUPPLEMENTARY TASKS (SOAR-IIS) FINAL REPORT

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

TRW

MCDONNELL DOUGLAS CORPORATION

MCDONNELL DOUGLAS

CONTRACT NAS8-28583
SHUTTLE ORBITAL APPLICATIONS AND REQUIREMENTS SUPPLEMENTARY STUDY
(PAYLOAD/ORBITER INTERFACE TRADE TASKS)

FINAL REPORT

MSFC-DRL 299/DR No. MA-04

SEPTEMBER 1973

MDC G4785

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PREFACE

This document summarizes the final results of the $100,000 five-month SOAR-IIS study activity and was prepared by McDonnell Douglas Astronautics Company supported by TRW, Inc.

This study (Contract NASA-MSFC, No. NAS8-28583) addresses six major tasks that (1) assess and resolve specific tradeoff issues in the Shuttle-payload-facility interface, (2) analyze the impact of payload vs. Shuttle ancillary equipment provided for accommodations and services, and (3) provide an early definition of requirements and accommodations for the future. The study focuses on the specific tasks by evaluating four classes of payloads to determine detailed requirements in the generic areas of:

- Shuttle-delivered automated spacecraft (e.g., EOS)
- Shuttle/Tug-delivered spacecraft (e.g., ATS/SMS/DSCS-II)
- Man-tended spacecraft (e.g., LST)
- Sortie missions

This document fulfills the requirements of MSFC-DPD No. 299 (dated March 1973), Line Item MA-04, Documentation Report, Final Task.

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CONTENTS

Section 1
INTRODUCTION

The Shuttle Orbital Applications Requirements (SOAR) studies were performed in parallel with the evolution of the Shuttle and Tug designs. In general, the studies were broad overviews, with in-depth analysis only in selected areas to clarify difficult interface situations. NASA's Marshall Space Flight Center funded and managed the studies, which include:

- SOAR-I (February 9 to December 8, 1971 - $400,000), which covered manned modules, automated spacecraft, and pallet-mounted experiments.
- SOAR-II (April 7, 1972 through April 6, 1973 - $400,000), which was constrained to automated spacecraft and upper stages including the reusable Tug.
- SOAR-IIS (April 7, 1973 through September 6, 1973 - $100,000), which is a limited effort concentrated on select areas identified during SOAR-II as needing additional study.

The objectives for the SOAR-IIS study were (1) to assess and resolve specific Shuttle/payload/facility interface tradeoff issues, (2) to analyze the impact of payload versus Shuttle ancillary equipment provided for accommodations/services, and (3) to provide an early definition of requirements and/or recommendations to support the Orbiter SRR and for future analyses. Figure 1-1 shows the tasks and the schedule of the IIS effort and its important milestones.

The study focused on the specific tasks of interest by evaluating four classes of payloads to establish detailed requirements in the generic areas of:

A. Shuttle-delivered automated spacecraft (i.e., EOS).
B. Shuttle/Tug-delivered spacecraft (i.e., ATS/SMS/DSCS-II).
C. Man-tended automated spacecraft (i.e., LST).
D. Sortie missions.

FIGURE 1-1

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SOAR-II SUPPLEMENTARY STUDY-SCHEDULE

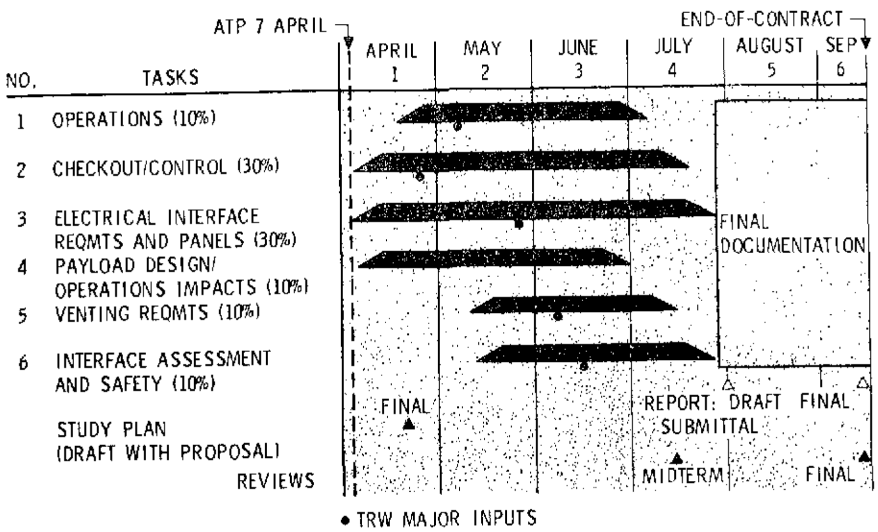

Figure 1-2 depicts the general flow of the SOAR-IIS study. It must be recognized that this effort consists of six somewhat independent tasks that are loosely knit together. These tasks, as shown, investigate specific areas of interest identified as being desirable in SOAR-II. The study approach utilizes payload data developed or assimilated in the earlier study of SOAR-II, and additional updated information from other current studies. Much of the data documented for SOAR-II in MDC reports G4471 through G4481 is still valid if taken in context of the more recent changes to the Orbiter. This earlier data is not in general repeated in this report. The study plan describing the tasks accomplished has been formally documented (see Report No. MDC G4497), dated April 1973.

The study team assembled for the SOAR-II Supplementary Study consists of the McDonnell Douglas Astronautics Company, responsible for Shuttle applications and payload integration, Space Tug, and the Shuttle, plus TRW as a subcontractor for automated spacecraft detailed requirements. In performing the study, this team applied the results of SOAR-I/II and other current Tug and DOD STS Payload Interface Study activities.

FIGURE 1-2

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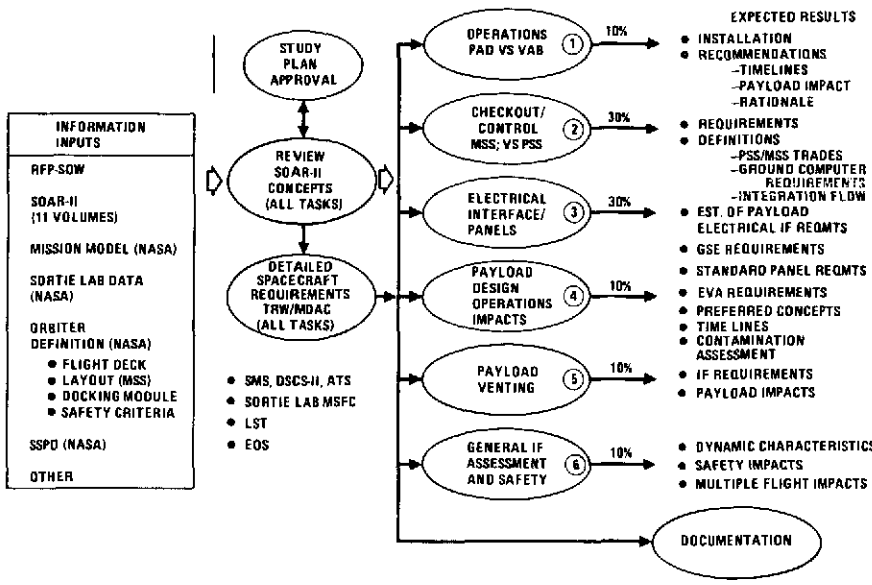
SOAR-II SUPPLEMENTARY STUDY FLOW



The study was performed based on the following NASA guidelines:

1. Existing payload hardware programs shall be reviewed as necessary to update reference sources of detailed subsystem/component monitoring/checkout characteristics and requirements.

2. Payloads analyzed in detail will include a representative set of Shuttle class payloads such as (a) Shuttle/Tug-delivered automated spacecraft, i. e., EOS, (b) Shuttle-delivered spacecraft, i. e., ATS/SMS/DSCS-II, (c) Man-tended automated spacecraft, i. e., LST, and (d) Sortie missions, i. e., sortie laboratory.

3. Sufficient depth of payload definition will be needed to enable adequate penetration of analysis in the checkout, control, and monitor requirements area.

4. The baseline sortie laboratory to be used in study efforts will be as defined in latest MSFC sortie laboratory documentation.

5. The Space Shuttle shall be considered as having a mission specialist station and one or more payload specialist stations with functional and equipment requirements to be determined. Selected basic functions pertaining to caution/warning will require routing to the mission specialist station.

6. Location options for payload monitor, control, or checkout equipment include Orbiter cargo bay, Orbiter crew compartment (flight deck and specialist stations), ground (launch or mission control facility), and combinations of these.

7. Where existing or planned ground facilities become a consideration, the Kennedy Space Center will be assumed to be the launch base.

8. On-orbit operation shall be considered for "Shuttle-attached" payloads and for payload activities that take place before release of an automated spacecraft/Tug payload.

Section 2
SUMMARY

The SOAR-IIS study effort involves representative Shuttle mission applications, with emphasis on select interface analyses.

The SOAR-IIS study is intended to have general application to a wide range of mission classes, as shown in Table 2-1. For meaningful data to be obtained on the interfaces and analyses being investigated, specific payloads have been adequately defined and examined. The spacecraft shown are representative of various classes. It is beyond the scope of the study to examine all the missions of the NASA traffic model to an equivalent depth. Previous SOAR-II investigations have analytically demonstrated the validity of using representative spacecraft that typify several missions.

TABLE 2-1

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SOAR - IIS MISSIONS

MISSION CLASS	NAME	REPRESENTATIVE SPACECRAFT
I	SHUTTLE DELIVERED AUTOMATED SPACECRAFT	EOS
II	SHUTTLE/TUG DELIVERED SPACECRAFT	ATS/SMS/DSCS-II CRYOGENIC SPACE TUG
III	MAN-TENDED AUTOMATED SPACECRAFT	LST
IV	SORTIE MISSIONS	SORTIE LABORATORY(S) AND PALLETS

The Shuttle and spacecraft under investigation are in various stages of definition ranging from conceptual design to hardware and are literally changing daily. Because the major hardware elements involved in this study are not finalized, it is important to identify the source of the data being used. Table 2-2 identifies the spacecraft and Tug sources and the Shuttle and traffic model being used for the study. Data from the literature have been used in many cases to amplify or clarify the information presented in the basic reports, which have been used as a point of departure.

TABLE 2-2

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SOAR-IIS MISSIONS/REFERENCES

- SHUTTLE DELIVERED AUTOMATED SPACECRAFT
  - EOS* – REF: EOS DEFINITION PHASE REPORT, GSFC, AUGUST 1971
    : SHUTTLE/TYPICAL PAYLOAD INTERFACE STUDY, GSFC RI, OCTOBER 25, 1972
- SHUTTLE/TUG DELIVERED SPACECRAFT
  - ATS* – REF: APPLICATIONS TECH. SAT. H/I SYSTEM FEASIBILITY REPORT, LERC, JUNE 1972
  - SMS* – REF: SYNCHRONOUS METEOROLOGICAL SATELLITE SYSTEM DESCRIPTION DOCUMENTS, VOL 1-4; GSFC, OCTOBER 71 - FEBRUARY 72
  - DSCS-II – REF: SUPPLEMENTAL DATA PACKAGE FOR AUTO. SPACECRAFT INTEGRATION, AEROSPACE – REV. A, OCTOBER 1972
  - TUG* – REF: SOAR-II FINAL REPORT MDC-G4473, VOLUME III, APRIL
- MAN-TENDED AUTOMATED SPACECRAFT
  - LST* – REF: LST PRELIMINARY STUDY, MSFC; FEB. 25, 1972; FINAL DEC. 15, 1972
    : PHASE A DESIGN UPDATE, MSFC, APRIL 1973
- SORTIE MISSIONS
  - SORTIE LAB – REF: SORTIE CAN CONCEPTUAL DESIGN, MSFC, MARCH 1, 1972
    : SORTIE LAB USERS GUIDE, MSFC, APRIL 1973
- SHUTTLE TRAFFIC MODEL
  - REF: MSC SHUTTLE RFP, MSC NO. TE72-FM-71, MARCH 21, 1972** AND TRAFFIC MODEL TMX-64731
- SHUTTLE
  - PAYLOAD ACCOMMODATIONS – REF: JSC-07700, VOL XIV, APRIL 13, 1973

*DELIVERY MISSIONS ONLY

** NEW MODEL EXPECTED IN JULY

Configurations identified for each of the four mission classes (Table 2-1) to aid in the integration and interface analysis tasks are discussed in the following listing.

I. Shuttle-Delivered Automated Spacecraft

The Earth Observation Satellite (EOS) as depicted in Figure 2-1 was selected for detailed study in SOAR-II/IIS because it represents the polar class of spacecraft and taxes the Shuttle's capability to deliver a payload into low Earth orbit. The data previously published in the SOAR-II final reports

FIGURE 2-1

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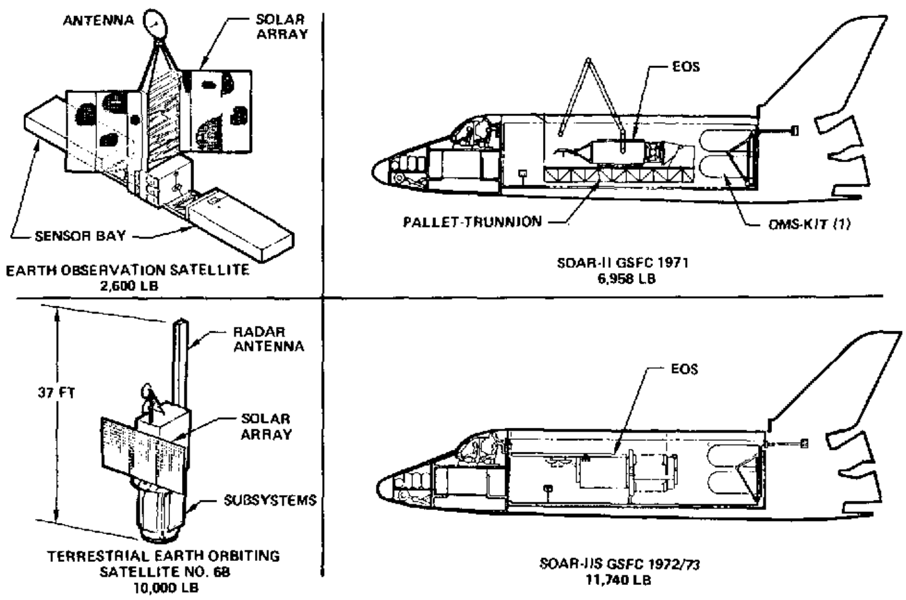
SHUTTLE DELIVERED AUTOMATIC SPACECRAFT



(MDC G4471 through G4481) is based on the general configuration shown in the upper half of this chart. Design studies are continuing on the EOS at GSFC. As a program, the EOS may involve as many as 20 missions of various configurations with different experiments and objectives. The 6B, a land-viewing satellite, is shown here as being representative of this class. The IIS configuration, as shown (lower), would exceed the presently defined Shuttle capability (April 73 - JSC-07700), but that fact is not relevant for the particular analysis being performed. In the future, the Orbiter polar capability may be increased or the payload weight may be reduced or modified to accomplish this particular mission.

II. Shuttle/Tug Delivered Spacecraft

There are three geosynchronous spacecraft studied in SOAR-II for which considerable data is available. All these spacecraft were used in the generation of requirements for this mission class. They include the ATS, the DSCS-II, and the SMS. A detailed definition of these spacecraft is available in the SOAR-II final reports and in the referenced documentation. The

Cryogenic Space Tug is the propulsive stage for these missions. Both the Tug and Tug/DSCS-II are also being studied by MDAC under separate contracts, and supporting data have been utilized as applicable (Figure 2-2).

III. Man-Tended Spacecraft

The large space telescope (LST) as shown in Figure 2-3 is representative of a man-tended spacecraft system. The configuration shows the LST in position for a delivery mission. The LST is delivered to a 28.5-degree-inclination by a 330-nmi-altitude orbit. The LST is representative of large spacecraft involving a large, 3-m optical system. It has three functional elements: (1) an optical telescope assembly (OTA), (2) a scientific instrument package (SIP), and (3) the support systems module. The LST systems and operations are described in detail in the SOAR-II final reports and in the referenced documentation.

IV. Sortie Missions

The sortie mission configuration shown in Figure 2-4 represents a class that may consist of as much as 50 percent of the NASA Orbiter traffic model. The

FIGURE 2-2

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SHUTTLE/TUG DELIVERED SPACECRAFT

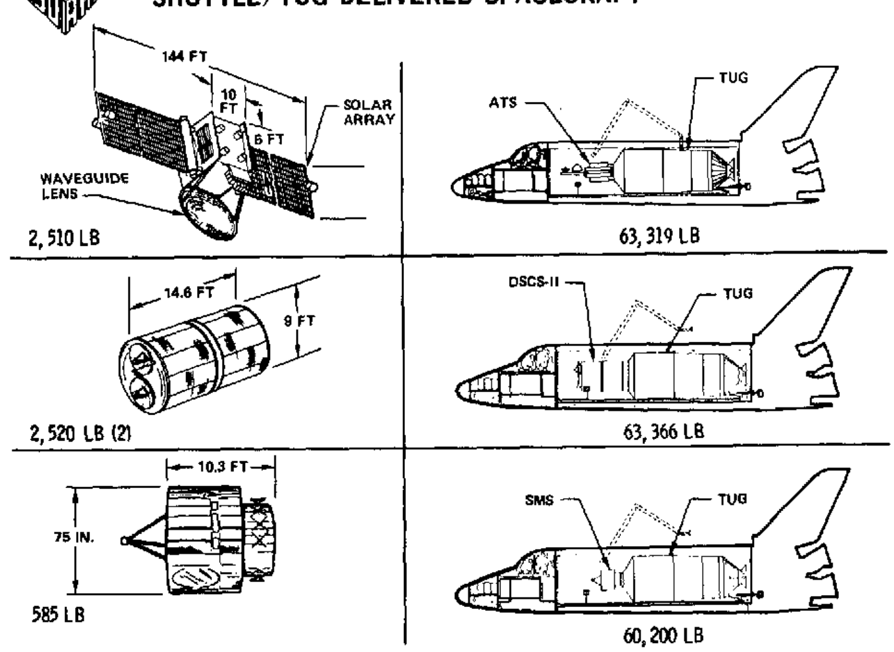

FIGURE 2-3

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MAN TENDED SPACECRAFT

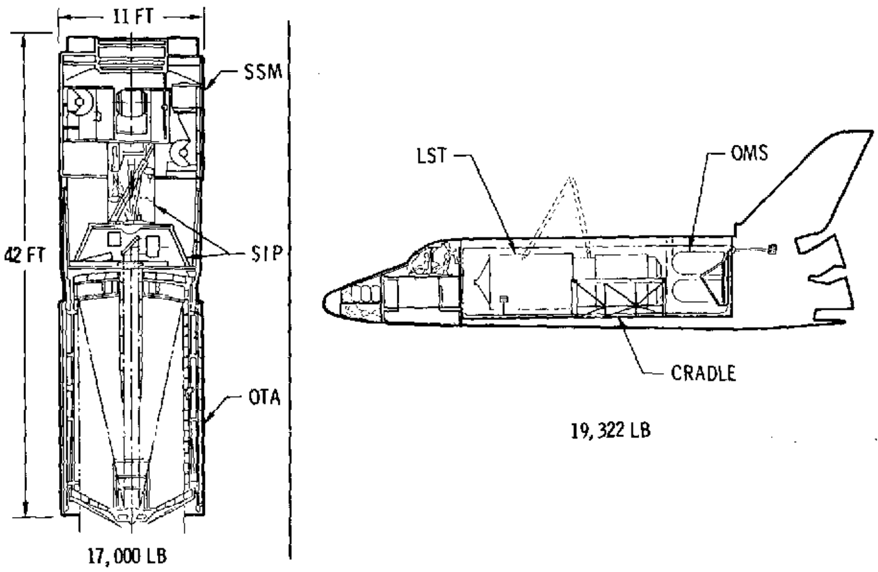

FIGURE 2-4

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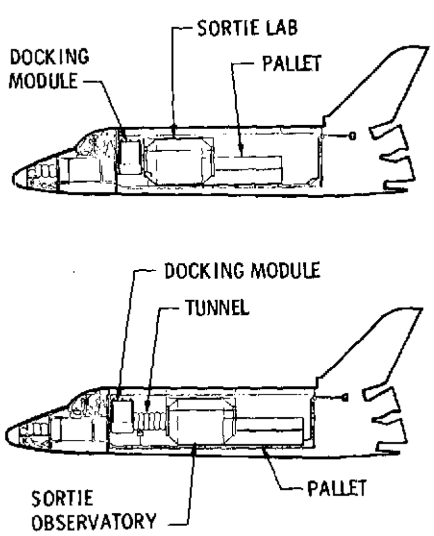
SORTIE MISSIONS



- ASTRONOMY (AS)
- SOLAR PHYSICS (SO)
- HIGH ENERGY ASTROPHYSICS (HE)
- ATMOSPHERE AND SPACE PHYSICS (AP)
- EARTH OBSERVATIONS (EO)
- EARTH AND OCEAN PHYSICS (EOP)
- SPACE PROCESSING APPLICATIONS (SPA)
- COMMUNICATIONS/NAVIGATION RESEARCH LAB (CNRL)
- LIFE SCIENCES (LS)
- SPACE TECHNOLOGY (ST)

Sortie Laboratory is shown with and without a tunnel. The tunnel is being considered as an approach to controlling the center of gravity for the missions. The sortie missions may also be pallet-only missions. They encompass 10 areas of discipline as indicated, and they include 46 representative sortie payloads and as many as 250 missions. The Sortie Laboratory is basically self-providing and has minimal interface requirements in the areas under examination in SOAR-IIS.

The six tasks completed in this study are summarized in the following section. The key results determined for each task are as follows:

Task 1 - Payload Operations Pad vs. VAB Installation

. . . . "To identify interface operational considerations and payload benefit which may influence alternative approaches to installation, removal, and integration of the payload into the Orbiter."

- Vertical installation is preferred from a payload point of view.
- Integration functions are relatively insensitive from mission class to class.

Task 2 - Payload Checkout/Control Requirements

. . . . "To define requirements and perform trade studies relative to the MSS/PSS and desired ground system implications for prelaunch."

- A common group of control and monitoring equipment can be utilized for a wide range of payloads examined.
- The MSS should control the Tug; the PSS controls all other payload activities.
- The Orbiter cabin allocation for PSS is adequate for required equipment.
- The Orbiter/PSS can provide valuable supplemental assistance to ground control status to determine payload condition prior to deployment.

Task 3 - Payload Interface Requirements

. . . . "To define complete electrical interfaces for selected payloads. . . to determine payload GSE requirements and. . . to define standard interface panel requirements."

- Orbiter service panel allocation for payload cables/fluid lines are adequate for missions examined.
- Payload bay cable installations vary from class to class but may be standardized within a given class.
- The LPS should process spacecraft stage (Tug) data after Orbiter mating for use by launch control; however, separate payload data transfer lines should be available to the user facilities when on the launch pad.

Task 4 - Payload Design Operations Impacts

. . . . "To assess the EVA operations and design impacts on the payloads associated with the Orbiter airlock/docking module and payload contamination."

A. Docking Module Analysis

- The use of a docking module constrains on-pad payload access.
- Docking module on-orbit transfer operations increase risk in rescue - other viable solutions warrant further considerations.
- Concurrent EVA/IVA operations are not recommended.

B. Contamination Analysis

- Spacecraft requiring high-quality cleanliness (10, 000 or better) must provide own sensor protection.
- Orbiter bay should be lined to provide a visually clean surface to ensure cleanliness.
- Operations related to Orbiter effluents must be controlled during critical payload operations.

Task 5 - Payload Venting Requirements Analysis

. . . . "To evaluate payload venting requirements for all phases of the Shuttle missions."

- The nominal payload venting required an Orbiter umbilical plate venting capability.
- The Shuttle criteria on payload fluids management and payload safety requires amplification.

Task 6 - General Interface Assessments and Safety

. . . . "To perform analytical studies in the area of payload placement and retrieval characteristics and to evaluate impact of Shuttle safety criteria."

A. Payload Placement and Retrieval Analysis

- The SAMS manipulator payload placement and retrieval capability is acceptable to the payloads examined.
- The SAMS payload deployment times may take about 30 minutes.
- The swing table has payload service growth in placement/ retrieval.

B. Shuttle Payload Safety Criteria Analysis

- Payload safety management has varied and important payload impacts.
- Payload safety design criteria can be demanding.
- The proposed (NASA) payload safety criteria levels are in some cases greater than the basic Shuttle requirements.
- Payload safety criteria are needed for the total scope identified by NASA Headquarters Safety Directives (e.g., Shuttle and payload safety and public safety) for all mission phases.

2.1 TASK 1 - PAYLOAD OPERATIONS - PAD VS. VAB INSTALLATION

The purpose of this task is to identify a preferred approach for installing the payload into the Shuttle Orbiter payload bay, based on operations analysis of the four payload classes considered in the study. Results of this analysis are presented in Appendix A.

The current payload/Orbiter integration model defined in the Shuttle baseline plan requires that payloads be installed in the horizontal position at the Orbiter maintenance and checkout facility (MCF) approximately eight days before Shuttle launch. A contingency payload integration mode is available whereby payloads can be installed in the payload bay at the launch pad while the Orbiter is in the vertical position.

The following aspects of Pad vs. MCF installations were addressed with respect to payload operations:

A. Baseline Shuttle ground operations
   1. Payload integration functional requirements
   2. Payload integration operations impacts to Orbiter turnaround constraints.

B. Influence of Orbiter operations on payload installation
   1. Orbiter orientation
   2. Orbiter location

C. Influence of payload operational requirements on installation
   1. Payload checkout
   2. Payload servicing

Recommendations resulting from the task analysis are as follows:

A. Vertical installation of payloads at the launch pad are preferable. This preference is consistent with current spacecraft designs relative to handling points, propellant systems, and thruster catalyst beds, and also reduces handling of the spacecraft. This approach offers the following advantages from a total payload (satellite plus stage) operational standpoint:
   1. Allows continuous access to payloads through launch minus two days
   2. Reduces Tug fleet size for Class II payloads by one Tug
   3. Reduces payload ground operation time by seven days

4. Simplifies payload/Orbiter interfaces for Class I and II payloads
5. Reduces payload integrated systems test requirements.

B. Payloads can be installed at the MCF in the horizontal position per the Shuttle baseline plan if the following inherent operational and cost disadvantages are accepted:

1. Limited or no access for seven days after payload/Orbiter integration is completed
2. Larger Tug fleet size
3. Increased payload ground operations time from notification to launch requirement
4. More complex payload/Orbiter interfaces for Class I and II payloads
5. Increased payload integrated systems test requirements.
6. May require spacecraft modification or special handling.

The analysis presented in Appendix A is summarized in the following paragraphs.

Each payload class was reviewed with respect to the functions required to accomplish the payload-Orbiter integration. The integration functions are effectively insensitive to the payloads in the classes analyzed. Each of the payload classes exhibits the same general integration functions.

Orbiter orientation was found to have only a minor effect on integration operations. All payloads studied are capable after being mated with Tug of being positioned in either the horizontal or vertical position from a structural point of view.

In the Class I and II payloads, however, which employ hydrazine propulsion systems, horizontal positioning during handling and installation has the tendency to create thruster injector-fouling catalyst "fines" in radial pointing thrusters whose catalyst beds are above the injectors. These payloads must assume a unique position in the payload bay to avoid this problem, which in turn must be reflected in the payload-Orbiter umbilical interface configuration.

Vertical installation of all payload classes at the launch pad involves a rail-mounted manipulator which "bear-hugs" the payload during installation (per JSC 07700). Manned access for umbilical connection before installation is required, which imposes severe GSE constraints on access on both the payload bay and manipulator.

The location of integration has rather significant effects on all classes of payloads.

For Class II, Tug-delivered payloads, on-pad installation of payloads reduces the KSC Tug fleet size by one Tug.

Additionally, if the payloads are installed at the MCF, the payloads are virtually inaccessible for about seven days after installation until the Shuttle arrives at the launch pad. This effective seven-day down-time could have significant implications for DOD payloads that have strict constraints on "time-from-notification-to-launch."

Installation of time-critical equipment in the sortie laboratory is compromised if payload integration occurs in the MCF nine days before launch. Current docking module design precludes access to the interior of the sortie laboratory after its installation in the payload bay. A change must be made in the docking module design or provisions must be made for an access hatch in the sortie laboratory to accomplish last-minute installation of such equipment at the launch pad.

Work done on the Cryogenic Tug Study currently being performed by MDAC indicates that for the anticipated KSC launch schedule for Class II payloads, the Tug fleet size can be reduced by one if payload-Orbiter integration occurs at the launch pad.

This savings can be accomplished due to the seven-day reduction in the overall Tug maintenance and turnaround time.

Once payload and Orbiter have been integrated, an abbreviated payload integrated systems test (IST) is desired after every major physical move involving the payload to verify that system functional integrity has been maintained.

Maintenance and checkout facility (MCF) installation of payloads involves two such operations:

A. Transportation from the PSA to the MCF and subsequent integration with the Orbiter
B. Erection of the Orbiter for mate with the external tank and subsequent rollout to the launch pad

and prefers an IST after each of these operations in the MCF and at the pad.

On-pad integration involves only one such operation (transportation from the PSA to the launch pad and subsequent installation in the lower environmental enclosure and rail-mounted manipulator) and requires only one IST at the pad. Equipment to perform an IST in the MCF is not required.

Payload-Orbiter integration in the MCF results in increased complexity of payload-servicing GSE. Although these payloads require minimum servicing before arrival at the launch pad (environmental control and battery trickle charge), if the payload is installed at the MCF, payload GSE that provides these services must be compatible with post-integration operations such as Orbiter erection and with the Shuttle mobile transporter.

On-pad installation of payloads reduces the complexity of GSE, and GSE need only be compatible with the payload and its transporter.

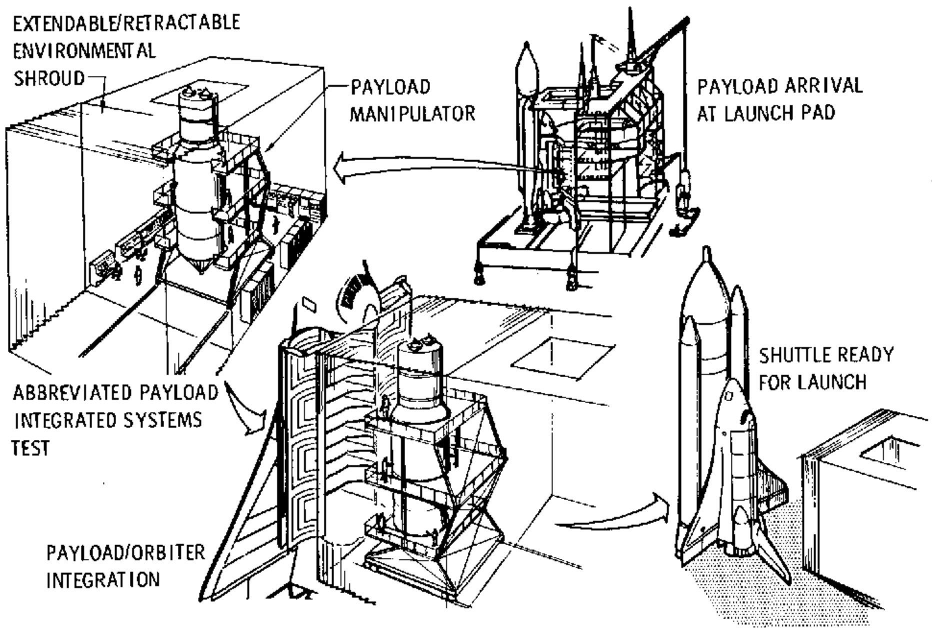
The majority of payload services (pressurization of the high-pressure vessel and loading of cryogenic gas and liquid) will occur at the launch pad regardless of the payload-Orbiter installation method adopted for safety reasons.

If payloads are installed at the launch pad (Figure 2-5), it is anticipated that installation of flight support equipment in the payload bay will still be required at the MCF. These operational requirements were identified and timelined for each payload class and are typically expected to require between 6 and 12 hours to accomplish.

Examples of these MCF activities are the installation, pressure test, and performance of an integrated systems test of the Sortie Laboratory docking module.

FIGURE 2-5

ON-PAD PAYLOAD/ORBITER INTEGRATION OPERATIONS



The current Orbiter baseline allocates 18 hours for MCF payload-dedicated operations, and no conflict with the Orbiter turnaround is anticipated.

Integration and installation functions for each payload class were defined from which functional flows and timelines were developed. It was found that from a time and schedule standpoint payload/Orbiter integration is essentially independent of payload class.

Integration of payloads at the launch pad typically requires about 24 hours to complete. Of this, about 14 hours of in-bay access are required. The current Orbiter baseline allocates only eight hours of in-bay access. There are however no known STS-imposed constraints that would preclude an additional six hours of on-pad, in-bay access.

The functional requirements for integration installation of each payload class and its associated flight support equipment were defined. These requirements were then developed into functional flows and timelines to determine the overall differences in time and schedule required for the four payload classes.

Although each payload class has its own peculiar type and quantity of flight support equipment and interfaces, it was found that integration time is essentially independent of payload class. All payload classes require about 24 hours to accomplish normal horizontal integration in the MCF, Figure 2-6.

The STS ground-processing baseline allocates 18 hours in the MCF for payload/Orbiter integration. Payload/Orbiter integration operations can be made compatible only by performing six hours of payload operations in parallel with Orbiter operations on a noninterference basis.

Integration of payloads in the MCF does not eliminate the requirement for on-pad, in-bay access to the payloads.

After arrival at the launch pad, it is anticipated that about 16 hours of payload operations will be required. Of this 14 hours, eight hours of in-bay access are required to perform payload integrated system testing, protective cover removal, and IFJ installation (if required).

FIGURE 2-6

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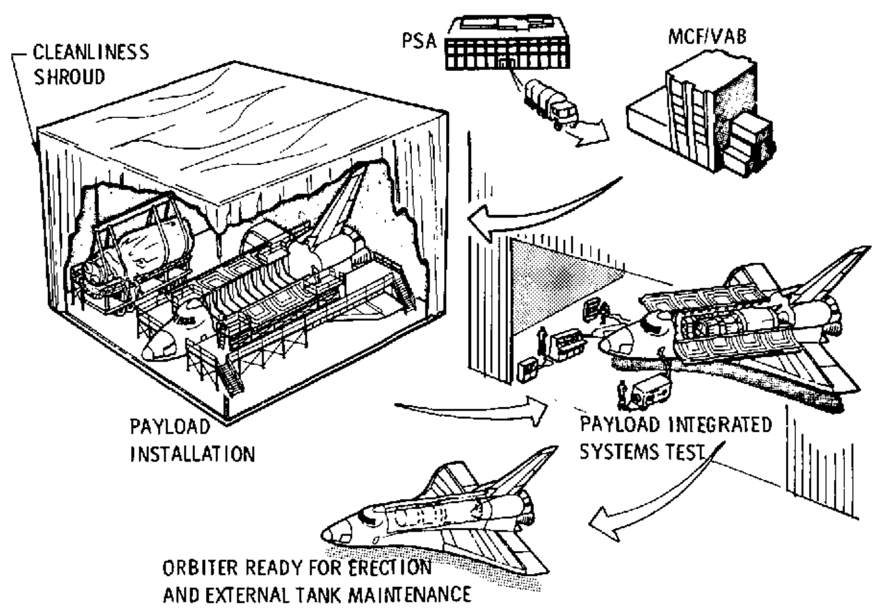
MCF PAYLOAD/ORBITER INTEGRATION OPERATIONS



The present Orbiter baseline currently allocates eight hours of in-bay access, and no incompatibility with the Orbiter launch pad activity requirements is anticipated.

From an Orbiter turnaround standpoint, it makes little difference whether payload/Orbiter integration occurs at the launch pad or at the MCF. In either case, if the Orbiter baseline turnaround schedule is met, the potential impact on schedule is about six hours. However, if the 12-hour estimate for installation of the flight support equipment at the MCF is correct, the current allocation of 18 hours for MCF payload operations could be reduced to 12 hours, and launch-pad operations (currently allocated at 31 hours) could be increased to 37 hours, resulting in no impact on the overall 231-hour Orbiter turnaround schedule. On-pad payload/Orbiter integration therefore would be preferred.

2.2 PAYLOAD CHECKOUT/CONTROL REQUIREMENTS

Use of the Space Shuttle for delivery into orbit of automated, man-tended, and Sortie Laboratory spacecraft imposes interface and equipment requirements to satisfy the Shuttle system safety criteria and to provide the operational capability to accomplish in-flight processing of the spacecraft.

The purpose of this task is the expansion of the SOAR II definition of the flight support systems and equipment required to facilitate Shuttle transport of automated Shuttle-delivered, automated Shuttle/Tug-delivered, man-tended, and sortie-mission spacecraft, (mission Classes I through IV, respectively). The flight support system definition is influenced primarily by implementation of an on-board C&W (caution and warning) system and the system required to accomplish in-flight checkout/monitoring/processing of the mission model spacecraft. Equipment definition is driven directly by system definition (requirements), but, beyond this point, it is also governed by consideration of operational aspects as related to assessments of human (astronaut) capabilities to perform.

The Checkout/Control Analysis is summarized in the following sections. Detailed analyses are presented in Appendix B.

The approach used to arrive at the total system definition was as follows:

- Derivation of Safety (Caution and Warning), and Control and Checkout requirements for each mission class.
- Definition of the system needed to satisfy the derived requirements.
- Establishment of support computer functional allocations and attendant machine and software requirements.
- Estimation of resources (power and energy) required from the Shuttle.
- Definition of PSS and MSS operational/functional activities.
- Formulation of representative PSS and MSS designs for payload management.

The significant conclusions resulting from performance of this task are as follows:

A. A common block of equipment is feasible to satisfy the basic requirements of satellites primarily because the similarity in satellite systems is ultimately reflected in the final requirements.

B. Shuttle-managed checkout (limited ORT) is a valuable supplemental tool in assisting controlling agencies (on the ground) to determine satellite systems health for LEO satellites.

C. Shuttle-derived checkout of geosynchronous satellites is directed primarily to monitoring housekeeping data and C&W activities.

D. Operational and equipment analyses indicate a preference for satellite management at the PSS, and Tug management at the MSS, with the driving factor being the geosynchronous missions wherein the payload comprises a multiple-vehicle combination.

E. The Shuttle cabin volume allocation is sufficient to accommodate installation of the satellite-required FSE in the PSS.

F. Power-energy allocation of 50 kWh for payload usage is insufficient (SOAR II conclusion) as further evidenced by the EOS requirement for 49.8 kWh with no allowance for contingency holds.

2.2.1 Safety

C&W display requirements were established for each mission class through examination of payload systems to establish hazardous items/systems (Table 2-3 and Figure 2-7) and evaluation of these items by generated C&W

TABLE 2-3

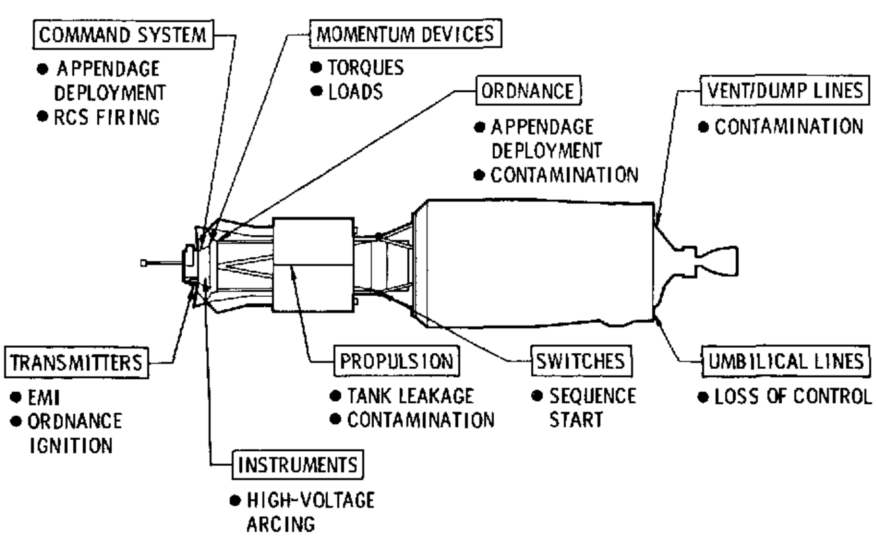
CANDIDATE C AND W FUNCTIONS

SYSTEM/FUNCTION	HAZARD
1. COMMAND SYSTEM	
a. UPLINK SIGNAL PRESENT	POTENTIAL OF ULTIMATE ACTUATION OF DEPLOYMENT DEVICES OR INJECTION OF CONTAMINANTS INTO PAYLOAD BAY AND/OR TUG ENGINE IGNITION
b. COMMAND EXECUTE	POTENTIAL OF ACTUATION OF DEPLOYMENT DEVICES OR INJECTION OF CONTAMINANTS INTO PAYLOAD BAY AND/OR TUG ENGINE IGNITION
c. INPUT POWER	SAME AS 1.a AND 1.b
2. ORDNANCE SYSTEM	
a. ARM	POTENTIAL OF FIRING ORDNANCE DEVICES
b. FIRE RELAY STATUS	SAME AS 2.a
3. ACS MODE	POTENTIAL OF INJECTING CONTAMINANTS INTO PAYLOAD BAY
4. MOMENTUM DEVICES	POTENTIAL DAMAGE DUE TO DEVICE FRAGMENTATION
5. PROPULSION SYSTEM	
a. PRESSURES	POTENTIAL TANK RUPTURE
b. TEMPERATURES	POTENTIAL TANK RUPTURE
c. LEAKS	CONTAMINATION IN PAYLOAD BAY
6. THRUSTER TEMPERATURE	INDICATIVE OF CONTAMINANT INJECTION INTO PAYLOAD BAY
7. SEPARATION SWITCHES	POTENTIAL OF SEQUENCING SATELLITE DEPLOYMENT SYSTEMS
8. DEPLOYMENT SWITCHES	POTENTIAL OF DAMAGE FROM LOOSE HARDWARE
9. SEQUENCER STATUS	SAME AS 7
10. DUMP LINES STATUS	POTENTIAL OF DUMPING CONTAMINANTS INTO PAYLOAD BAY
11. VENT LINES STATUS	POTENTIAL OF VENTING CONTAMINANTS INTO PAYLOAD BAY
12. ELECTRICAL UMBILICAL STATUS	LOSS OF PAYLOAD CONTROL BY ORBITER
13. PROPULSION UMBILICAL STATUS	LOSS OF PROPULSION SYSTEM CONTROL
14. TILT TABLE STATUS	SAME AS 8.
15. POWER SYSTEMS	
a. PRESSURES	POTENTIAL OF SOURCE RUPTURE
b. TEMPERATURES	POTENTIAL OF SOURCE RUPTURE
c. VOLTAGES	HIGH VOLTAGE ARCING
d. CURRENTS	POTENTIAL OF SHORT CIRCUITS
16. TRANSMITTERS' OUTPUTS	POSSIBLE ACTUATION OF ORDNANCE DEVICES
17. ENGINE IGNITION INHIBIT	POTENTIAL ENGINE IGNITION IN PAYLOAD BAY

FIGURE 2-7

HAZARD ANALYSIS

40367



criteria. The C&W hardwire display requirements are shown in Tables 2-4 through 2-7 for each mission class. C&W criteria are summarized in Appendix B. Backup C&W data are realized via on-board processing of the payload telemetry signal (PCM). Payload telemetry signal characteristics are summarized in Table 2-8.

2.2.2 Orbital Readiness Testing/Checkout

Each class of mission payloads was examined to determine Shuttle-attached and released ORT sequences. The following mission phases and configurations were considered:

- Attached to Shuttle during prelaunch, ascent, and LEO periods
- Released from Shuttle at LEO
- Geosynchronous station attached to Tug (Class II only)
- Geosynchronous station released from Tug (Class II only)

Table 2-9 presents a summary of the resultant checkout activities for the mission classes. A more detailed delineation is provided in Table 2-10.

The prime benefits of performing Shuttle-controlled attached checkout (Table 2-11) of satellite systems are exemplified by the EOS mission. Figure 2-8 provides a description of the hardwired system utilized to accomplish pre-Shuttle release experiment systems checks.

EOS A has six experiments containing some 40 channels or detectors; EOS B has four experiments with 36 channels. Under conditions of normal satellite operation, the detector outputs are amplified by photo multiplier tubes (PMT's) or solid-state devices, and their outputs are conditioned for entry into the data-processing systems. The processing systems multiplex the conditioned signals in accordance with stored sequences, digitize the data samples, and perform processing to reduce data rates. Since each operation performed on the analog data must be reversed to provide a data display, and data rates reach 30 MPBS in the multi-megabit operation multiplexer system (MOMS), a simpler experiment interface exists if detector outputs are transferred in analog format to the payload specialist station (PSS) where they can be selectively displayed in an amplitude/time format (A Scope) or as an image using a scan converter and conventional CRT. Use of the PSS for the tests

TABLE 2-4

CAUTION AND WARNING-SATELLITES

MISSION CLASS

FUNCTION	I (EOS)	II (ATS/SMS/DSCS)	III (LST)	ASSIGNMENT	ANNUNCIATORS
ORDNANCE SAFE-ARM	•	• • •(2)	•	WARNING	2
PROPELLANT/GAS PRESSURE	•(2)	• • •(2)	•	CAUTION	1
PROPELLANT/GAS TEMPERATURE	•(2)	• •(2) •(2)	•	CAUTION	
DEPLOYMENT SWITCHES	•	• • •(2)	•	WARNING	2
DUMP LINES STATUS	•	• • •(2)	-	WARNING	2
VENT LINE STATUS	•	• • •(2)	-	WARNING	2
LEAK DETECTION*	•	• • •(2)	-	WARNING	2

*LEAK DETECTION IS DERIVED FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

TABLE 2-5

CAUTION AND WARNING-TUG

FUNCTION	ASSIGNMENT	ANNUNCIATORS
TANK PRESSURES (6)	CAUTION	1
TANK TEMPERATURES (6)	CAUTION	
ACCUMULATOR PRESSURES (2)	CAUTION	1
ACCUMULATOR TEMPERATURES (2)	CAUTION	
FUEL CELL PRESSURES	CAUTION	1
FUEL CELL TEMPERATURES	CAUTION	
DUMP LINE STATUS (2)	WARNING	2
VENT LINE STATUS (2)	WARNING	2
ELECTRICAL UMBILICAL STATUS	WARNING	1
TUG LATCH STATUS	WARNING	1
ENGINE IGNITION INHIBIT	WARNING	1
COMMAND SYSTEM INHIBIT	WARNING	1
*LEAK DETECTION (6)	WARNING	6

*LEAK DETECTION FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

TABLE 2-6

CAUTION AND WARNING-FLIGHT SUPPORT EQUIPMENT

40450-3

FUNCTION	MISSION CLASS I (EOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)	ASSIGNMENT	ANNUNCIATORS
HOLDING TANK PRESSURE (OPTION)	•	•	•	•	-	-	CAUTION	1
HOLDING TANK TEMPERATURE (OPTION)	•	•	•	•	-	-	CAUTION	
TILT TABLE LATCH STATUS	-	•	•	•	-	-	CAUTION	1
C&W POWER SOURCE NO. 1	•	•	•	•	•	•	CAUTION	
C&W POWER SOURCE NO. 2	•	•	•	•	•	•	CAUTION	1
MSS/PSS CONTROL POWER	•	•	•	•	•	•	CAUTION	
*LEAK DETECTION (OPTION)	•	•	•	•	-	-	WARNING	1
TIE DOWN STATUS	•	-	-	•	•	•	WARNING	1

*LEAK DETECTION FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

TABLE 2-7

CAUTION AND WARNING-SORTIE LABORATORY

40450-4

FUNCTION	ASSIGNMENT	ANNUNCIATORS
*OXYGEN TANK PRESSURE (2)	CAUTION	
*OXYGEN TANK TEMPERATURE (2)	CAUTION	
*HYDROGEN TANK PRESSURE (2)	CAUTION	
*HYDROGEN TANK TEMPERATURE (2)	CAUTION	1
*NITROGEN TANK PRESSURE	CAUTION	
*NITROGEN TANK TEMPERATURE	CAUTION	
*FUEL CELL STACK TEMPERATURE	CAUTION	
DOCKING MODULE PRESSURE	CAUTION	
COMPARTMENT OXYGEN	WARNING	
COMPARTMENT CO_2	WARNING	
*FUEL CELL STACK TEMPERATURE	CAUTION	
H_2O QUALITY	WARNING	
*ELECTRIC POWER	WARNING	1
COMPARTMENT PRESSURE	CAUTION	
COMPARTMENT TEMPERATURE	CAUTION	
*CLOCK	WARNING	1
*COMPUTER (FAILURE)	WARNING	1
*LEAK DETECTION (7)	WARNING	7

*INDICATES FUNCTIONS TO SHUTTLE INTERFACE

TABLE 2-8

40370

DATA REQUIREMENTS

	MISSION CLASS						
	I	II				III	IV SORTIE
	EOS	**ATS	DSCS	SMS	TUG	LST	LAB
DATA RATE (BPS)	*1K-12.5K	384	250	194	51K/ 1.6K	51.2K/ 1.6K	UNDF
BITS PER WORD	UNDF	9	8	9	UNDF	8/8	UNDF
MAIN FRAME PERIOD (SECS)	UNDF	9	1.024	2.97	UNDF	0.02/1	UNDF
FRAME SYNC (WDS)	UNDF	IN 1ST 16	1ST 4	1ST 2	UNDF	4/4	UNDF
MAIN FRAME (WORDS)	UNDF	368	32	64	UNDF	128/200	UNDF
DWELL MODE	PROBABLE	YES	PROBABLE	YES	UNDF	PROBABLE	UNDF
FORMAT	UNDF	BIØ-L	NRZ-L	UNDF	NRZ-L	UNDF	UNDF
SUBCOMMUTATION WORDS	UNDF	LAST 16 16 DEEP	64 & 128	32 & 64	UNDF	UNDF	UNDF

*VARIABLE-SELECTABLE BY PROGRAMMING; **ATS F&G; ATS H&I UNDEFINED

indicated provides the benefits of real-time control; i.e., it provides the opportunity to vary instrument settings during passage over truth sites until they are correct rather than programming adjustments, waiting for a remote tracking station to come into view, dumping the data, waiting for the data to be transferred to the laboratory, calculating new settings after evaluation, and then repeating the process.

The primary benefit for attached checkout of the LST systems stems from the fact that the total satellite activation/calibration period by ground control includes a 150-hour wait period for thermal stabilization of the optics, which then coupled with the activation procedure exceeds the normal seven-day Shuttle stay time. Thus, an early measure of LST performance is required to permit return of a malfunctioning spacecraft with the delivery Shuttle.

As previously stated, attached checkout of geosynchronous satellites is restricted to monitoring of housekeeping data and C&W parameters. These restrictions stem basically from consideration of satellite thermal operating limits, difficulties in achieving operational configurations, e.g., deploying

TABLE 2-9

CHECKOUT/ORT SUMMARY

ALL MISSIONS

- POST SHUTTLE INTEGRATION INTERFACE FUNCTIONAL TEST (LAUNCH SITE)
- CAUTION AND WARNING AND HOUSKEEPING DATA MONITORING (CONTINUOUS FROM SHUTTLE INTEGRATION THROUGH PAYLOAD RELEASE)

EOS AND LST MISSIONS

- ATTACHED SATELLITE SYSTEMS CHECKS AT LOW EARTH ORBIT BY SHUTTLE CONTROL
- ORBITAL TEST PLAN PERFORMANCE SUBSEQUENT TO RELEASE FROM SHUTTLE BY GROUND CONTROL

GEOSYNCHRONOUS MISSIONS

- SATELLITES

  ORBITAL TEST PLAN PERFORMANCE AT GEOSYNCHRONOUS STATION BY GROUND CONTROL

TUG

- ATTACHED TO SHUTTLE

  NAVIGATION DATA DURING SHUTTLE ASCENT

  COMMAND SYSTEM CHECKS

  FUEL CELL ACTIVATION

  GUIDANCE SYSTEM UPDATE

- RELEASED FROM SHUTTLE

  AUTO SELF CHECKS

TABLE 2-10

40444

CHECKOUT/ORT SUMMARY

MISSION CLASS	PRELAUNCH (ON SITE)		ASCENT TO LOW EARTH ORBIT	LOW EARTH ORBIT: ATTACHED TO SHUTTLE	LOW EARTH ORBIT: SEPARATED FROM SHUTTLE	GEOSYNC ORBIT
I (EOS)	• INTERFACE TEST • C&W MONITOR • HEALTH DATA		• C&W MONITOR • HEALTH DATA	• C&W MONITOR • HEALTH DATA • ORT (SHUTTLE CONTROL) POWER DEPLOY TEST COMMAND/DATA EXPERIMENTS	• ORT (ORBITAL TEST PLAN) GROUND CONTROL SHUTTLE ESCORT/ASSIST	
	SATELLITE	TUG	SATELLITES AND TUG	SATELLITES AND TUG	TUG	SATELLITES
II (ATS/SMS/DSCS-TUG)	• INTERFACE TEST • C&W MONITOR • HEALTH DATA	• INTERFACE TEST • C&W MONITOR • HEALTH DATA • AOT	• C&W MONITOR • HEALTH DATA	• C&W MONITOR • HEALTH DATA	• AUTO SELF CHECKS	• ORT (ORBITAL TEST PLAN) GROUND CONTROL TUG ESCORT
			TUG	TUG		
			• NAVIGATION DATA	• FUEL CELL CHECKS AND ACTIVATION • SYSTEMS TURN ON • GUIDANCE UPDATE • COMMAND/DATA • INTERNAL TEST		
III (LST)	• INTERFACE TEST • C&W MONITOR • HEALTH DATA		• C&W MONITOR • HEALTH DATA	• C&W MONITOR • HEALTH DATA • ORT (SHUTTLE CONTROL) ACS CMG'S DEPLOY TEST POWER COMMAND/DATA EXPERIMENTS	• ORT (ORBITAL TEST PLAN) GROUND CONTROL SHUTTLE ESCORT/ASSIST	
IV (SORTIE LAB)	• INTERFACE TEST • C&W MONITOR		• C&W MONITOR	• C&W MONITOR • EXPERIMENT OPERATION		

ORT IS: OBSERVATION OF DATA RESULTING FROM A SPECIFIC SYSTEM INPUT (STIMULUS)

TABLE 2-11

40518

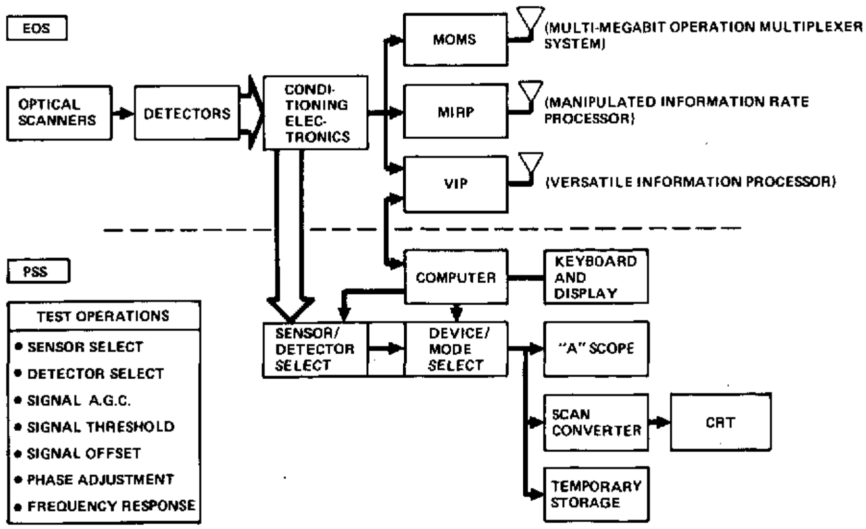
ORBITER ATTACHED CHECKOUT BENEFITS

- EXPERIMENT CHECKOUT DURATION COMMENSURATE WITH ORBITER STAY TIME
- ALLOWS REAL-TIME ADJUSTMENT OF EQUIPMENT VARIABLES OVER TRUTH SITES
- AVAILABILITY OF UNPROCESSED DETECTOR OUTPUTS SIMPLIFIES CHECKOUT EQUIPMENT

FIGURE 2-8

40366

EOS/PSS EXPERIMENT ORT INTERFACE



arrays and antennas, and the potential of time criticality in regard to phasing to achieve proper longitudinal station. Subsequent to arrival at geosynchronous orbit, orbital test plan performance would be performed (current procedure) via ground station control with Tug acting as escort.

2.2.3 Summary of Control/Display Requirements

Tables 2-12 through 2-14 provide a summary of control and display requirements stemming from satisfaction of safety, ORT/checkout, and general operational requirements such as deployment preparations and test preparation.

2.2.4 System Definition

The equipment/system that satisfies the mission classes' control and display requirements is shown in Figures 2-9 and 2-10. The DSCS systems is categorized as the worst case because two satellites are involved (in addition to Tug), which requires interleaving and demultiplexing equipment to handle data from both satellites, and DOD communication security equipment.

TABLE 2-12

IIS

40368

CAUTION AND WARNING RELATED CONTROLS

	MISSION CLASS					
FUNCTION	I (EOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)
SATELLITES						
ORDNANCE SAFE-ARM	•	•	•	• (2)	•	-
PROPELLANT DUMP	•	•	•	• (2)	-	-
PROPELLANT VENT	•	•	•	• (2)	-	-
N_2 TANK VENT	•	•	-	-	•	-
TUG / SORTIE LAB						
HYDROGEN TANK PRESSURIZE	-	•	•	•	-	•
HYDROGEN TANK DUMP	-	•	•	•	-	•
HYDROGEN TANK VENT	-	•	•	•	-	•
OXYGEN TANK PRESSURIZE	-	•	•	•	-	•
OXYGEN TANK DUMP	-	•	•	•	-	•
OXYGEN TANK VENT	-	•	•	•	-	•
COLD HE TANK VENT	-	•	•	•	-	-
AMBIENT HE TANK VENT (2)	-	•	•	•	-	-
FUEL CELL CONTROL (2)	-	•	•	•	-	•
N_2 TANK VENT	-	-	-	-	-	•
PAYLOAD BAY						
HOLDING TANK VENT (OPTIONAL)	•	•	•	•	-	-
HOLDING TANK DUMP (OPTIONAL)	•	•	•	•	-	-
HOLDING TANK PRESSURIZE (OPTIONAL)	•	•	•	•	-	-

TABLE 2-13

40499

SATELLITES AND SORTIE LAB CONTROL AND RELATED MONITORING FUNCTIONS

CONTROL	MONITOR	MISSION CLASS I (EOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)
TIE-DOWN RELEASE	RELEASE/SECURE	●	-	-	●	●	-
COLD GAS VENT	OPENED/CLOSED	●	-	-	-	●	-
HYDRAZINE VENT	OPENED/CLOSED	●	●	●	●	-	-
HOLDING TANK DUMP (OPTIONAL)	OPENED/CLOSED	●	●	●	●	-	-
S&A SAFE-ARM	SAFE/ARMED	●	●	●	●	●	-
ELEC. UMBILICAL RELEASE	DISCONNECTED/CONNECTED	●	-	-	-	●	-
PROPULSION UMBILICAL RELEASE	DISCONNECTED/CONNECTED	●	●	●	●	-	-
TRANSFER TO INTERNAL POWER	INTERNAL/EXTERNAL*	●	●	●	●	●	-
EXTERNAL POWER	EXTERNAL/INTERNAL*	●	●	●	●	●	●
TRICKLE CHARGE (OPTIONAL)	ON-OFF	●	●	●	●	●	-
TELEMETRY SYSTEM	ON-OFF	●	●	●	●	●	●
TRACKING SYSTEM	ON-OFF	●	●	●	●	●	-
COMMAND SYSTEM	ON-OFF	●	●	●	●	●	-

* COMMON

TABLE 2-14

40369

TUG CONTROL AND RELATED MONITOR FUNCTIONS

FUNCTION	CONTROL	MONITOR
IMU	ON-OFF	ON-OFF
IMU PREHEAT	ON-OFF	ON-OFF
GUIDANCE COMPUTER	ON-OFF	ON-OFF
TELEMETRY SYSTEM	ON-OFF	ON-OFF
TRACKING SYSTEM	ON-OFF	ON-OFF
COMMAND SYSTEM	ON-OFF	ON-OFF
POWER SYSTEM	INTERNAL-EXTERNAL	INTERNAL-EXTERNAL
POWER SELECT	BATTERY/FUEL CELL	INTERNAL-EXTERNAL
ELECTRICAL UMBILICAL	RELEASE	(STATUS)
PROPULSION UMBILICAL	RELEASE	(STATUS)
TILT TABLE TIE-DOWN	RELEASE	(STATUS)
TILT TABLE	RELEASE (TUG)	(STATUS)
FUEL CELL SHUT OFF VALVES (2)	OPEN-CLOSE	OPEN-CLOSE

FIGURE 2-9

40445

SYSTEM DEFINITION
EOS-ATS/SMS-LST-SORTIE LAB

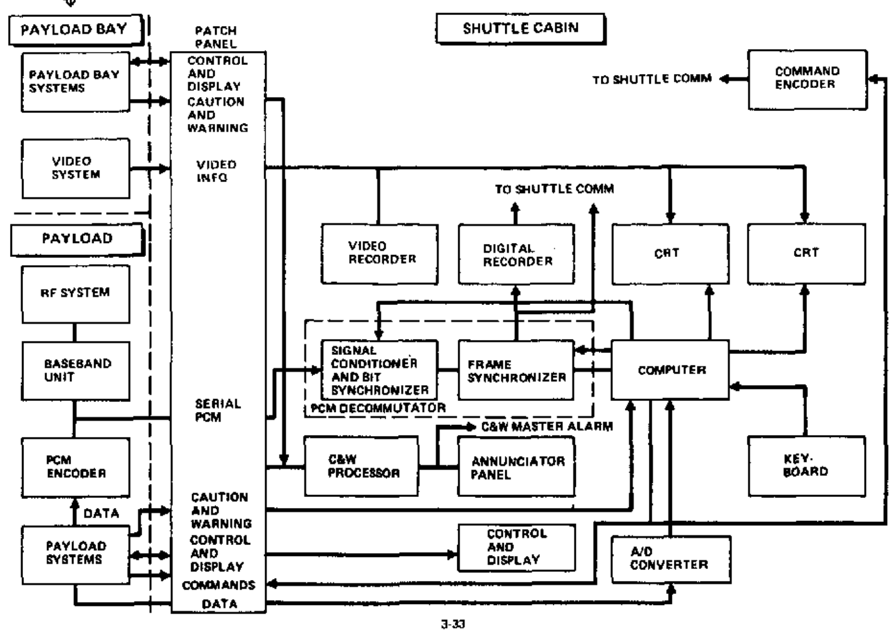


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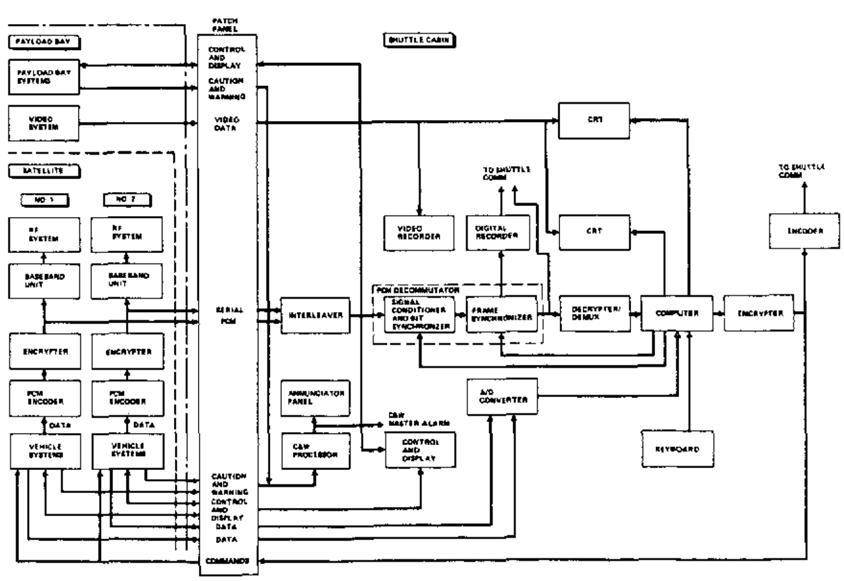
FIGURE 2-10

P253

40446

SYSTEM DEFINITION-DSCS-II



2.2.5 Commonality Assessment

Commonality of equipment usage was assessed to establish equipment sources, i.e., GFE- or user-(program) supplied. The results are shown in Table 2-15.

It is generally recommended that most of the equipment should be GFE, inasmuch as it is apparent that basic satellite requirements can be satisfied by a common block of equipment. Variances in satellite systems/requirements are handled through software changes, overlays for nomenclature differences on C/D panels, and by management of the electrical interface through the patch panel. (Figures 2-9 and 2-10.)

2.2.6 MSS/PSS Equipment Allocations

Equipment allocations were established for the MSS and PSS based primarily on a determination of the items of equipment involved during the various phases of the mission profile and an assessment of the operators' capabilities to perform the functions on the basis of the degree of activity during flight and

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TABLE 2-15

40447

EQUIPMENT ALLOCATION

ITEM	SUPPLIER/CLASS	REMARKS
COMPUTER CRTS KEYBOARD	GFE (BASIC)	ALL MISSIONS REQUIRE FOR SYSTEMS DATA PROCESSING
ANNUNCIATOR PANEL C&W PROCESSOR	GFE (BASIC)	ALL MISSIONS REQUIRE FOR C&W DISPLAY
INTERCOMM PANEL	GFE (BASIC)	REQUIRED FOR ALL MISSIONS
PCM DECOMMUTATOR PCM SIMULATOR	GFE (BASIC)	REQUIRED FOR ALL MISSIONS FOR SYSTEMS DATA PROCESSING
PATCH PANEL	GFE (BASIC)	REQUIRED FOR ALL MISSIONS
CONTROL AND DISPLAY PANEL	GFE (BASIC)	MISSION CLASSES HAVE SIMILAR REQUIREMENTS. USE OVERLAYS FOR NOMENCLATURE CHANGES
POWER CONDITIONING	GFE (BASIC)	REQUIRED FOR ALL MISSIONS
A/D CONVERTER	GFE (BASIC)	MISSION CLASSES HAVE SIMILAR REQUIREMENTS
SPECIAL PURPOSE EQUIPMENT ENCODER DECRYPTER/DEMULTIPLEXER DSCS–2 CONTROL AND DISPLAY MODULE MULTIPLEXER	USER (UNIQUE)	REQUIREMENTS/SYSTEMS CHARACTERISTICS ARE WIDELY DIVERSE
EXPERIMENTAL CHECKOUT EQUIP WIDEBAND RECORDERS OSCILLOSCOPES SCAN CONVERTER	USER (UNIQUE)	WIDELY DIVERSE REQUIREMENTS
RECORDERS DIGITAL VIDEO	GFE (BASIC)	REQUIRED FOR ALL MISSIONS

the presumed degree of training of the operators. The Class II missions (geosynchronous) were used for this analysis because the Tug involvement is the most taxing with regard to the magnitude of operators' activities and required skills. Analysis of the Class II mission timeline (Figure 2-11) resulted in the judgment that the numbers of Tug-related activities that occur at low Earth orbit during the 20- to 25-minute deployment period should be performed at a station relieved of satellite-related functions. The MSS was therefore selected to provide Tug control, because Tug is a segment of the STS and it was judged that the MSS operator would be well trained in Tug systems. Relief of satellite activities for the MSS is achieved by assigning satellite control to the PSS. The basic PSS was then configured as a function of mission by the addition of equipment or kits to support all payloads exclusive of the Tug. This allocation allows the MSS to remain in a static condition independent of payload and devoted solely to the Shuttle Transportation System (STS) elements, Orbiter and Tug. PSS manning would be dependent upon payload sophistication with three- as well as four-man Orbiter crews considered possible.

A summary of MSS/PSS responsibilities/activities is presented in Table 2-16.

Representative equipment installations were developed for the PSS and MSS to determine the practicality of installing the required equipment in the Shuttle cabin volume allocated to the PSS. Table 2-17 provides a list of the required equipment with salient features. Figure 2-12 provides a PSS layout, and Figure 2-13 shows a typical installation.

Tug control/display needs are satisfied by complementing the baseline Shuttle facilities (computer, CRTS, keyboard, etc.) with the four items of equipment shown in Figure 2-14, i.e., control and display panel, PCM simulator, PCM decommutator, and caution and warning processor.

2.2.7 Payload Power/Energy Requirements

Estimates of payload power and energy requirements were established by reviewing equipment operating times throughout the mission flight profile, commencing with a transfer from ground power to Shuttle power at T minus 30 minutes. These estimates are shown in Figure 2-15. It should be noted that the figure reflects only power requirements for payload systems and

FIGURE 2-11

40448

MISSION CLASS II SHUTTLE INTEGRATED OPERATIONAL PLAN

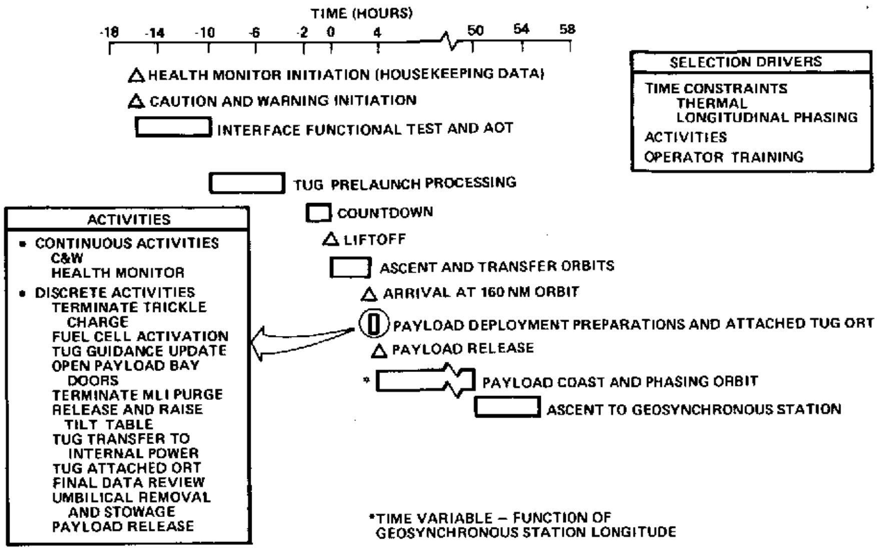


TABLE 2-16

40376

EQUIPMENT ALLOCATIONS

STATION/EQUIPMENT	MISSION CLASS I	II	III	IV
PSS	FUNCTIONS			
●BASIC CONTROL/DISPLAY PANEL COMPUTER/CRTS KEYBOARD DATA PROCESSOR C&W PROCESSOR POWER CONDITIONING DIGITAL RECORDER VIDEO RECORDER	SATELLITE CONTROL AND DISPLAY			EXPERIMENT CONTROL AND DISPLAY IF/AS REQUIRED
●UNIQUE COMMAND ENCODER ENCRYPTER DECRYPTER/DEMULTIPLEXER DSCS PANEL EXPERIMENT TEST EQUIPMENT INTERLEAVER	SPECIAL PURPOSE FUNCTIONS AND/OR USER SUPPLIED EQUIPMENT			
MSS				
●BASIC (BASELINE SHUTTLE EQUIPMENT)	ORBITER SYSTEMS CONTROL AND DISPLAY MANAGEMENT OF PAYLOAD SERVICES			
●UNIQUE TUG MISSION MODULE CONTROL DISPLAY PANEL C&W PROCESSOR DATA PROCESSOR	N/A	TUG CONTROL AND DISPLAY	N/A	N/A

TABLE 2-17

PSS EQUIPMENT CHARACTERISTICS

ITEM	POWER (WATTS)	WEIGHT (POUNDS)	VOLUME (INCH ^{3})	I.D. NO.
BASIC				
CRT (2) EACH	80	100	1,458	1
KEYBOARD	15	15	500	2
DISPLAY/CONTROL PANEL	15	15	168	3
COMPUTER/TAPE RECORDER	150	50	763	4
ANNUNCIATOR PANEL	5	10	80	5
INTERCOMM PANEL	6	6	150	6
PCM SIMULATOR	5	10	160	7
PATCH PANEL	-	20	200	8
POWER CONDITIONER	25	20	448	9
PCM DECOMMUTATOR	50	20	400	10
C&W PROCESSOR	15	10	100	11
DIGITAL RECORDER	30	25	2,700	12
VIDEO RECORDER	100	40	2,700	13
A/D CONVERTER	5	3	100	17
SPECIAL PURPOSE				
WIDEBAND RECORDER	50	22	650	15
SCAN CONVERTER	150	100	8,490	16
DECRYPTER/DEMULTIPLEXER	21	19	128	18
ENCRYPTER	11	9	128	19
COMMAND ENCODER	5	10	128	20
DSCS-II CONTROL & DISPLAY	35	20	420	21
A OSCILLOSCOPE	40	20	640	22
MULTIPLEXER	10	10	128	23
*THERMAL GENERATOR SERVICE UNIT	15	290	17,280	14

*N/R FOR STUDY MISSION CLASSES

FIGURE 2-12

40379

PSS - PAYLOAD EQUIPMENT REQUIREMENTS

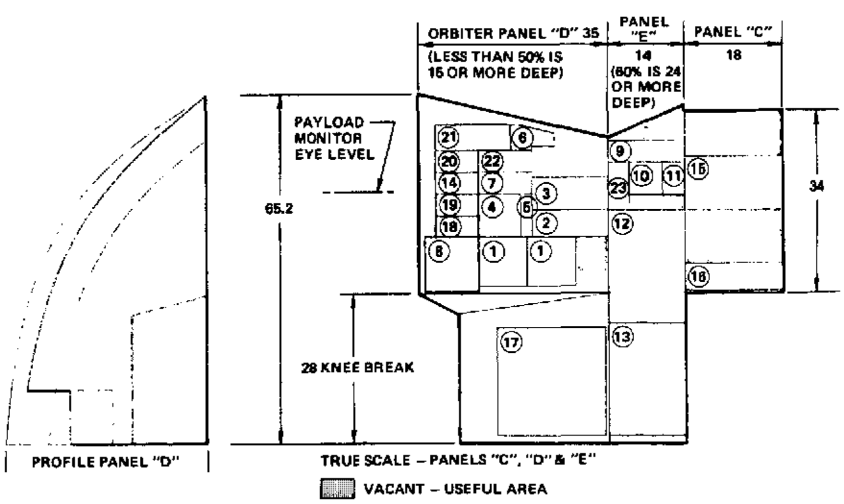


FIGURE 2-13

40380

PAYLOAD SPECIALIST STATION

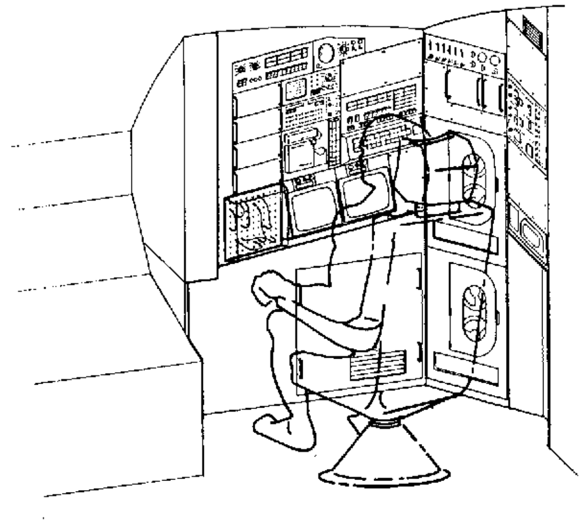


FIGURE 2-14

40381

MISSION SPECIALIST STATION - TUG NEEDS

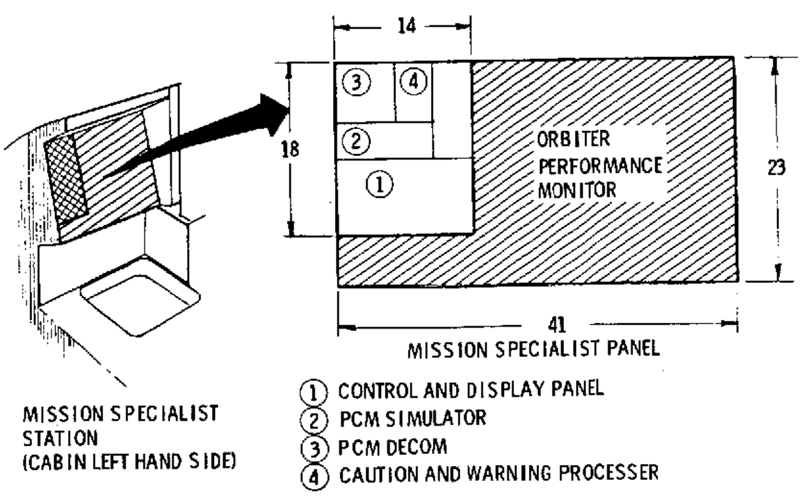
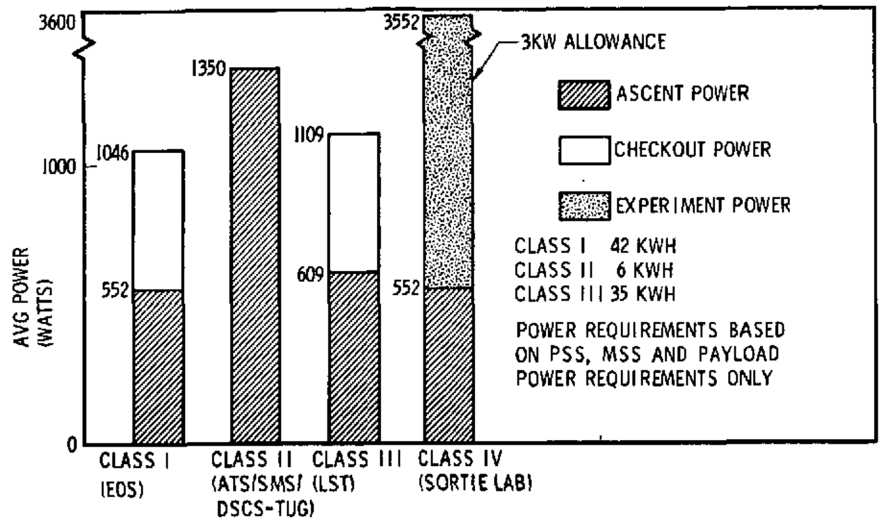


FIGURE 2-15

PAYLOAD POWER/ENERGY REQUIREMENTS

40372



MSS/PSS equipment, leading to a reiteration of the SOAR-II conclusion that the Shuttle energy allocation to LEO payloads (50 kWh) is insufficient in that power for other operations (such as deployment) may be charged to the payload, and no margin of energy is available for contingency holds.

2.3 TASK 3 - PAYLOAD INTERFACE REQUIREMENTS

The purpose of this task was to define cable and service requirements between the payload/Orbiter and payload GSE. The task was approached by initially developing data transfer, control, and power requirements for four classes of payloads consisting of the EOS, LST, synchronous-orbit spacecraft, and Tug and the Sortie Laboratory. These, in turn, were based upon operations analyses conducted in Task 2, which were performed to define mission and payload specialist console functions and equipment. The electrical requirements were then transformed into cable segments between payload bay interfaces, after conducting implementation trades and the segments interfacing with GSE used in conjunction with fluid interfaces to establish the payload service panel design. As a final study product, payload bay cable installations were developed, and interfacing launch area tests and GSE were identified.

Key results of the study are the following:

- Separate payload data transfer lines (non-interleaved bit streams) should be available to user facilities when payloads are on the launch pad.
- Orbiter service panels have adequate area but cable run diameters are limited for Tug-launched payloads.
- Payload bay cable installations vary with mission class but may be standardized within a given class.
- The launch processing system should process spacecraft and Tug data after Orbiter mating for use by launch control.
- DOD and NASA payload/Tug maintenance and checkout ground operations flows should be similar.

2.3.1 Cable Harness Requirements

Interface connections within the payload bay were developed for study payloads based upon previously defined requirements for prelaunch testing and monitoring, orbital readiness testing, safety criteria, and operations such as deployment. The connections, illustrated by Figure 2-16, were developed on an equipment segment basis. The electrical interface functions for each segment were then identified by source or system, characteristics, the originating requirement, and the number and types of wire to be used. The cable harness back to the payload specialist station was found to contain the following quantities of wire: EOS, 4 #12 and 114 TSP; LST, 4 #12 and 52 TSP; Class II, 2 #12 and 73 TSP; Laboratory, 12 #12, 95 TSP, 1 Coax. When the wires contained within the T-26-minute connector cable are added to the forward bulkhead connector cables, the diameter of the bay cable run is seen to be appreciable.

2.3.2 Data Transfer Analysis

Prior to actually assigning the latter column quantities, a trade was performed to select the method of data transfer. General criteria for data transfer were reviewed, and its applicability to development of payload bay wiring was discussed. The status of Tug and Orbiter data transfer system design was also reviewed, inasmuch as the bay wiring should be compatible with these systems. The result of the analysis and trade are shown in Table 2-18. Bi-phase level was selected for the modulation scheme, and TSP wiring was

FIGURE 2-16

EQUIPMENT INTERCONNECTION - EOS AND LST

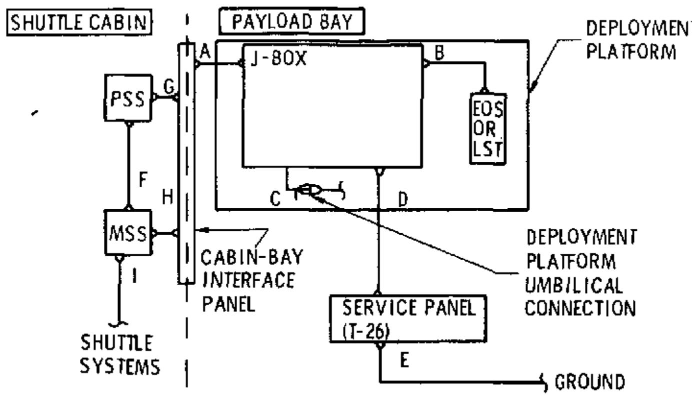


TABLE 2-18

DATA TRANSFER TECHNIQUE SELECTION

CABLE TYPE

ALTERNATIVE	BANDWIDTH	WEIGHT	COST	NOISE ATTENUATION
TSP	TO 10 MHz	1 TO 2 LB/100 FT	$18/500 FT	56 DB AT 1 MHz, 53 DB AT 10 MHz
COAX	TO 500 MHz	15 TO 20 LB/100 FT	$100/500 FT	38 DB AT 1 MHz, 51 DB AT 10 MHz

SELECTION: TSP FOR DIGITAL DATA

MODULATION TYPE

NO. OF ALTERNATIVES	COMMONLY USED	AC COUPLED	SELF CLOCKING
23	NRZ - LEVEL	NO	NO
	BIO - LEVEL	YES	YES
	BI - POLAR*	YES	YES

SELECTION: BIO - LEVEL

*LEAST COMMON

selected over coaxial as the transfer medium. A tradeoff between the use of multiplexing and hardwire revealed an expected weight/volume crossover at 28 channels in favor of the time-sharing system, although the cost of the latter was always higher. It was the approach selected on the basis of a number of factors, including compatibility with current payload design, computer control, and display control panel availability. Cable characteristics were also reviewed, resulting in the selection of standard round cable rather than flat or belted varieties, standard NASA 40 Mxxx series connectors, and Teflon-insulated wiring in the Shuttle cabin and Kapton-insulated wiring in the payload bay.

2.3.3 Payload Bay Installation Drawings

Following the trade studies, cabling schematics were developed for each of the mission classes (as illustrated by Figure 2-17) together with cable wire lists (illustrated by Table 2-19). Junction box layouts were also prepared as source material for the payload bay cable installation drawings shown in simplified form in Figure 2-18.

2.3.4 Service Panels

Following the definition of payload bay cables and routing installations, concepts for the GSE/service panel were developed, as shown in Figure 2-19, on the basis of connector separation, available hardware, and operations. The selected panel configuration embodies the use of existing flight-qualified hardware, the separation of signals by function, and the separation of signals by vehicle. The panels also incorporate fill and vent lines for the fluid and gas interfaces chosen by mission class in Tables 2-20 and 2-21.

On the basis of the signals brought out to the T minus 0 and T minus 26-minute service panels (and their originating test or operational requirement), interfacing electrical aerospace ground equipment (EAGE) was identified at the launch pad or launch umbilical tower (LUT), mobile transporter and Orbiter integration facility.

FIGURE 2-17

EOS/LST EQUIPMENT CABLING

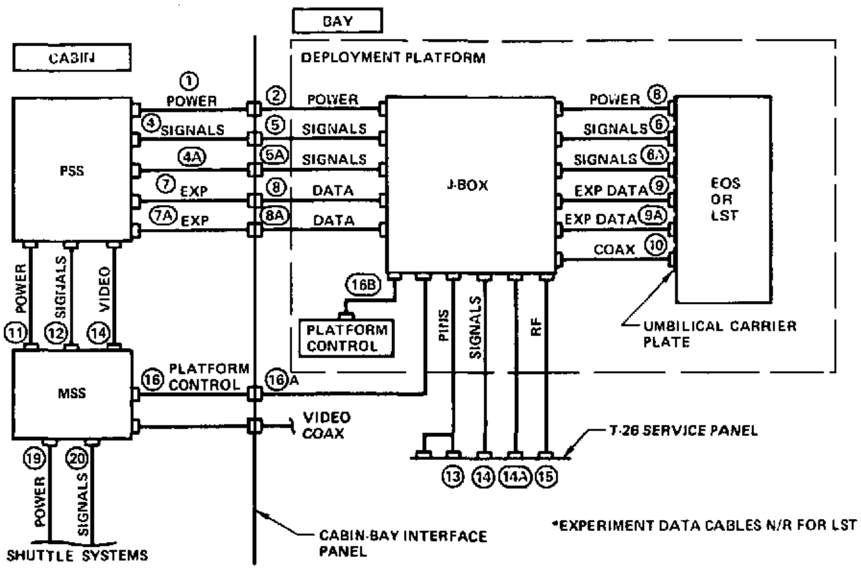


TABLE 2-19

EOS/LST CABLING DEFINITION

CABLE I.D.	FUNCTION	PINS-GAGE	CONN. DIAMETER
1, 2, 3	POWER	4-12	1-1/2 IN.
4, 5, 6	SIGNALS	61-20	1-1/2 IN.
4A, 5A, 6A	SIGNALS	61-20	1-1/2 IN.
*7, 8, 9	EXPERIMENT DATA	61-20	1-1/2 IN.
*7A, 8A, 9A	EXPERIMENT DATA	26-20	1 IN.
10, 15	RF (GROUND	MULTIPLE COAX	1-1/2 IN.
11	POWER	8-12	1-1/8 IN.
12	SIGNALS	55-20	1-3/8 IN.
13	POWER (GROUND)	8-12	2 IN (2)
14	SIGNALS (GROUND)	61-20	1-1/2 IN.
14A	SIANGLS (GROUND)	32-20	1-1/8 IN.
15	RF (GROUND)	MULTIPLE COAX	1-1/2 IN.
16, 16A	PLATFORM CONTROL	32-20	1-1/8 IN.
16B	PLATFORM CONTROL	55-20	1-3/8 IN.
17, 18	VIDEO	MULTIPLE COAX	1-1/2 IN.
19	POWER	6-12	1-1/2 IN.
20	SIGNALS	6-20	5/8 IN.

*N/R FOR LST

Figure 2-18.
PAYLOAD BAY CABLING

EOS

LST

CLASS II

SORTIE LAB

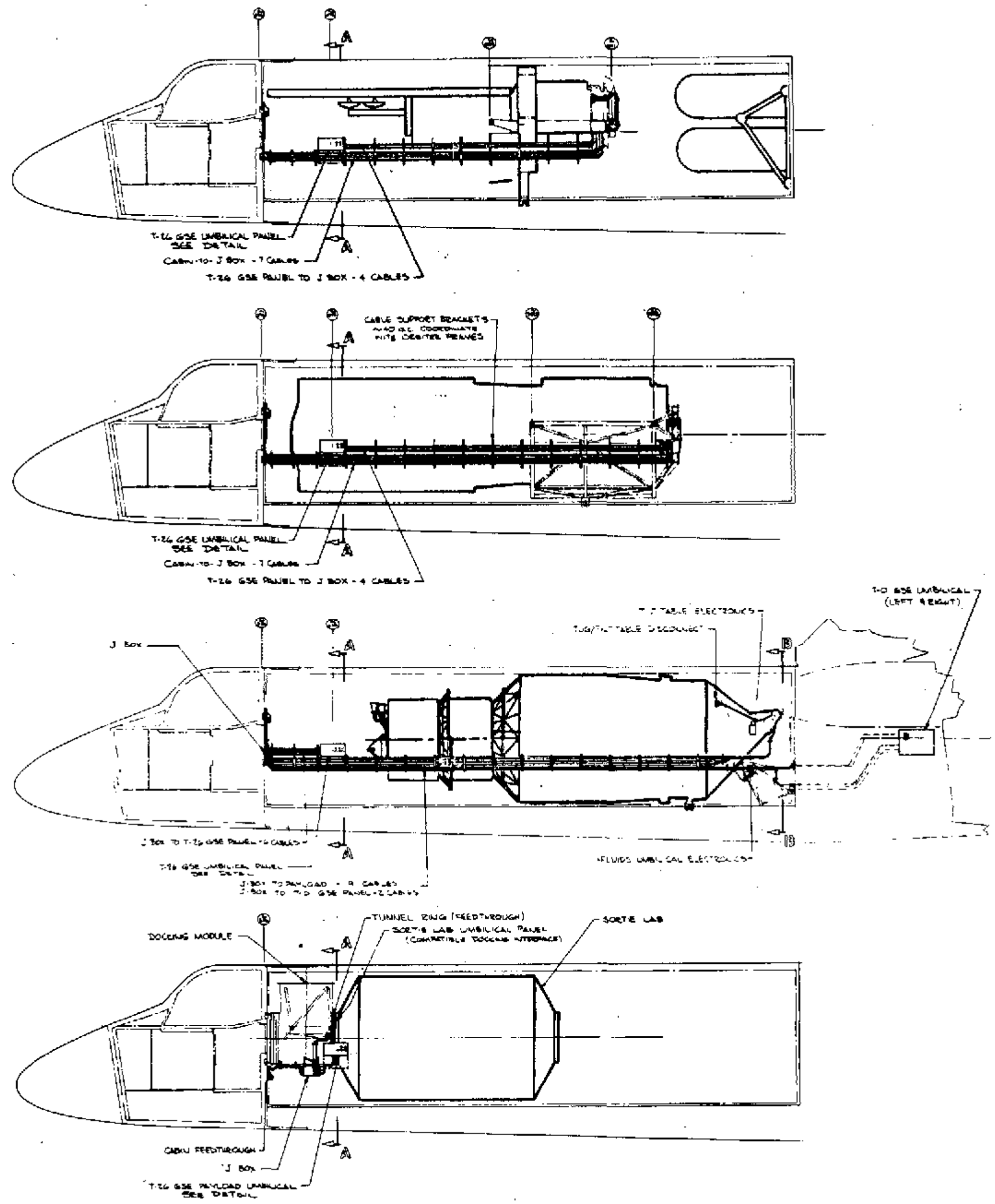


TABLE 2-20

40384-1

PAYLOAD LIQUID INTERFACES (INTERIM)

	MISSION CLASS I EOS	II ATS/SMS DSCS-II	II TUG	III LST	IV SORTIE LAB	SPECIAL
N_2H_4	PRELOADED-DRAIN RQD (NOT THRU PANEL)	PRELOADED-DRAIN RQD (NOT THRU PANEL)	-	-	-	
LH_2	-		1-2" FILL/DRAIN 1 - TBD DUMP (MAY NOT BE RQD)	-	TBD	
LO_2	-		1-2" FILL/DRAIN 1 - TBD" DUMP (MAY BE IN INFLIGHT ONLY)	-	TBD	
ECS	-		-	-	USES SHUTTLE ECS - NO PAD REQMN'T	MJS REQUIRES RTG THERMAL CONTROL

TABLE 2-21

40384

PAYLOAD GAS INTERFACES (INTERIM)

	MISSION CLASS I EOS	II ATS/SMS DSCS-II	II TUG	III LST	IV SORTIE LAB	SPECIAL
N_2	PRELOADED-NO PAD REQMN'T	PRELOADED-NO PAD REQMN'T	-	PRELOADED - NO PAD REQMN'T	USES SHUTTLE N_2 -NO PAD REQMN'T	
H_E	-	-	1-1/2" COLD HE 1-1/2" AMB HE	-	-	
GO_2	-	-	1-1/2" VENT 1-2" FILL	-	USES SHUTTLE GO_2-NO PAD REQMN'T	
GH_2	-	-	1-1/2" VENT 1-2" FILL	-	-	
AIR	10,000 CLASS CLEANLINESS	-	-	10,000 CLASS CLEANLINESS IF LST SHROUDED	PURGE MAY BE RQD (POS P)	

2.3.5 Pad Electrical Aerospace Ground Equipment (EAGE)

The EAGE required at the LUT, which interfaces with the payload service panel, is seen to be the following:

A. RF Amplifiers
B. Video Amplifiers
C. Line Amplifiers for Serial PCM and Commands
D. Voice Communications Relay Equipment
E. Battery Chargers
F. Payload Power Supplies
G. Command Decoders and Relay Drivers
H. Remote Multiplexers
I. Patch Panel and Distribution Equipment

2.3.6 Mobile Launcher Equipment

The only interfaces with the Orbiter and payload service panels appear to be the following:

A. Battery Charge and Monitor
B. Caution/Warning Monitor

2.3.7 Orbiter Maintenance and Repair Facility

No requirements for service panel access have been found in the Orbiter/maintenance and repair facility, with the exception of battery chargers and caution/warning monitoring.

2.3.8 Launch Area Operations

Tests or operations, test or interface connectors, and GSE were identified for the Tug, payload processing, and payload servicing facilities to provide a more complete understanding of the launch area operations. Facility sheets containing the name of the test or operation, the connectors involved, and the GSE equipment required were prepared as illustrated by Table 2-22. The difference in the handling of DOD and NASA payloads was discussed, and a recommendation made that one flow pattern be established.

FIGURE 2-19

SERVICE PANEL OPTIONS - ELECTRICAL

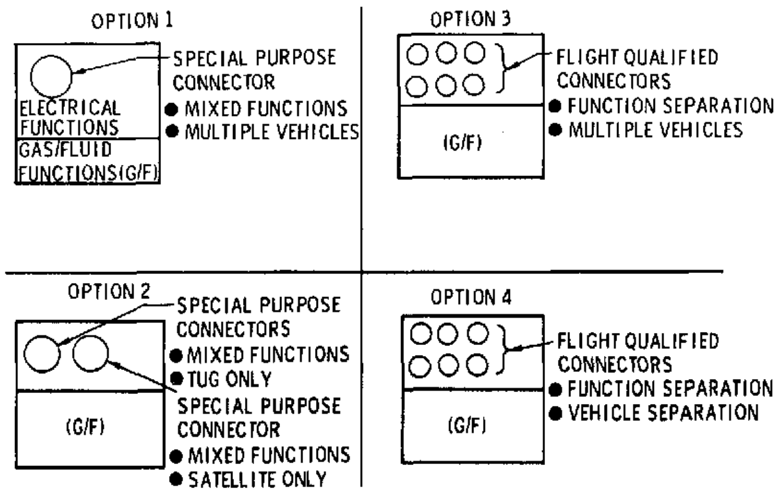


TABLE 2-22

SPACECRAFT PROCESSING FACILITY TESTS/EQUIPMENT

TEST OPERATION	CONNECTION	EQUIPMENT
REACTION CONTROL SYSTEM LEAK TEST	TEST CONNECTOR	1 RCS TEST SET
BATTERY INSTALLATION, CHARGE, MONITOR	INTERFACE CONNECTOR	2 BATTERY CHARGER AND PANEL
INTERNAL/EXTERNAL POWER TEST	INTERFACE CONNECTOR AND TEST CONNECTOR	3 POWER SUPPLY AND CONTROL UNIT
INTEGRATED SYSTEMS TEST	INTERFACE CONNECTOR AND TEST CONNECTOR	4 DATA ACQUISITION, DISPLAY / CONTROL PANEL COMPUTER
SCF COMPATIBILITY TEST	INTERFACE CONNECTOR	5 COMMAND PROCESSOR, ENCRYPTION/ DECRYPTION EQUIPMENT
COMMUNICATIONS PERFORMANCE TEST	NONE	6 GROUND STATION
SOLAR ARRAY ILLUMINATION TEST	TEST CONNECTOR	7 CHECKOUT DRAWER, DISCRETE CONTROLS AND DISPLAYS
COUNTDOWN TIME TEST	INTERFACE CONNECTOR	4
PROPELLANT LOADING AND FIRING TEST	TEST CONNECTOR	1 2ND SET
PREINSTALLATION MATING SIMULATION	INTERFACE CONNECTOR	8 TUG/ORBITER SIMULATORS
SAFE AND ARM DEVICE TEST	INTERFACE CONNECTOR	9 ORDNANCE TEST DRAWER
ORDNANCE INSTALLATION	FLIGHT SYSTEMS	10 NONE
LRU TESTS	NONE	11 LRU TEST CONSOLES

2.4 TASK 4 - PAYLOAD DESIGN OPERATIONS IMPACTS

The purpose of this task is to identify payload design and operations impacts that result from incorporating a docking module in the Orbiter payload bay and, to expand the contamination control requirements identified in the SOAR II Study for payloads identified as involving 10,000-class cleanliness standards.

The detailed analysis for each of these subtasks are included in Appendices D and H, respectively.

2.4.1 Docking-Module Analysis

The results of the analysis included in Appendix D are summarized below.

The docking module configuration included in the Shuttle PRR baseline was used as the basis for the study analysis. It is recognized that subsequent configuration changes are under consideration, such as

- Straight-through crew compartment/docking module/payload access
- Aft-located SAM's/

These configuration modifications do not, however, affect the analysis results.

It is estimated that up to 66 percent of the Shuttle traffic model could potentially utilize a docking module, and that on-pad access to these mission payloads during launch operations will be required. Requirement for payload access is anticipated for (among others)

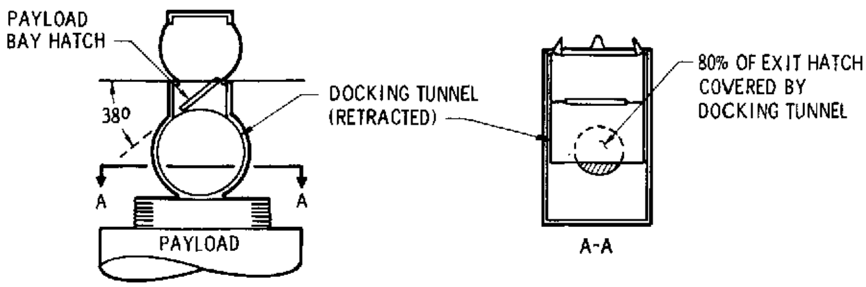
- Replacement of failed system components
- Installation of time-critical equipment
- Protective cover removal
- Connection of test connectors for performance of payload integrated system tests

As indicated in Figure 2-20, in-bay access to payloads is precluded for Shuttle missions on which docking modules of the PRR configuration are flown.

FIGURE 2-20

40414

PRELAUNCH ON-PAD PAYLOAD ACCESS CONSTRAINT

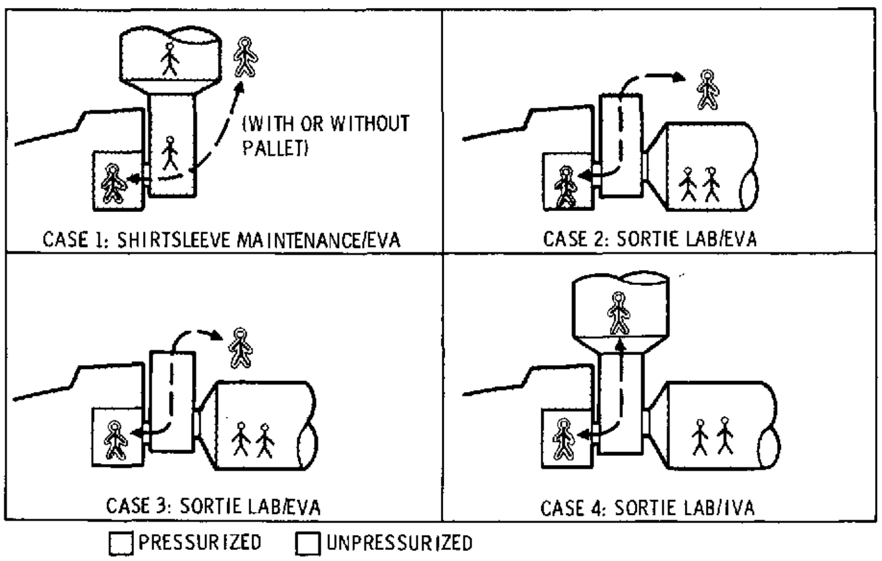


- DOCKING MODULE PRECLUDES ACCESS TO 66% OF SHUTTLE PAYLOADS THROUGH AIRLOCK AT LAUNCH PAD
- UP TO 226 (25%) OF SHUTTLE MISSIONS CARRY PAYLOADS OF CURRENT DESIGN WHICH MAY REQUIRE ON-PAD ACCESS FOR IFJ CONNECTION, PROTECTIVE COVER REMOVAL, ETC
- UP TO 367 (41%) OF SHUTTLE MISSIONS CARRY SORTIE LABS WHICH MAY REQUIRE INSTALLATION OF TIME CRITICAL EQUIPMENT AT THE LAUNCH PAD

FIGURE 2-21

40415

CONCURRENT SHIRTSLEEVE AND EVA/IVA OPERATIONS CASES STUDIED



The four combinations of concurrent shirtsleeve and EVA/IVA operations studied are illustrated in Figure 2-21. It was assumed that for all cases, a backup EVA crewman would be fully suited and standing by in the Orbiter airlock during EVA and IVA operations. A nominal crew size of four was assumed; however, a larger crew would not affect analysis results.

Each of the four cases was examined to determine the acceptability of concurrent shirtsleeve and EVA/IVA operations.

Concurrent operations are not recommended for missions utilizing a docking module because a high potential risk exists for the crew in the event of an emergency requiring shirtsleeve or EVA/IVA crew return to the crew compartment.

The following three rescue modes (identified in Figure 2-22) were considered:

A. Docking with manipulator assist: The disabled Orbiter is equipped with a docking module. The rescue Orbiter is launched with a docking

FIGURE 2-22

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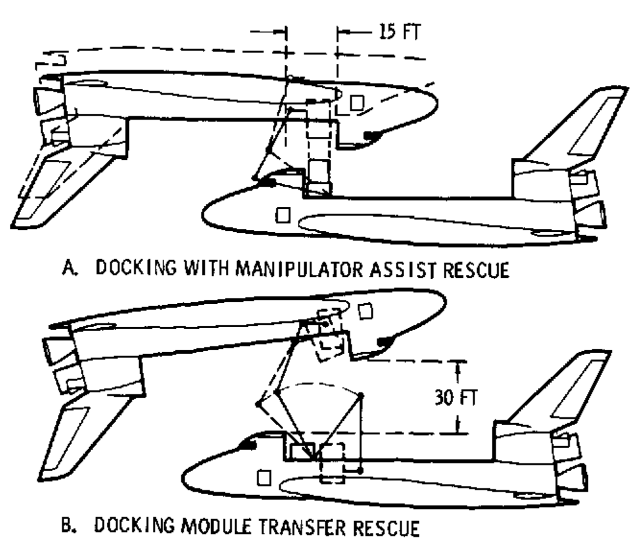
DISABLED ORBITER RESCUE OPERATIONS SCENARIO



A. DOCKING WITH MANIPULATOR ASSIST RESCUE

B. DOCKING MODULE TRANSFER RESCUE

C. EVA RESCUE (NO DOCKING MODULE)

module which, after the two Orbiters rendezvous, is docked with the module of the disabled Orbiter with the assistance of the rescue Orbiter SAMS. Shirtsleeve rescue is then effected.

B. Docking module transfer: The disabled Orbiter is not equipped with a docking module. The rescue Orbiter is launched with two docking modules. After rendezvous, the rescue Orbiter transfers and installs one docking module in the payload bay of the disabled Orbiter and then docks to it with assistance from the rescue Orbiter SAMS. Shirtsleeve rescue is then effected.

C. EVA rescue: Does not depend on the existence of a docking module.

For shirtsleeve rescue from an Orbiter that was not launched with a docking module, three payload Orbiter configurations affect rescue operations.

For two of the three configurations, the disabled Orbiter payload must be jettisoned before docking module transfer operations, whereas only one configuration requires payload jettison for EVA rescue operations. Adoption of an emergency egress EVA hatch in the crew compartment and/or the payload or payload/Orbiter access tunnel would entirely eliminate the requirement for payload jettison.

Because of the complex operations involved in jettisoning the payload of the disabled Orbiters coupled with the complexity of docking module transfer and assembly, EVA rescue operations are preferred. Additionally, in the event that rescue operations are required, it is highly probable that the crew of the disabled Orbiter would be in their pressure-suits as a precautionary measure.

Docking module analysis conclusions and recommendations are summarized as follows:

- Docking module constrains on-pad payload access and involves high risk for rescue operations.
- Concurrent EVA/IVA operations endanger both the EVA/IVA and shirtsleeve payload crew.

- Potential solutions/recommendations for further consideration -
  - Accept higher risk operations
  - Fly docking module on all missions and accept shorter payloads (impacts $\approx$20 percent of missions)
  - Consider EVA escape hatch in Orbiter crew compartment
  - Reconsider airlock/docking port in Orbiter crew compartment.

The detailed operations required for the Orbiter to perform docking with another orbital element were not included in the analysis because detailed docking module design and configuration information is unavailable. For Shuttle docking missions, it was assumed that docking is accomplished with assistance from the Shuttle attached manipulator system.

The docking module analysis task of the SOAR-IIS study was based on the Shuttle PRR docking module concept as depicted on R.I. Drawing No. VL70-003115. Subsequent to completion of this analysis, R. I. Drawing No. VL70-004094 depicting the revised docking module baseline design was received. This revised design is presented in Figure 2-23. A review of the revised baseline module revealed that the results of analyses conducted utilizing the PRR baseline module remained unaffected with except regarding the permissible length of payloads stowed in the payload bay and accessibility to payloads through the module prior to launch.

The dimensional characteristics of the PRR docking module permitted stowed payloads of 52 ft in length. The revised baseline module design reduces the permissible length of payloads to 51 ft 5 in.

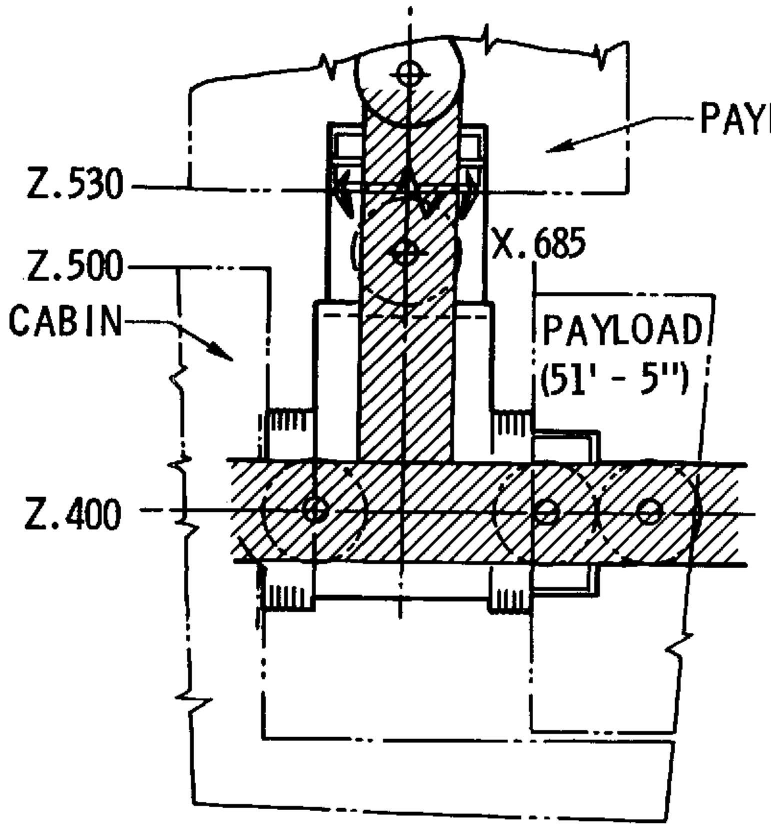
Physical interference of the crew compartment/payload bay hatch with the retracted docking tunnel prevented access to payloads through the docking module from the crew compartment before launch, when the PRR module concept was utilized.

The revised docking module assembly baseline has eliminated this interference and allows straight-through access to the payload from the Orbiter crew compartment while the docking tunnel is retracted. All payloads attached to the module are therefore accessible internally before launch.

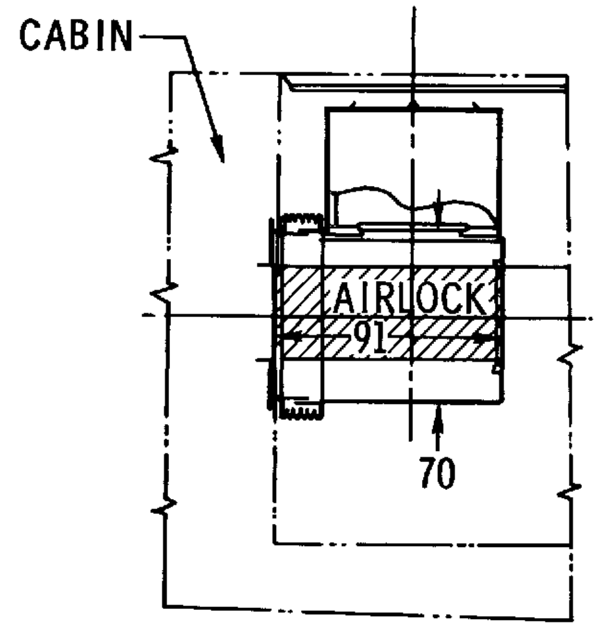
FIGURE 2-23

DOCKING MODULE ASSEMBLY
MCRO200 R2 BASELINE 6-11-73

(R. I. DWG. NO. VL70-00494)



40" MIN. PASSAGE TO PAYLOAD
STOWED/DOCKED



AIRLOCK-MODULE CLOSED

2.4.2 Contamination Analysis

In general, spacecraft cleanliness requirements tend to become more stringent as program definition progresses. This trend was evident during the SOAR studies, where cleanliness requirements for seven baseline spacecraft increased while none decreased. Experience with past programs such as Skylab has shown that if contamination control techniques are not introduced at the design definition phase, significant schedule and funding impact may be encountered. Hence, it is the purpose of this analysis to contribute to the definition of Shuttle contamination control requirements as early as possible in its program time frame. The complete contamination analysis is presented in Appendix H.

During the course of the SOAR-II study, the most stringent spacecraft cleanliness requirement identified was class-10,000 per Federal Standard 209A - Clean Room and Work Station Requirements, Controlled Environment. A review of the SOAR-II payloads reveals three spacecraft that require 10,000-class cleanliness: the Large Space Telescope (LST), Earth Observatory Satellite (EOS), and High-Energy Astronomy Observatory-C (HEAO-C) mission. (Program and configuration definitions of HEAO-C have undergone major changes since its evaluation in SOAR-II; therefore, this payload was not included in the detailed examination afforded the other two spacecraft.)

The SOAR-II studies identified potential contaminant sources, examined Orbiter effluent discharges, and identified methods of controlling spacecraft contamination. Since ten different spacecraft were considered, the contamination control measures were general in nature in order to be all-encompassing. In this study, the cleanliness requirements of the LST and EOS have been examined in greater detail, and recommendations made specifically for these two spacecraft. These specific control measures are the most stringent to be encountered; however, many subsystem elements such as star trackers and radiometers are common to other spacecraft as well, and recommendations should be applicable to them also.

An important question regarding contamination control at the point in Shuttle development is which contamination control measures are best assumed by the Shuttle as opposed to the spacecraft. This study has attempted to provide insight into this matter.

Several important inferences can be made from past contamination control methods. First, many of the Skylab precautions and control measures are due to its continuous generation of effluents, which is somewhat analogous to the period when the Orbiter is in the payload vicinity. After Orbiter departure, however, on-orbit contamination sources can be expected to be reduced to insignificance. Second, the ATM was built, checked out, and transported in a continuously maintained 10,000-class cleanliness environment over a period of two years. Even so, certain instruments not further protected by localized 100-class purges required cleaning before launch. The adequacy of a certain atmospheric particulate cleanliness level is therefore dependent upon the length of exposure of critical components. ATM experience would suggest that 10,000-class cleanliness may be too stringent for an entire spacecraft, while it is inadequate for sensitive optics. Third, many optical instruments have sealed optical paths so that external contamination is basically a problem only at the light entrance window. Fourth, while specification of atmospheric cleanliness levels per Federal Standard 209A may be adequate to ensure desired cleanliness in ground-based clean rooms, a surface cleanliness level is also necessary for the Shuttle payload bay to avoid gross secondary emissions during liftoff and boost.

The Shuttle effluents and their sources have been identified and defined by Rockwell International. The effluent characteristics are described in the Appendix H, Table H-3. These effluents consist of particulates and gases generated from the external tank system, the solid rocket boosters, and the Orbiter systems (e.g., pyrotechnics, RCS, EPS, ECLSS, etc.).

The optical surfaces on the LST and EOS are the most contamination-sensitive areas exposed to the environment. Contamination has been categorized into four types as listed in Table 2-23. Film deposits, in which the contaminant contacts and spreads over the optical surface, are caused by

TABLE 2-23

40477

CONTAMINANTS AND THEIR EFFECTS ON OPTICS

TYPE	MAJOR EFFECTS
FILM DEPOSITS (OILS, WATER OUTGASSING RCS EFFLUENTS)	REDUCES SPECTRAL BANDWIDTH (ESPECIALLY UV) REDUCES MIRROR REFLECTANCE DEGRADES RESOLUTION
PARTICLE DEPOSITS (DUST, WATER DROPLETS ICE CRYSTALS RCS EFFLUENTS)	SCATTERS LIGHT DECREASES SIGNAL-TO-NOISE RATIO REDUCES MIRROR REFLECTANCE
MOLECULAR CLOUDS (H_2, N_2, O_2, NH_3 RCS EFFLUENTS OUTGASSING)	DECREASES SIGNAL-TO-NOISE RATIO ABSORBS SPECIFIC WAVELENGTHS
PARTICULATE CLOUDS (WATER DROPLETS ICE, DUST)	SCATTERS LIGHT CREATES FALSE OBJECTS DECREASES SIGNAL-TO-NOISE RATIO

adhesion condensation. Particulate deposits are caused by dust, liquid droplets, ice crystals, and other materials that adhere to the optical surfaces. Molecular clouds can be expected from outgassing and RCS exhaust, and particulate clouds created by Orbiter effluents such as water droplets, dust, ice, etc.

The contamination-critical elements of the LST and EOS are shown in Figures 2-24 and 2-25. Both involve large optical systems. The LST involves a 3-m primary Cassegrainian mission system with special imaging systems. Orbital operation of the Large Space Telescope (LST) under conditions free of Earth atmosphere obscuring effects will result in three distinct improvements over ground-based telescopes: (1) objects previously too dim may now be seen, (2) light wavelengths previously obscured (principally ultraviolet below 0.3 μm) may now be sensed, and (3) optical resolution can be improved to the point where it is limited by design state-of-the-art rather than by the environment.

FIGURE 2-24

40392

LST CRITICAL CONTAMINATION CONTROL AREAS

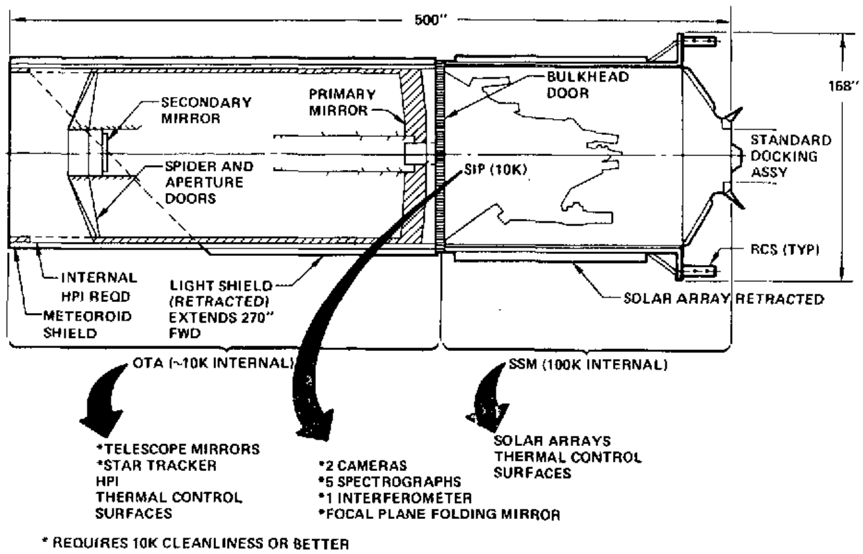
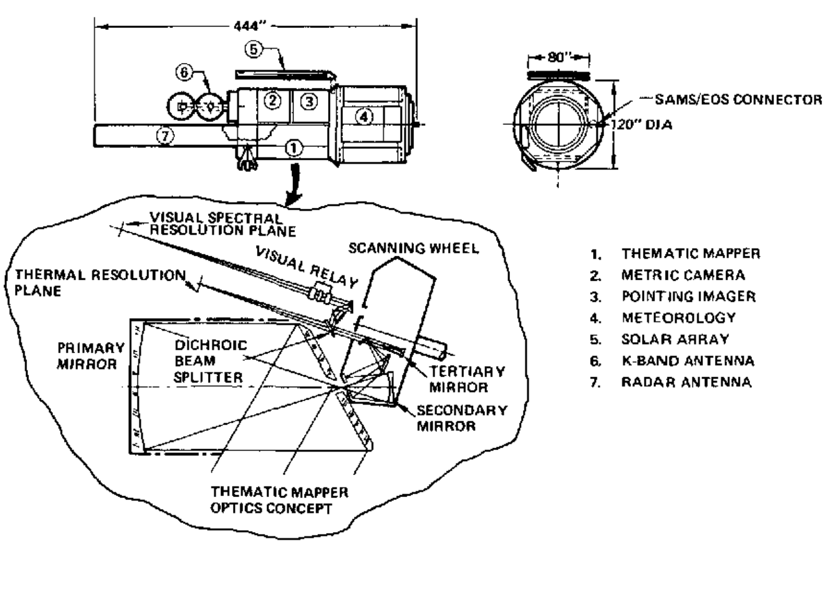


FIGURE 2-25

40390

EOS CRITICAL CONTAMINATION CONTROL AREAS



Clearly, the introduction into the LST environment of contaminants that encroach upon its sensitivity, spectral bandwidth, or resolution power tends to obviate its purpose and usefulness to the scientific community.

The Earth Observatory Satellite (EOS) mission objective is to provide a space platform for testing experimental sensors and spacecraft subsystems. Later EOS flights can be expected to become increasingly operational with more emphasis given to the sensed data rather than the sensors. Typical instruments to be flown on the EOS are listed. The thematic mapper is perhaps one of the more sensitive to contamination, being a catoptric system that uses a 40-cm-diameter primary mirror.

Both the LST and EOS contain scientific and spacecraft instruments that necessitate meticulous design, fabrication, and handling to maintain a high degree of cleanliness. The cleanliness levels specified or implied for each program are significantly more stringent than will be provided in the Shuttle Orbiter bay. During deployment or maintenance operation, a less predictable and perhaps uncontrollable environment will be encountered. It therefore appears unreasonable to impose more-stringent particulate cleanliness requirements on the Orbiter bay than the presently specified 100, 000-class level. Rather, it is proposed that the spacecraft contain provisions to ensure that cleanliness levels are maintained in an unclean environment. Various control methods have been examined and suggested methods made, as listed in Table 2-24, in order to ensure that proper cleanliness is maintained throughout the mission.

Similarly, the requirements imposed on the Orbiter by the payload are minimized in Table 2-25.

The 100-class particulate cleanliness level is considered adequate for the Orbiter bay, assuming more stringent spacecraft requirements will be met by spacecraft systems. Unless a spacecraft bag is employed (which could become quite complicated for retrieval), a payload bay surface cleanliness should also be specified consistent with the 100, 000-class clean atmosphere. A 50-percent relative humidity maximum is recommended to suppress arcing and chemical

TABLE 2-24

40458

SUGGESTED LST AND EOS CONTAMINATION CONTROL METHODS

LST	EOS	
X		POSITIVE INTERNAL ΔP EXCEPT WHEN OPERATING
X		10K CLASS CLEAN, 30% HUMIDITY AIR PURGE WHEN MANNED
X		10K CLASS CLEAN, DRY GN_2 PURGE WHEN UNMANNED
X	X	CLEAN BAG USED DURING GROUND HANDLING
X	X	INHIBIT ORBITER DUMP, VENT, AND RCS (IF PRACTICAL)
X	X	AUTOMATED PROTECTIVE COVERS USED ON CRITICAL SENSORS
X	X	SPACECRAFT APPROACHED BY ORBITER FROM SELECTED DIRECTION
X	X	ALLOW SEVERAL DAYS FOR OUTGASSING AND CLOUD DISPERSAL

TABLE 2-25

40389

SUGGESTED ORBITER CONTAMINATION CONTROL REQUIREMENTS

- PAYLOAD BAY
  - 100,000 CLASS CLEAN ATMOSPHERE
  - *VISUALLY CLEAN SURFACES (SMOOTH LINING PREFERRED)
  - *50% MAX RELATIVE HUMIDITY
- PAYLOAD MANNED SERVICE PROVISIONS
  - 100,000 CLASS CLEAN ATMOSPHERE
  - *10 PPM LOW VAPOR PRESSURE (10^{-2} MM HG) NON-PARTICULATES
  - *15 PPM HIGH VAPOR PRESSURE, HARD TO OXIDIZE NON-PARTICULATES
  - *30% MAX RELATIVE HUMIDITY
  - 100,000 CLASS CLEAN AREA (E.G. DOCKING MODULE)
- ORBITER EFFLUENTS
  - NO DUMPING OR VENTING NEAR PAYLOAD
  - *RCS INHIBIT DURING CRITICAL MAINTENANCE PERIODS
  - SMALLER (25 LBF) THRUSTERS AND/OR LARGER ATTITUDE DEAD BAND

*NEW OR MORE STRINGENT THAN EXISTING REQUIREMENT

reactions. Orbiter effluent discharge should be inhibited in the spacecraft vicinity where possible. RCS inhibit using smaller thrusters, such as the 25-lbf engines recently incorporated, alleviate much of the RCS contamination problem.

2.5 — TASK 5 PAYLOAD VENTING REQUIREMENTS ANALYSIS

The objective of the payload venting analysis is to determine the impacts on the payload and on the Shuttle of payload venting. The payload-associated fluid flows throughout the various mission phases can be appreciable, and in some cases critical flows are dependent upon either the rigor of payload safety requirements or the Shuttle's capability for vent installations and operational constraints on venting. Payload safety requirements that call for all payload pressure vessels to provide pressure-limiting relief vents can be a key factor. Conditions where design conditions will permit no-vent operations may relieve some payload impacts. The definition of the Shuttle vent services to the payloads is an evolving activity with many basic features yet to be defined. The complete venting requirements analysis is presented in Appendix E.

The representative mission classes have fluid types as listed in Table 2-26 that may be involved in payload venting. The major quantity flows are the payload bay cooling gas flows and the purge gas flows generally involved with all payloads and the propellants in the Space Tug. The other venting flows are small and expected to be intermittent during the mission as indicated by Table 2-27.

Reactive and hazardous fluid vents such as hydrazine, hydrogen, and batteries will require dedicated vent piping overboard in the Orbiter with associated disconnects when the payload is separated from the Orbiter in orbital delivery.

Examination of the total management of payload fluids, which includes loading, venting, unloading, and dumping, shows that all usually are interrelated and frequently have common plumbing. Simplification of the payload Shuttle interfaces leads to multiple-use piping.

For piped flows, the common solution tends to focus on the Orbiter exterior umbilical panels, which may be suitable for payload fill and drain operations. Their suitability for vent and dump operations may be limited.

TABLE 2-26

40465

PAYLOAD EFFLUENTS DISCHARGE

MISSION CLASS	PAYLOAD	PAYLOADS FLUIDS TYPES: He	GN_2	GO_2	CO_2	HYDRAZINE	LH_2/LO_2	PURGE	BATTERIES	OUTGASSING	REMARKS
I	EOS		YES			YES		YES	YES	YES	VENTS POSSIBLE
II	ATS		YES			YES		YES	YES	YES	VENTS POSSIBLE
	SMS		YES			YES		YES	YES	YES	VENTS POSSIBLE
	DSCS-II		YES			YES		YES	YES	YES	VENTS POSSIBLE
	TUG	YES				POSSIBLE	YES	YES	YES	YES	VENT LINES
III	LST		YES					YES	YES	YES	VENT LINES PROBABLE
	ANCILLARY EQUIPMENT USED ON CLASSES I, II, III	YES	YES					YES		YES	VENTS POSSIBLE
IV	SORTIE LAB	YES	YES	YES	YES			YES	YES	YES	VENT LINES PROBABLE

AUG 73

TABLE 2-27

EFFLUENTS PROBLEM

SPACECRAFT	EFFLUENTS: TYPE	AMOUNT (LBS)	TIME FLOWS	CONTROLLED VENTING
EOS				
GSFC EOS PROJECT OFFICE	HYDRAZINE AND GN_2	100 50	• ORBIT TRIM (1/30 DAYS) • ATTITUDE CONTROL WITH COLD GAS • STATIONKEEPING WITH *HYDRAZINE*	THRUSTERS CAN BE FIRED AS NECESSARY TO USE UP REMAINING GAS
SMS				
GSFC PHASE-B STUDY JANUARY 1970	HYDRAZINE	72	INITIAL ADJUST = 6 # S/C ORIENT = 5 = E-W STATIONKEEP = 3 = N-S STATIONKEEP = 37 = NUTATION CONTROL = 15 = STATION RELOCATE = 5 =	BURN-OFF IS POSSIBLE
ATS-H-I				
ATS-H/I SYSTEM FEASIBILITY REPORT VOL II, JUNE 1972, LEWIS RES CENTER	HYDRAZINE SECONDARY SYSTEM	180	HYDRAZINE IS BACKUP SYSTEM FOR UNLOADING THE GYROS AND FOR 1 LONGITUDE REPOSITIONING MANEUVER, LIFE TIME IS 1 YR PLUS 1 REPOSITIONING, OR 2 YR W/O REPOSITIONING	BURN-OFF IS *POSSIBLE IN* THEORY
LST				
NASA TM X-64726 PHASE-A FINAL REPORT, (VOL. 5), DECEMBER 1972	GN_2 (COLD GAS)	43	EMERGENCY/BACKUP SYSTEM ONLY. ALSO USED AS PRIMARY FOR DOCKING MANEUVER AGENA THRUSTERS USED	NO PROBLEM VENTING GAS BECAUSE COLD GAS THRUSTERS ARE INACTIVE (I.E., NO HEAT IS GENERATED)
DSCS-II				
DSCS-II AREA TRW	HYDRAZINE	120/SAT.	AS NECESSARY. EVERY 21 DAYS AFTER ON-ORBIT. MOST FUEL USED FOR REPOSITIONING ON DEMAND. INITIAL STATION ACQUISITION = 22 =, STATIONKEEPING = 50-60 =	THRUSTERS CAN BE BURNED CONTINUOUSLY TO USE UP ALL FUEL

The present definition of the Orbiter overboard venting for payloads is shown in Figure 2-26. The three Orbiter umbilical panels, one forward and two aft on the sides, are the main piping accesses. The ten bay atmosphere discharge vents and ingestation ports are the main "unpiped" flow paths. There are potentials for boat-tail piped outlets, although presently only Shuttle outlets are specified. Uncontrolled flows within the payload bay must not hazard the bay doors to an overpressure condition and structural damage.

Nominal payload venting appears to be workable, provided the Orbiter can accept venting outlets at the exterior umbilical panels or for some vents in the Orbiter boat-tail. In general, payload fluids venting will be special situation flows for safety requirements and only minor outgassing, free-flight propulsion, or inerting flows prior to retrieval are envisioned after launch. The Shuttle criteria in payload safety and Shuttle ability to accept payload fluids, vent, fill, drain, and dump operations remain indefinite. The Shuttle definitions for items listed in Table 2-28 will materially contribute to confirmation of payload vent plan acceptability or will point up the need for added design and possible operations solutions.

2.6 – TASK 6 – GENERAL INTERFACE ASSESSMENTS AND SAFETY

This effort consists of two analyses: Payload placement and retrieval, and an analysis of shuttle safety criteria impacts on the payload. These analyses are summarized in the following sections and presented in detail in Appendices F and G.

2.6.1 Payload Placement and Retrieval Analysis

The objective of this analysis is to determine if the offered Shuttle characteristics are adequate for the needed payload services in the operations of payload placement and payload retrieval. The Shuttle baseline equipment and operations concepts for payload placement and retrieval utilizes the manipulator, SAMS, for payload movement out of the payload bay and for payload release. After macro and micro rendezvous of the Orbiter with a passive payload to be retrieved, the SAMS completes the final payload capture and the subsequent payload restowing in the bay. The low velocities, accelerations, and forces capabilities of the SAMS which is the final contact and the initial contact with payloads results in "soft" release and "soft" dockings.

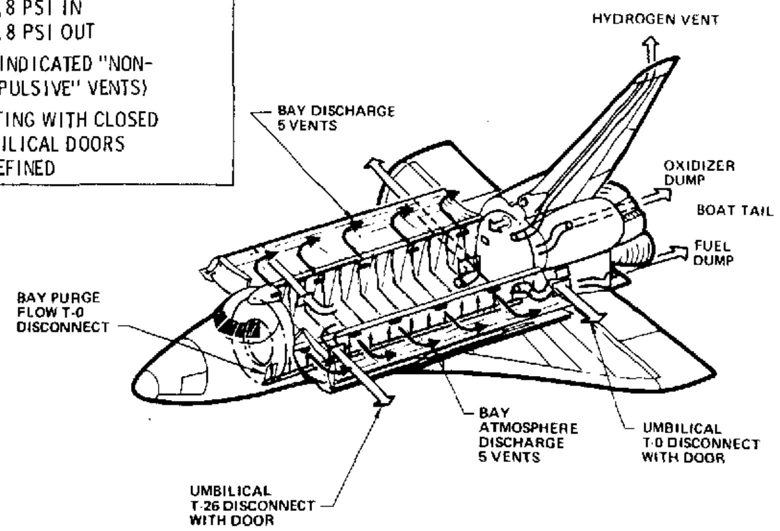
FIGURE 2-26

IIS

40462

ORBITER OVERBOARD PAYLOAD VENTING

NOTE: BAY DOOR LOADS LIMITS
ΔP 0.8 PSI IN
ΔP 1.8 PSI OUT
- (NO INDICATED "NON-PROPULSIVE" VENTS)
- VENTING WITH CLOSED UMBILICAL DOORS UNDEFINED



AUG 73

TABLE 2-28

TABLE 2-28 SHUTTLE CRITERIA FOR PAYLOAD VENTING

- DEFINITION OF PRESSURE VESSEL CRITERIA
  - WHERE PRESSURE RELIEF AND VENTING IS REQUIRED
  - WHERE NO PRESSURE RELIEF AND NO VENTING IS REQUIRED
  - PAYLOAD CAUTION AND WARNING REQUIREMENTS, DIAGNOSE CAPABILITY AND CONTROLS FOR PRESSURE VESSELS
- DEFINITION OF VENT FLUID ACCEPTABILITY
  - NO QUALITY RESTRICTIONS
  - QUALITY RESTRICTIONS
  - QUANTITY RESTRICTIONS
    - FREE FLOWS
    - PIPED FLOWS
    - BAY DOORS CLOSED
- OPERATIONS MODE VENT LIMITATIONS
  - PRELAUNCH
  - LAUNCH
  - ABORT
  - ORBIT
  - SAMS
  - EVA
  - DEORBIT/RE-ENTRY
  - POST-LANDING
- VENT OUTLET LIMITATIONS
  - FREE FLOW
  - PIPED FLOW
    - LOCATION
    - TYPE OF VENT
    - MISSION MODE LIMITATIONS
- PAYLOAD BAY VENT SYSTEM INTERFACES
  - PIPING RACEWAYS
    - LOCATION/SIZE
    - X DIRECTION, YZ DIRECTION
  - WALL LOCATION/SIZE
  - OVERBOARD OUTLET
    - LOCATION/SIZE
    - FEATURES
  - BAY LINER FLUID BARRIER

Payload placement events, Table 2-29, when focused upon the payload release actions and the residual disturbances of the payload at release involve various potential contributors such as indicated in Figure 2-27. These potential payload excitations are all minor (with the exception of the separation velocity) because of the very low Orbiter and SAMS motions. The consequence is that payloads may expect to experience much lower tipoff disturbances from Shuttle departures, as much as one-third to one-fifth of those disturbances possible in the present expendable launch vehicles.

The one exception to this low disturbances, the payload separation velocity of 1- to 5-feet per second is an erroneous mingling of separation performance and tipoff disturbance in the Shuttle specifications, which should be treated separately. Payload velocities of 1- to 5-ft/sec relative to the Orbiter can be achieved in any of three ways: (1) the use of a stored energy device in the SAMS to accelerate the payload (not now in the Shuttle SAMS concept), (2) the Orbiter movement away from the payload by RCS thrusting, or (3) the payload movement away from the Orbiter by payload thrusting.

In the consideration of other payload separation systems, swing tables or tilt tables without the SAMS, payload placement may be equally "soft" as with the baseline SAMS concept, or payload separation velocities may be used which "harden" the separation, Table 2-30.

The elements of Shuttle payload retrieval detailed in Table 2-31 for the Shuttle baseline concept involves an active Orbiter closing to a passive spacecraft. The conditions at payload capture involve Orbiter micro-station keeping on the payload so that the SAMS completes the capture by a "soft" engagement. Other payload capture concept options are possible, including the "hard" docking capture of the payload to the Shuttle docking module, Figure 2-28, and the hard docking to a tilt table in the payload bay.

These "hard" docking conditions are required to stroke the normal docking attenuation system, to remove any misalignments between the payload and the docking face, and to complete the payload capture latching. The Shuttle baseline SAMS capture concept, Table 2-32, involves Orbiter station keeping

TABLE 2-29

40466

SHUTTLE PAYLOAD PLACEMENT

EVENT	SCOPE	ASSOCIATED EVENTS	BASELINE DEPLOYMENT CONCEPT
PAYLOAD DEPLOYMENT	FROM: PAYLOAD LATCHED IN PAYLOAD BAY TO: PAYLOAD READY FOR RELEASE	PAYLOAD: – ACTIVATION – EARTH LINK – STAR LINK – READINESS CHECKS	SHUTTLE MANIPULATOR
PAYLOAD RELEASE	FROM: PAYLOAD READINESS PLUS SHUTTLE READINESS TO: PAYLOAD RELEASE FROM SHUTTLE	SHUTTLE: – STABILIZATION – POINTING – UNLATCHING PAYLOAD: – STABILIZATION – RESIDUAL MOTIONS	MANIPULATOR UNLATCH
PAYLOAD SEPARATION FROM SHUTTLE	FROM: MOMENT OF RELEASE TO: SAFE SEPARATION DISTANCE FOR ACTIVATION OF PAYLOAD SYSTEMS	SHUTTLE: – CONTROL OF RCS EFFLUENTS – CONTROL OF OVER-BOARD DISCHARGES PAYLOAD: – CONTROL OF EFFLUENT IMPACTS ON SHUTTLE – CONTROL OF HAZARDOUS PAYLOAD SYSTEMS	ORBITER RCS TRANSLATION AND ROTATION FROM PAYLOAD

FIGURE 2-27

40482

ELEMENTS OF PAYLOAD TIP-OFF AT PAYLOAD RELEASE

RESIDUAL RATES IMPARTED TO DEPLOYED PAYLOAD BY SAMS

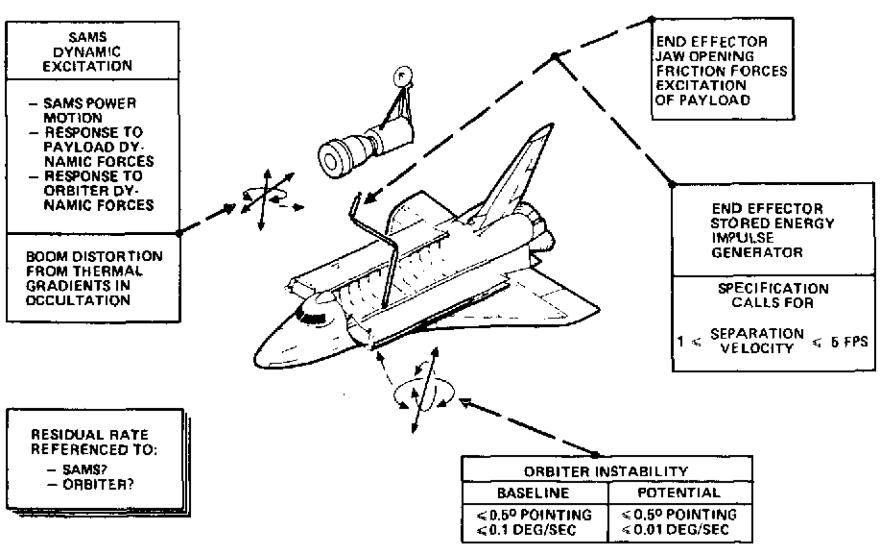


TABLE 2-30

40478

CONSTRAINTS IN PAYLOAD RELEASE TIP-OFF

- SOFT SEPARATION	< 0.1 DEG/SEC < 0.1 FT/SEC	HARD SEPARATION	< 1.0 DEG/SEC < 5.0 FT/SEC
- SHUTTLE SPECIFICATION	VOLUME X VOLUME XIV	< 0.75 DEG/SEC, SEPARATION VELOCITY ≥1≤5 FT/SEC < 0.15 DEG/SEC, SEPARATION VELOCITY ≥1≤5 FT/SEC	
- OPENING VELOCITY	• VEHICLE SEPARATION: 1.0 FT/SEC • VEHICLE PROPELLANT SETTLING: 5.0 FT/SEC (TRANSTAGE)		
- RELEASE ACCELERATION	< 0.1 FT/SEC^2	ALLOWS SATELLITE BOOMS AND PANELS TO BE EXTENDED AT RELEASE	

4-37

TABLE 2-31

40461

ELEMENTS OF SHUTTLE PAYLOAD RETRIEVAL

EVENT	SCOPE	ASSOCIATED EVENTS	BASELINE RETRIEVAL CONCEPT
PAYLOAD MACRO RENDEZVOUS	FROM: INITIAL PAYLOAD LOCATION (UP TO 24 MILES) TO: PAYLOAD LOCATED WITHIN ONE MILE OF ORBITER	PAYLOAD BEACON, PAYLOAD: – POSITION KEEPING – STABILIZATION – COMMAND LINK – PAYLOAD CONTROL TRANSFER FROM GROUND TO ORBITER ORBITER MANEUVERS	TUG CLOSING .3V 70 NMI TO 24 NMI ORBITER CLOSING 24 NMI TO 1 NMI
PAYLOAD –READINESS FOR CAPTURE	PAYLOAD: – STABILIZATION – COOPERATION – PASSIVATION	ORBITER: – STATUS LINK – READINESS TEST COMPLETION – FINAL APPROACH TO 30 FEET	PAYLOAD: – SELF SAFING – COMMANDED FROM GROUND – COMMANDED FROM ORBITER
PAYLOAD MICRO RENDEZVOUS	FROM: PAYLOAD ABOUT 1 MI TO: PAYLOAD FITTING 2 FT ENVELOPE	ORBITER: – MANEUVERS TO 30 FT UP TO ONE TENTH FPS	– ORBITER CLOSES 1 MI TO 30 FT – MANIPULATOR CLOSES 30 FT TO 2 FT
PAYLOAD CAPTURE	FROM: ORBITER SYNCH-RONIZATION OF PAY-LOAD MOTIONS TO: MANIPULATOR TO PAYLOAD ENGAGE-MENT AND CAPTURE	ORBITER – 2 FT SPHERE ENVELOPE – ONE 0.01º PER SECOND ERRORS MANIPULATOR – CLOSE AND LATCH	– MANIPULATOR CLOSES 2 FEET
PAYLOAD STATUS READINESS FOR MOUNTING/STORAGE	PAYLOAD: – SYSTEMS PASSIVATION – INDEXING FOR MOUNTS – APPENDAGES STOWAGE – SAFETY INSPECTION	ORBITER: – LIMITATIONS ON MANEUVERS – LIMITATIONS OF MANIPULATOR LOCATIONS	PAYLOAD: – AUTOMATIC SEQUENCING – RF ACCESS – NO HARDWIRE
PAYLOAD MOUNTING IN PAYLOAD BAY	PAYLOAD DE-DEPLOYMENT, MOUNTING AND LATCHING	MANIPULATOR MOTIONS PAYLOAD FSE ACTIVATION	PAYLOAD: – UMBILICALS MATED AFTER MOUNTING

4-39

FIGURE 2-28

40481

PAYLOAD CAPTURE OPTIONS

ACTIVE ORBITER

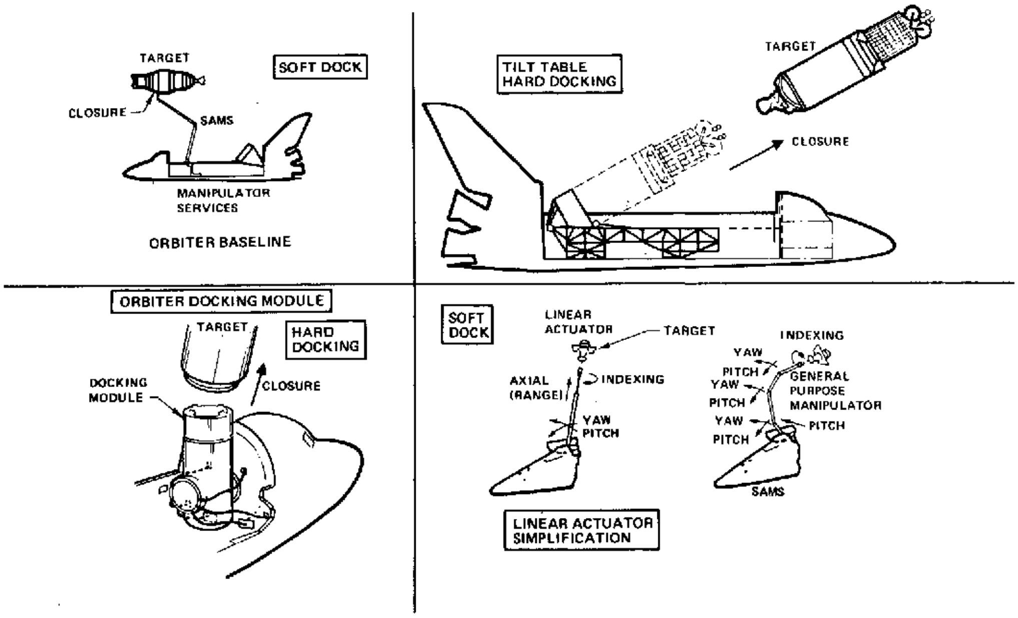


TABLE 2-32

40483

PAYLOAD CAPTURE

HARD DOCKING

<u>ORBITER CLOSING</u>
- APPROACH VELOCITY 0.5 FT/SEC
  ANGULAR $\leq$ 1.0 DEG/SEC
- CONTACT
  CLOSING VELOCITY $0.3 \leq V_C \leq 0.5$ FT/SEC
  LATERAL VELOCITY $V_L > 0.045$ TO 0.075 FT/SEC

<u>PAYLOAD MOTION</u>
$\leq$0.1 DEG/SEC (ANY AXIS)
<1 DEG AMPLITUDE
>1.5 FT CORRIDOR

<u>MISALIGNMENT</u>
LATERAL ±0.5 FEET
ANGULAR ±5 DEGREE
ROLL 7 DEGREE

<u>STAND-OFF DISTANCE</u>
(WHEN SAMS COMPLETES CAPTURE WITH A SOFT DOCK)
$\geq$30 FEET
(<45 FEET FROM CG)

SOFT DOCKING

<u>SAMS CLOSING</u>
CONTACT VELOCITY >0.8 FT/SEC
ANGULAR $\leq$ 0.1 DEG/SEC

<u>ORBITER STATION KEEPING</u>
≈±1 FOOT RELATIVE POSITION
<0.35 FT/SEC RELATIVE VELOCITY
<45 FEET TARGET FROM ORBITER CG

<u>PAYLOAD MOTION</u>
$\leq$0.01 DEG/SEC
< 1 DEGREE AMPLITUDE (ANY AXIS)

<u>MISALIGNMENT - SAMS JAW</u>
LATERAL ±2 INCHES
ANGULAR SMALL (TBD)
ROLL SMALL (TBD)

<u>STAND-OFF DISTANCE AND MOTION</u>
(ORBITER STATION KEEPING ENVELOPE)
< ±1 FOOT
<0.01 DEG/SEC (ANY AXIS)
<0.1 FT/SEC

stand-off position on the payload so that a relative position of ±1 ft, less than 0.01 ft/sec^2 acceleration and less than 0.1 ft/sec velocity permits the SAMS grappler to close and capture. If this Orbiter performance can be used for the regular docking engagement, it would be possible to design out the "hard" docking conditions and "soft dock" all payload captures.

The function of the SAMS in the baseline payload placement and retrieval, other than movement of the payload into and out of the payload bay, appears to employ only a small fraction of its versatility. Simpler systems, such as a linear actuator or docking faces, would suffice. In the SAMS, movement of the payload into and out of the bay, the more positive tilt table would reduce deployment times as well as retain other services such as umbilical services. The SAMS does not appear to be justifiable for payload placement and retrieval activities.

The conclusion that other capture options are competitive with the SAMS is predicated upon the Orbiter micro-station keeping performance. If this station keeping is not achieved, the capture tends toward hard docking. The increased demands upon the SAMS could exceed its capabilities. There is no Orbiter microstation keeping performance requirement presently listed in the Shuttle Level II Volume X Specification. Can the Shuttle-Orbiter perform as required for the baseline capture operation?

If the Shuttle performance is achieved, it appears that the payloads can satisfactorily operate in placement and in retrieval.

Additional details on this analysis appear in Appendix F.

2.6.2 Impacts of Shuttle Safety Criteria on Payloads*

This task involves the determination of the impacts of Shuttle safety criteria on payloads. Payload related safety criteria appear in fragmented form in various Shuttle Level II specifications. The greatest detail in safety criteria is presently undergoing active coordination from a draft version, 7 June, for Section 11.0 of Volume XIV which was used for this impact analysis. As a

*See Errata Note on bottom of page 71.

consequence of the 7 June draft susceptibility to change; the impact conclusions can only be indicative of the safety trends.

The draft criteria dealt with safety management and with specific safety design features. The scope of payload safety covered includes the two boxed areas in Figure 2-29. The launch program areas, shown in the dashed box, were largely omitted as were the other payload items outside of the boxes. The relationship between the payload supplier and the Space Shuttle Program Office (SSPO) were defined in the criteria draft as a two-party interaction as sketched in Figure 2-30. The identification of a single payload spokesman was made to sustain the two-party activities. Two general types of payloads were recognized; one, a single payload which would be represented by a payload supplier; and two, a multiple payload case where a designated owner/operator for integrated payload would be selected. The SSPO assesses the hazards presented by the payload supplier and accepts the risks. In the course of these reviews, several areas of SSPO approvals are obtained. The SSPO does not cover payload safety and hazards associated only with payload mission objective achievement so long as the hazards do not affect mission safety for the Shuttle/Payload integrated system.

In carrying out these safety management activities, the payload supplier is accountable, Figure 2-31, to the SSPO for: (1) analysis including safety and hazard analysis and the hazards tracking system, (2) corrective actions that achieve hazard resolutions, (3) documentation for the various analyses, instructions, reports, procedures and etc., (4) conduct hazard reduction verification tests, analyses, demonstrations, and (5) conduct the safety reviews/assessments.

An examination of the responsible payload groups representing: (1) the sources-the Sortie Lab, the Spacecraft/Satellite, the Space Tug, Propulsive Stages, Flight Support Equipment and the Experiments and sensors (2) the handlers - the payload packager, the payload integrator, the payload refurbisher, and (3) the major payload sponsors such as NASA centers, DOD and etc, points up the variety of payload safety interested parties. Some aspects of payloads safety are treated early in the mission genesis - design solutions, others are confirmed or demonstrated in tests at various development and packaging/integration stages. It therefore is not readily evident that a single payload

FIGURE 2-29

41410

TOTAL SHUTTLE PAYLOADS SAFETY RESPONSIBILITY

SAFETY MANAGEMENT	MISSION PHASE	PAYLOAD TOTAL SAFETY PROVISION FOR: SHUTTLE SAFETY INTACT CREW, ORBITER & PAYLOAD	PAYLOAD SAFETY MISSION SUCCESS	INDUSTRIAL SAFETY	PUBLIC SAFETY
SPACE SHUTTLE PROGRAM OFFICE HAZARDS ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	PAYLOAD ELEMENT DESIGN AND DEVELOPMENT	X	X	X	
	PAYLOAD PACKAGING	X	X	X	
	PAYLOAD FERRY FLIGHT		X	X	X
LAUNCH PROGRAM OFFICE: HAZARD ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	PAYLOAD PACKAGING	X	X	X	
	PAYLOAD FINAL INTEGRATION AND CHECKOUT	X	X	X	
	PAYLOAD LOADING	X	X	X	
	SHUTTLE LOADING	X	X	X	
	SHUTTLE MATE	X	X	X	
	SHUTTLE TRANSPORT	X	X	X	
	LAUNCH PAD LOAD AND CHECKOUT	X	X	X	
	PAYLOAD CHANGEOUT	X	X	X	
SPACE SHUTTLE PROGRAM OFFICE: HAZARDS ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	LAUNCH	X	X		X
	ORBIT OPERATIONS	X	X		X
	RETRIEVAL	X	X		X
	DEORBIT	X	X		X
	PAYLOAD UNLOAD	X	X		
	PAYLOAD DISASSEMBLY		X	X	
	PAYLOAD MAINTENANCE AND REFURBISHMENT	X	X	X	

FIGURE 2-30

41409

SHUTTLE SAFETY MANAGEMENT FOR PAYLOADS

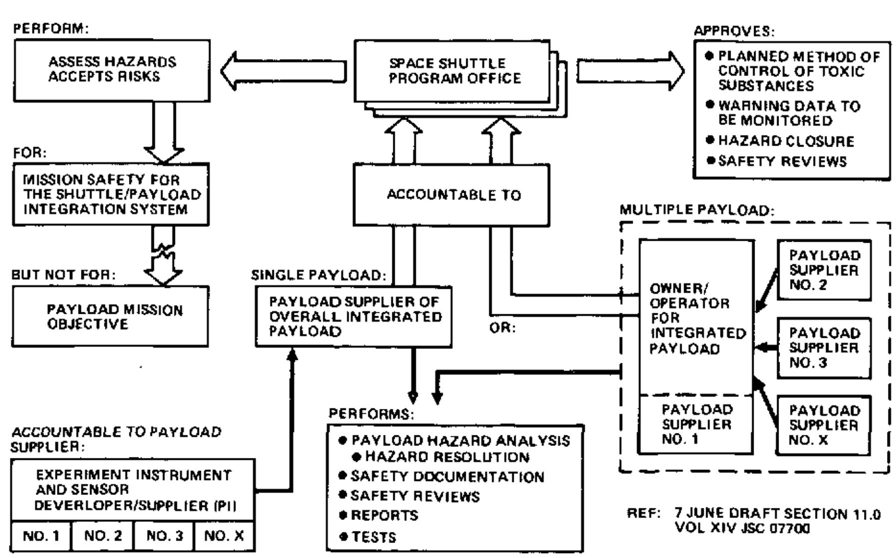


FIGURE 2-31

41408

PAYLOAD ACCOUNTABILITY TO THE SHUTTLE PROGRAM

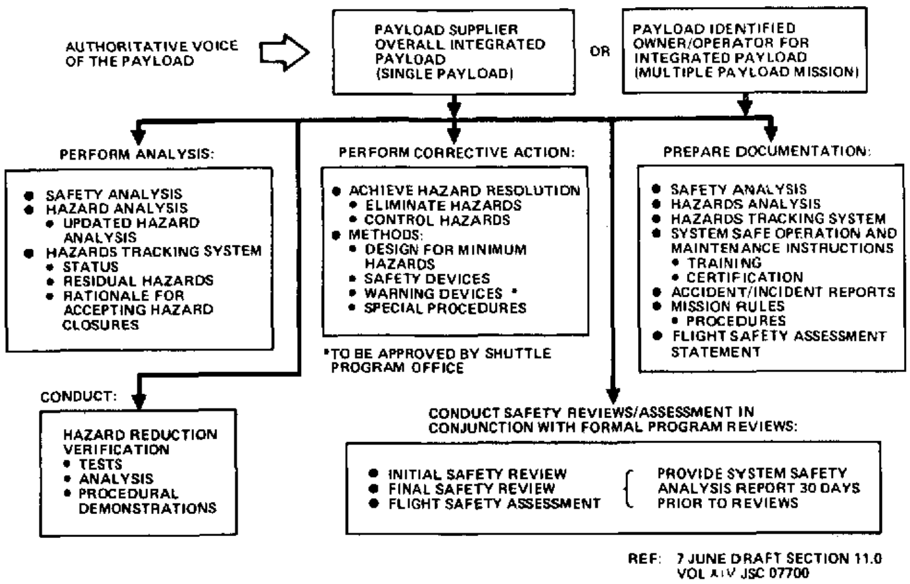
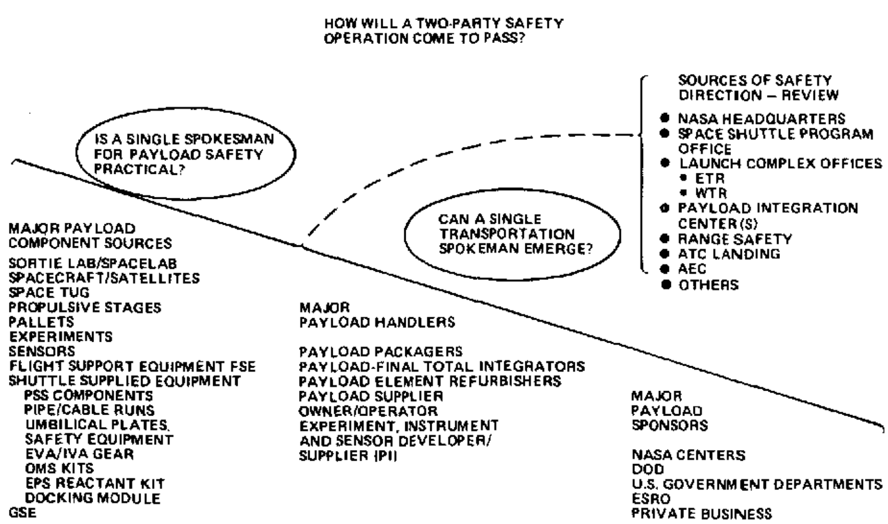


FIGURE 2-32

41411

SAFETY MANAGEMENT INVOLVEMENTS



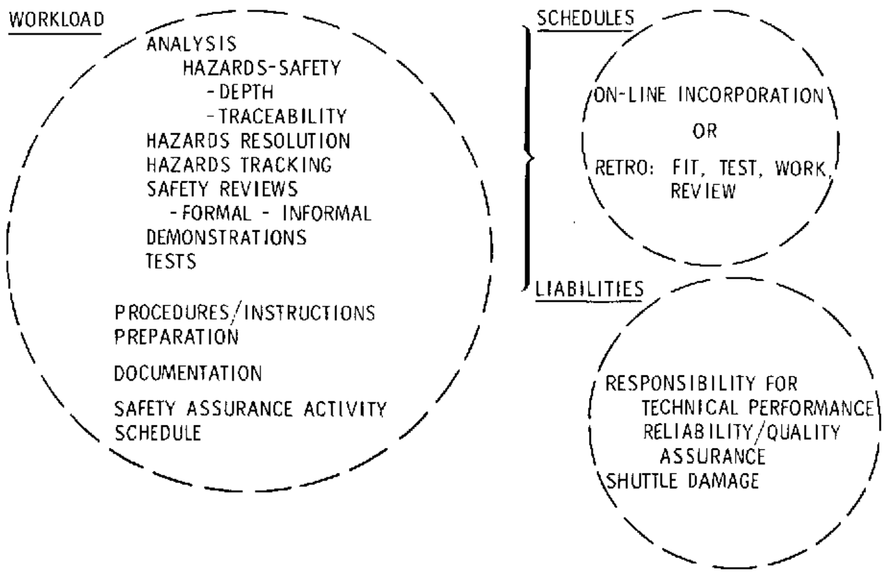
spokesman on safety can be practical. The uncertainty of a single spokesman for payload safety opens up the question of whether also a single spokesman can be assured for the Space Transportation System, Figure 2-32. The possible sources of safety direction and payload safety review may be eventually focused into one authority so that the draft criteria objective of a two-party safety operation could be realized. At present, the scope of the draft criteria as generalized previously in Figure 2-29 does not appear to cover the total safety needs. When total payload effectiveness and liability are considered as well as payload costs in procedures, documentation and time, payload safety can become a significant management problem as suggested in Table 2-33 for only the Shuttle related safety. The payload safety workload is appreciable in the analysis, resolutions, reviews and demonstrations even when it is accomplished "on-line." If redo or retro work is involved, especially where some sources of safety direction only become active later in the flight readiness schedule, work and schedule impacts become serious. Likewise, documentation and liabilities will influence safety costs particularly for missions that involve several major payload components as suggested in Figure 2-32.

The draft safety criteria includes specific design criteria items as well as the safety management criteria just discussed. These design criteria are subject to ongoing coordination changes; however, they can be generalized into three areas as follows and as outlined in Table 2-34. Certain criteria appear to exceed Shuttle features. This greater level of payload safety in itself may not be undesirable especially considering the isolated in-payload bay conditions. However, some criteria can impact Shuttle interfaces such as the caution and warning audible signal or the need for a payload dedicated ground return wire where the Shuttle uses a structural return. Also where payload safety generates non-productive payload complexities and added costs, the payload sponsor can challenge the need for a possible two-class safety arrangement, Shuttle class and Payload class.

TABLE 2-33

41371

PAYLOAD SAFETY ASSURANCE TASKS IMPACTS



AUG 73

TABLE 2-34

TABLE 2-34 SHUTTLE PAYLOAD SAFETY CRITERIA

CRITERIA MAY EXCEED SHUTTLE FEATURES	SHUTTLE SPECIFIED
PAYLOAD CAUTION AND WARNING	
– DETACHED PAYLOAD ACTIVE	SILENT
– AUDIBLE SIGNAL	LIGHT MATRIX
PAYLOAD JETTISON	SILENT – ABORT LANDING WITH PAYLOAD
AUTOMATIC PRESSURE LIMITS – PAYLOAD TANKS	SILENT
REDUNDANT FLUID LINES – WIRING	PARTIAL
UMBILICAL ELECTRICAL	
– SEPARATION FROM FLUIDS	PARTIAL
– DEDICATED GROUND WIRE	NO
NOISE LEVEL 72.5 DB	145 DB OASPL
VENT PAYLOAD FLUIDS	UNRESTRICTED VENT UNCLEAR
REMOTE PROPELLANT PRESSURIZATION	SILENT – SHUTTLE HAS ACTIVE RCS AND OMS

SCOPE OF CRITERIA UNCLEAR

SHUTTLE SAFETY OBJECTIVES:	CRITERIA STATES:
ABILITY TO SUCCESSFULLY TERMINATE MISSION	SILENT
– INTACT CREW	INFERRED
– INTACT SHUTTLE	SILENT
– INTACT PAYLOAD	SILENT
REUSABLE SHUTTLE	SILENT
OPERATIONS SAFETY	PARTIAL
ASSOCIATED FUNCTIONS/ELEMENTS:	
GROUND SAFETY	PARTIAL
INDUSTRIAL SAFETY	SILENT
POPULATION SAFETY	SILENT
PROPERTY SAFETY	SILENT

PERFORMANCE POSSIBLY EXCEEDS SHUTTLE SAFETY NEEDS

PAYLOAD:	COMMENT
FAIL SAFE	BASIC PAYLOAD REQUIREMENT FOR SHUTTLE SAFETY
FAIL OPERATIONAL/ FAIL SAFE	WHEN DOES PAYLOAD RESIDUAL OPERATIONAL CONDITION RELATE TO SHUTTLE SAFETY?
FAIL SAFE/FAIL SAFE	SPECIFIC SOLUTIONS RATHER THAN GENERAL

JETTISON PAYLOAD (PAYLOAD IS BASICALLY SAFE)
REMOTE PROPELLANT PRESSURIZATION
MICRO-BIOLOGICAL EXPERIMENTS

SELF SAFING	NOT COVERED

Another group of criteria appear to require payload safety performance in excess of the Shuttle needs: the needs in the sense of payload hazard to Shuttle successful mission termination, Table 2-34. A "fail safe" payload appears to satisfy the basic requirement of the Shuttle on the payload. A higher level of payload safety performance such as fail operational/fail safe (draft paragraph 11.2.2.3a) or even fail safe/fail safe would appear to not enhance the Shuttle's capability to successful mission termination. Payload fail operational/fail safe features appear to be outside of the Shuttle safety area of formal concern, although the payload feature may be desired by NASA or others for other performance/assurance reasons. Likewise payload fail safe/fail safe appears to go beyond Shuttle formal concerns. A fail safe payload that is required to be jettisoned is being jettisoned for reasons other than payload hazards to the Shuttle arising from a payload— initiated hazard. The fail safe/fail safe concept is so broad that unproductive payload safety effort may be involved, hence a workable arrangement would be where specific fail safe/fail safe features are only levied on the payload; for example, a double-walled sealed pressure vessel to contain micro-biological experiments while in the Orbiter.

A third area is the uncertainty in scope of the criteria, Table 2-34. Shuttle safety objectives are documented in Shuttle specifications, a one-for-one correlation with the draft criteria is missing. Also other areas of mission safety are not covered in the draft design criteria.

It is improper to be conclusive about the draft criteria and their payload impacts except to observe that payload safety management is important and deserves close attention. Likewise design and operations criteria are important and warrant early refinements. Additional discussion of this analysis appears in Appendix G.

ERRATA NOTE: The Safety portion of this report includes MDAC interpretations of the NASA safety requirements contained in an early draft version of Section 11, Vol. XIV, JSC 07700, and does not necessarily reflect the NASA position. Subsequent to the analysis in this section, the JSC Safety Office has advised that Shuttle safety criteria have been extensively revised. The latest NASA documents should be consulted for the current safety criteria.

Section 3
SUPPORTING RESEARCH AND TECHNOLOGY (SRT)

The SRT requirements describe the supporting work that must be accomplished in order to preclude a relatively high degree of performance or development risk at the onset of Phase D development. The SOAR-IIS study was limited in scope to specific tasks or analyses based on the select spacecraft and missions described in the Section 2, Summary. These analyses resulted in no new SRT items being identified. However, for reference three items were identified and described in detail in the SOAR-II final report MDC G4480 (April 1973), Volume X, Section 5, that are still considered applicable to the general areas of Shuttle payloads. These items are:

A. A contact heat exchanger to transfer heat from the payload to the Orbiter radiator system.
B. Spacecraft and propulsive stage pressure vessel rupture bay and warning device to provide early warning of impending failure.
C. Spacecraft and propulsive stage pressure vessels that do not produce shrapnel upon rupture.

Eight other applicable items were described in a similar manner in the earlier SOAR-I final report MDC G-2546 (December 1971), Volume VIII, Book III, Section 5. These items are:

A. An image enhancement device to improve image quality electronically.
B. A high-density tape recording to handle missions involving high data rate sensors.
C. A voice recognition interface with a computer controlled system to simplify man-machine interfaces.
D. A high-density tape information retrieval and storage read/write head.
E. An IMS storage address capability for displays and controls to improve data accessibility from storage.

F. Spacecraft man-machine servicing manipulator or other system to perform on-orbit maintenance and repair operations.

G. Contamination analyses to determine contaminant sources and sensors development to detect leakage, gases, etc.

H. A dynamics analysis for Shuttle mounted experiments requiring fine pointing.

Appendix A

PAYLOAD OPERATIONS ANALYSIS: PAD VS VAB INSTALLATION

The payload operations analyzed in the study involved the payload-to-Orbiter installation operations including physical installation/removal and functional integration for each of the four payload classes defined for analysis in the study.

The overall study objective of the payload operations analysis was to identify a preferred approach for payload installation into the Shuttle Orbiter payload bay. The two installation approaches considered in the study were:

A. Horizontal installation at the Maintenance and Checkout Facility (MCF). The Shuttle Program has currently baselined this installation mode.

B. Vertical installation at the launch pad. The Shuttle Program currently utilizes this installation mode for contingency on-pad payload change-out only.

Selection of the preferred installation method was based on the following approach:

- o Review the baseline Shuttle ground operations.
- o Determine the integration functions for each payload class.
- o Develop integration flows and timelines for each payload class and each integration method (horizontal and vertical) to identify impacts to the Orbiter turnaround time constraints and benefits to payloads resulting from the integration mode.
- o Determine the influence of Orbiter orientation and location for each payload class.
- o Review the ground reviewing and checkout requirements for each payload class.

The current Shuttle ground processing flow, presented in Figure A-1, baselines horizontal payload/orbiter integration at the MCF. The significant elements in the baseline flow which influences horizontal integration operations are as follows:

FIGURE A-1

STS GROUND PROCESSING BASELINE *

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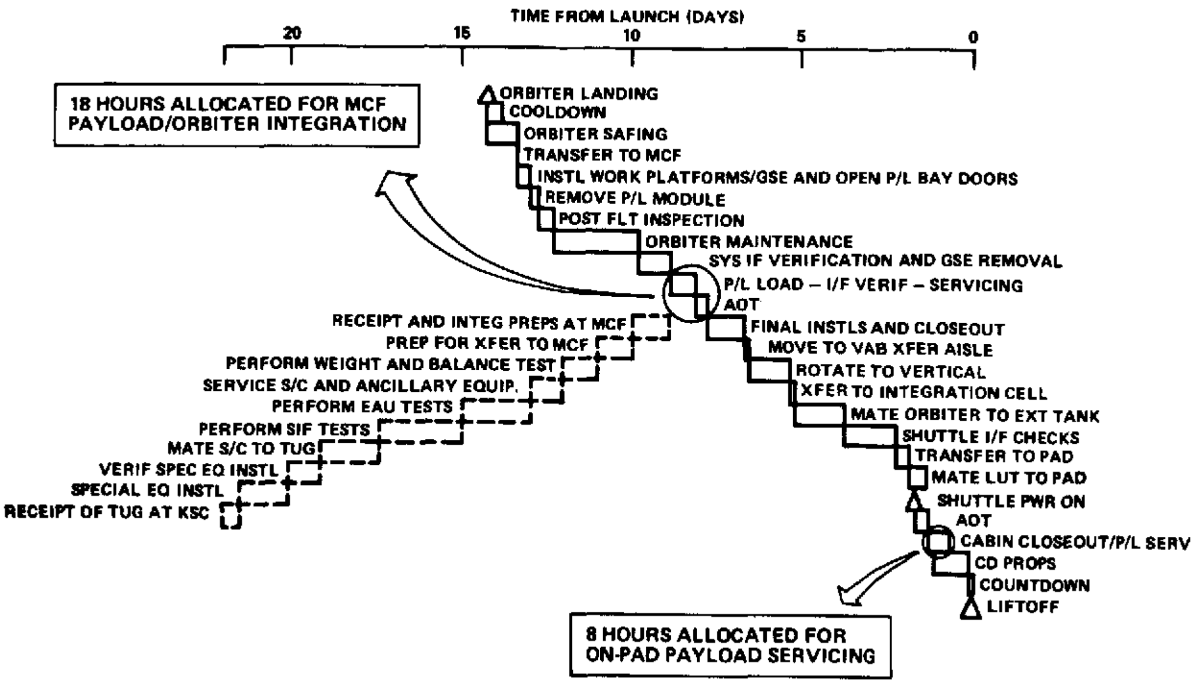


*KSC SHUTTLE OPERATIONS PLANNING OFFICE, MARCH 6, 1973, SOAR II VOLUME V, OPERATIONS

A. The Orbiter turnaround time is constrained to 231 working hours.

B. Eighteen hours are allocated for payload/Orbiter integration and interface verification at the MCF.

C. Integration operations must be completed 125 working hours prior to launch.

D. Eight hours are allocated for payload servicing at the launch pad.

E. The payload must be processed through the launch site facilities described below.

A.1 PSA (PAYLOAD SERVICE AREA)

This general group of payload facilities provides for all payload operations required prior to payload/Orbiter integration. Typical payload operations which occur at this facility are:

A. Recieving and inspection

B. Final spacecraft integration and checkout

C. Ancillary equipment integration

D. Structural Interface Fixture checks

E. Electronic Analog Unit Checks

F. Service Loading

G. Spacecraft/Upper stage mating

A.2 MCF (MAINTENANCE AND CHECKOUT FACILITY)

In addition to Orbiter maintenance / checkout operations, payload installation into and removal from the Orbiter payload bay occurs at this facility with the Orbiter in the horizontal position.

A.3 VAB (VERTICAL ASSEMBLY BUILDING)

This facility provides for rotation of the Orbiter (and its integrated payload) to the vertical position for final integration with the external tank and SRM's and checkout prior to transport to the launch area on the Shuttle mobile launch platform.

A.4 PAD (LAUNCH AREA)

This facility provides the final launch operations facilities for cryogenic loading, final payload servicing (if required), crew boarding, and launch checkout and countdown.

A.5 PAYLOAD INTEGRATION FUNCTIONS/FLOWS/TIMELINES

In order to successfully integrate each payload class with the Shuttle Orbiter certain payload class peculiar integration functions must be performed. These integration functions include those required by the payload itself as well as its respective flight support equipment and associated software.

A key driver in the development of these integration functions is the level of cleanliness which is required by the payload and which must be maintained during integration and post-integration operations. Of the four classes of payloads, two (EOS-Class I and LST-Class III) require specified particulate cleanliness levels of 10,000 class or better. (It was assumed that the Sortie Lab requires a particulate cleanliness level of 100,000 class and that its pallet-mounted experiments employ localized contamination control if levels better than 100,000 class are required.) Additionally, the LST (Class III) requires a specified relative humididty level of $\leq 35\%$.

Since the MCF is assumed to provide a 100,000 class particulate cleanliness level and a relative humidity level of $\leq 50\%$, and because of relatively large payload physical dimensions, it was further assumed that the EOS and LST would both require a flight environmental shroud which is installed on the payload in the Payload Service Area (PSA) prior to transportation of the payload to the MCF for integration in the Orbiter. The EOS and LST are thus both integrated with their respective shrouds attached and required installation functions and interfaces for the Class I and III payloads are necessarily similar.

For the above reasons, the Class I and III payloads were logically grouped in order to develop their installation integration functions.

Another feature which influences the payload integration operations is the interfaces required by the payload during the integration process. A survey of each payload class was made utilizing information developed in the SOAR II and the DOD STS Payload Interface studies and the required payload interfaces which were identified are tabulated in Table A-1.

A.6 HORIZONTAL INTEGRATION

In developing the integration flows and timelines for horizontal integration, it was assumed that the MCF eighteen hour allocation does not include operations involved in opening and closing the payload bay doors and that this period is dedicated solely to the payload installation and integration operations. This assumption has significant bearing on the amount of time available to perform the integration operations since in the horizontal position, a total of eight hours are required to open and close the doors as illustrated in Figure A-2.

The functional flows and timelines developed for each payload class generally follow the integration scenario presented in Figure A-3 are shown in Figures A-4 through A-9.

Development of the functional flows revealed that each payload class had, as might be expected, its own unique flight support equipment and installation integration functions. Examples of these unique characteristics are presented in Table A-2.

TABLE A-1

	MCF PAYLOAD/ORBITER INTEGRATION																				
	CLASS I			CLASS II									CLASS III			CLASS IV			TUG		
	EOS			SMS			DSCS II			ATS			LST			SORTIE			TUG		
	MCF	XPORT	PAD	MCF	XPORT	PAD	MCF	XPORT	PAD	MCF	XPORT	PAD	MCF	XPORT	PAD	MCF	XPORT	PAD	MCF	XPORT	PAD
DATA PROCESSING CONSOLE	X		X	X		X	X		X	X		X	X		X	X		X	X		X
TIM & CMD CONSOLE	X		X	X		X	X		X	X		X	X		X	X		X	X		X
COMMUNICATIONS CONSOLE	X		X	X		X	X		X	X		X	X		X	X		X	X		X
CONTROL CONSOLE	X		X	X		X	X		X	X		X	X		X	X		X	X		X
BATTERY CHARGING UNIT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
ORDNANCE TEST SET	X		X	X		X	X		X	X		X							X		X
SHROUD ENVIRONMENT CONDITIONING UNIT	X	X	X										X	X	X						
SHROUD ENVIRONMENT MONITORING UNIT	X	X	X										X	X	X						
GN_2 FILL			X			X			X			X			X						X
VENT			X			X			X			X			X						X
GH_2 FILL																					X
VENT																					X
GO_2 FILL																					X
VENT																					X
LH_2 FILL																		X			X
DUMP																		X			X
LO_2 FILL																		X			X
DUMP																		X			X
N_2H_4 FILL																					
DUMP			X			X			X			X									
GHE FILL																		X			X
VENT																		X			X
PAYLOAD/ORBITER/GSE UMBILICAL FUNCTION																					
POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X
COMMUNICATIONS & DATA HANDLING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X
ORDNANCE	X		X	X		X	X		X	X		X									X
ATTITUDE CONTROL	X		X	X		X	X		X	X		X	X		X						X
SEPARATION/DEPLOY	X		X	X		X	X		X	X		X	X		X				X		X
OTHER	X		X	X		X	X		X	X		X	X		X	X		X	X		X

	ON-PAD PAYLOAD/ORBITER INTEGRATION													
	CLASS I		CLASS II						CLASS III		CLASS IV		TUG	
	EOS		SMS		DSCS II		ATS		LST		SORTIE		TUG	
	XPORT	PAD	XPORT	PAD	XPORT	PAD	XPORT	PAD	XPORT	PAD	XPORT	PAD	XPORT	PAD
DATA PROCESSING CONSOLE		X		X		X		X		X		X		X
TIM & CMD CONSOLE		X		X		X		X		X		X		X
COMMUNICATIONS CONSOLE		X		X		X		X		X		X		X
CONTROL CONSOLE		X		X		X		X		X		X		X
BATTERY CHARGING UNIT	X	X	X	X	X	X	X	X	X	X				
ORDNANCE TEST SET		X		X		X		X						X
SHROUD ENVIRONMENT CONDITIONING UNIT	X	X							X	X				
SHROUD ENVIRONMENT MONITORING UNIT	X	X							X	X				
GN_2 FILL		X		X		X		X		X				X
VENT		X		X		X		X		X				X
GH_2 FILL														X
VENT														X
GO_2 FILL														X
VENT														X
LH_2 FILL												X		X
DUMP												X		X
LO_2 FILL												X		X
DUMP												X		X
N_2H_4 FILL														
DUMP		X		X		X		X						
GHE FILL												X		X
VENT												X		X
PAYLOAD/ORBITER/GSE UMBILICAL FUNCTION														
POWER	X	X	X	X	X	X	X	X	X	X		X		X
COMMUNICATIONS & DATA HANDLING	X	X	X	X	X	X	X	X	X	X		X		X
ORDNANCE		X		X		X		X						X
ATTITUDE CONTROL		X		X		X		X		X				X
SEPARATION/DEPLOY		X		X		X		X		X				X
OTHER		X		X		X		X		X				X

FIGURE A-2

ORBITER PAYLOAD BAY DOOR OPERATIONS (HORIZONTAL)*

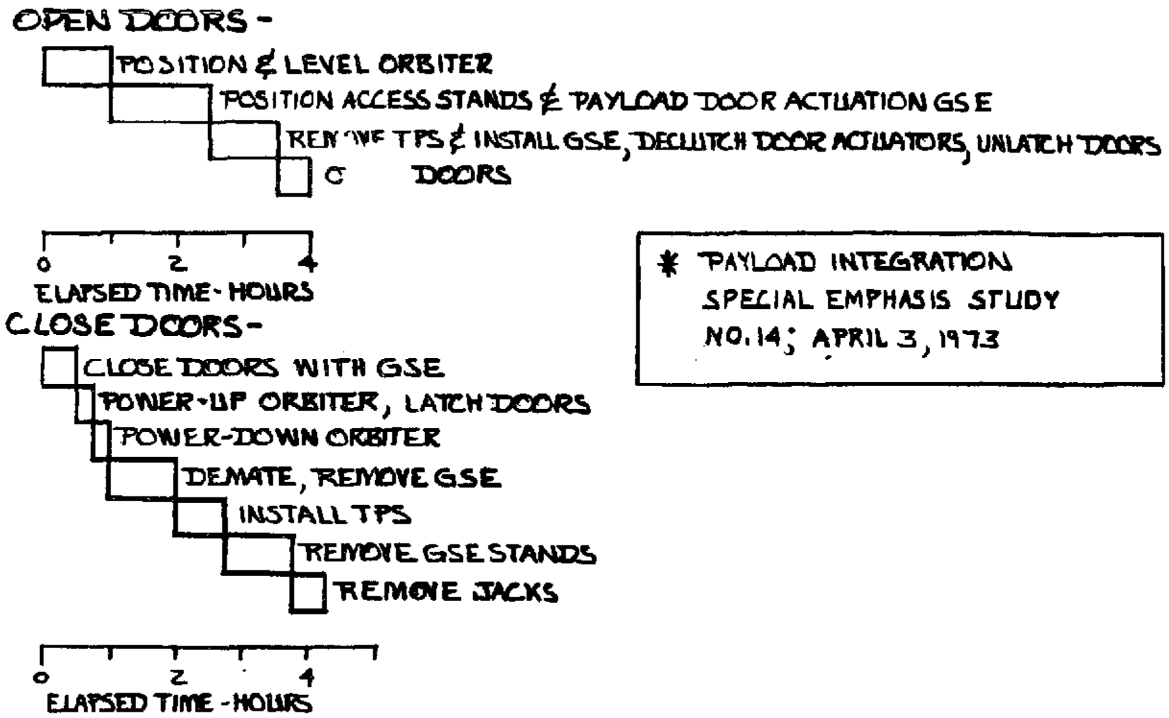


FIGURE A-3 40296

MCF PAYLOAD/ORBITER INTEGRATION OPERATIONS

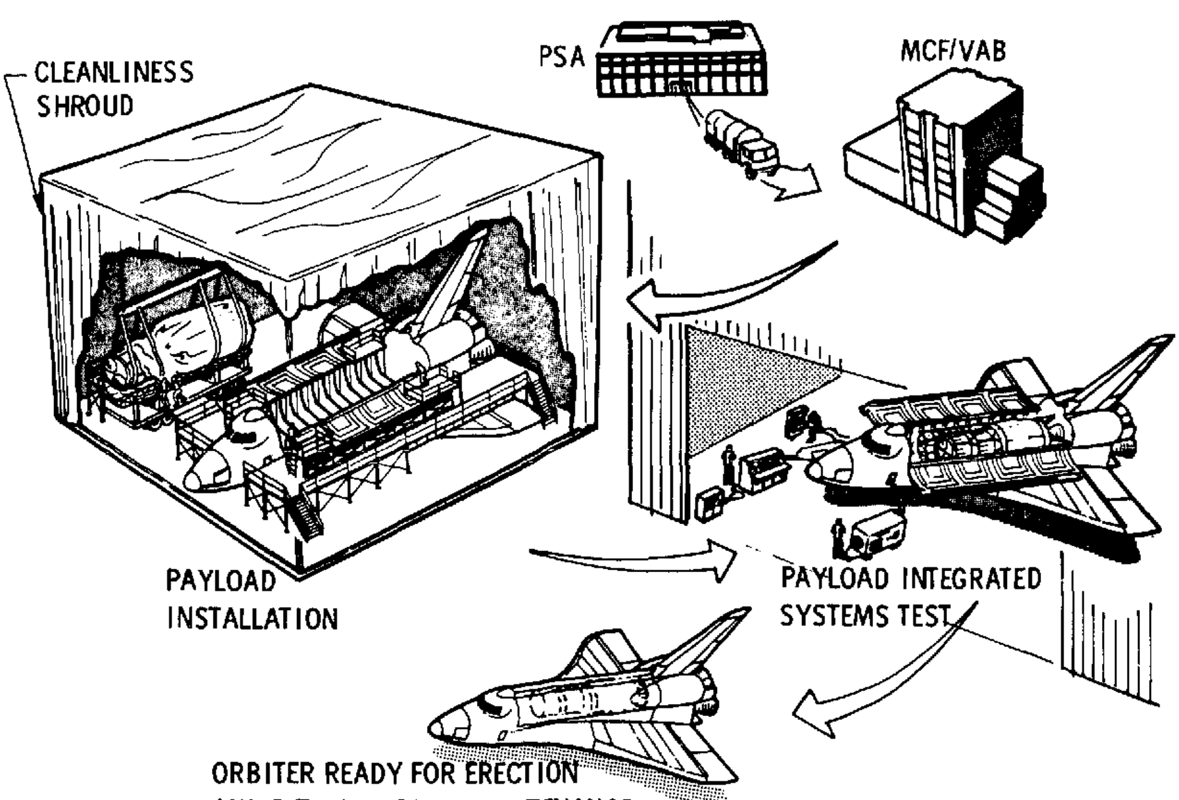


TABLE A-2

PAYLOAD CLASS	UNIQUE EQUIPMENT
I & III	• Shroud support beam • Shroud/cradle
II	• Aft bulkhead Tug support fitting • Tug LOX abort dump line • Support beam/cradle
IV	• Docking Module

FIGURE A-4

CLASS I & III PAYLOAD/ORBITER INTEGRATION TIMELINE

HORIZONTAL IN THE MCF

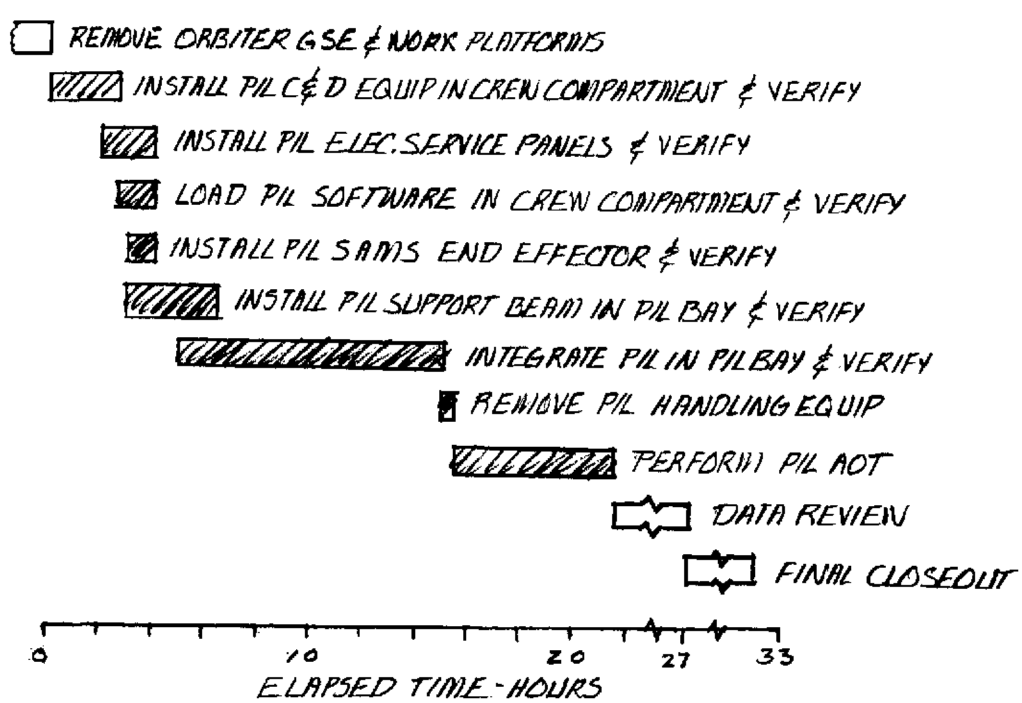


FIGURE A-5

CLASS I & III PAYLOAD/ORBITER INTEGRATION FUNCTIONAL FLOW HORIZONTAL IN THE MCF

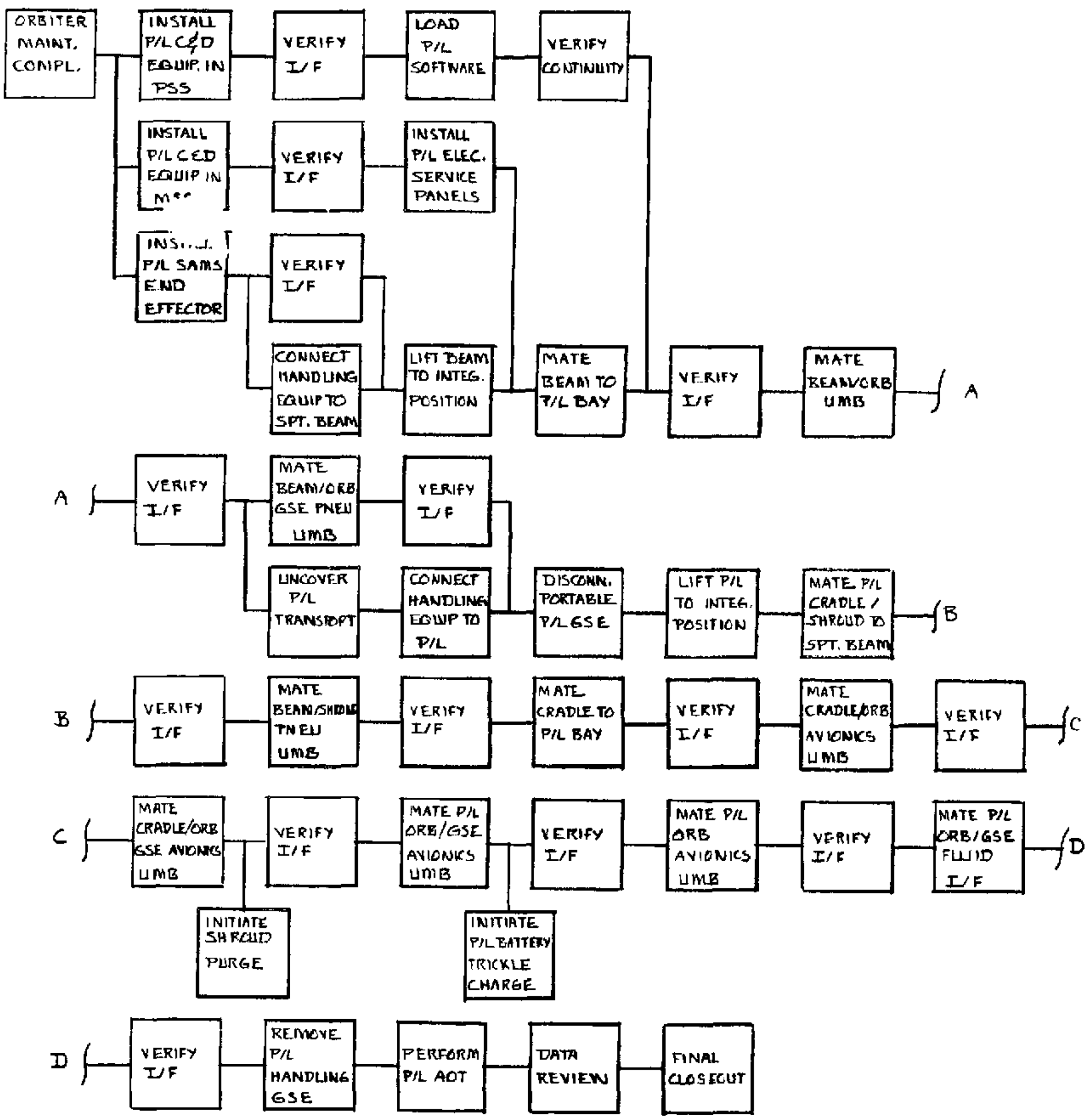
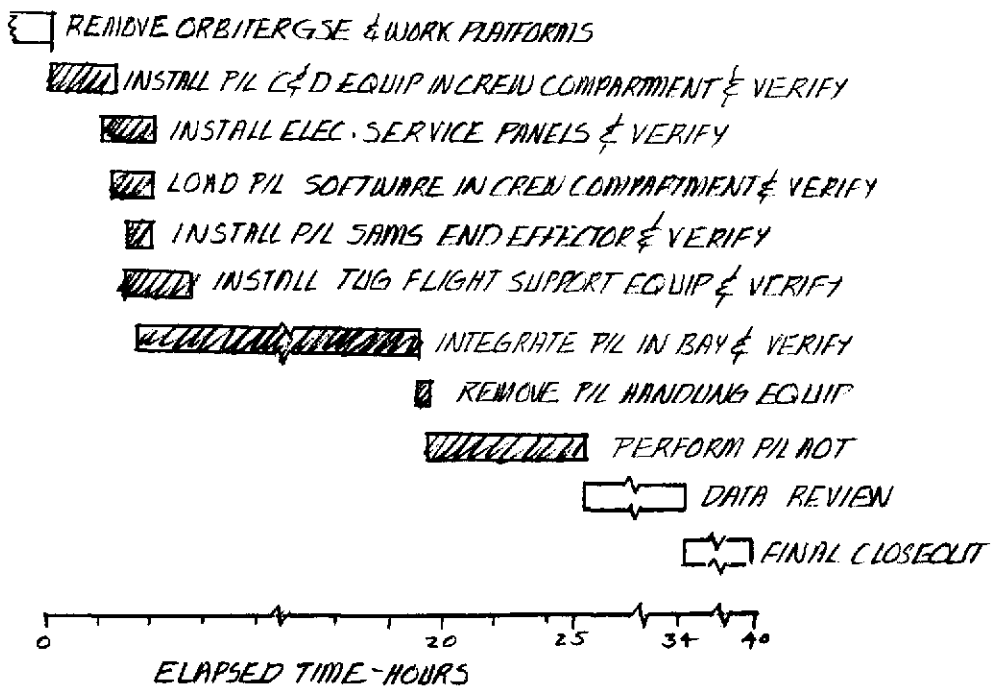


FIGURE A-6

CLASS II PAYLOAD/ORBITER INTEGRATION TIMELINE
HORIZONTAL IN THE MCF



Additionally, each payload class exhibits certain common integration functional characteristics such as

A. Installation of payload peculiar control and display equipment at the Orbiter crew compartment Payload Specialist Station (PSS) and Mission Specialist Station (MSS).

B. Installation of payload peculiar Shuttle Attached Manipulator Systems (SAMS) end effectors.

C. Installation of payload peculiar SAMS manipulation software programs.

D. Performance of a five hour post integration payload Avionics Operational Test (AOT).

Although each payload class requires both unique and varied as well as common integration equipment and functions, timelines of each payload functional flow revealed that payload/Orbiter integration time and functional requirements are essentially independent of payload class. For the payloads analyzed, between 22 hours and 26 hours are required to perform the following typical integration functional requirements:

FIGURE A-7

CLASS II PAYLOAD/ORBITER INTEGRATION FUNCTIONAL FLOW HORIZONTAL IN THE MCF

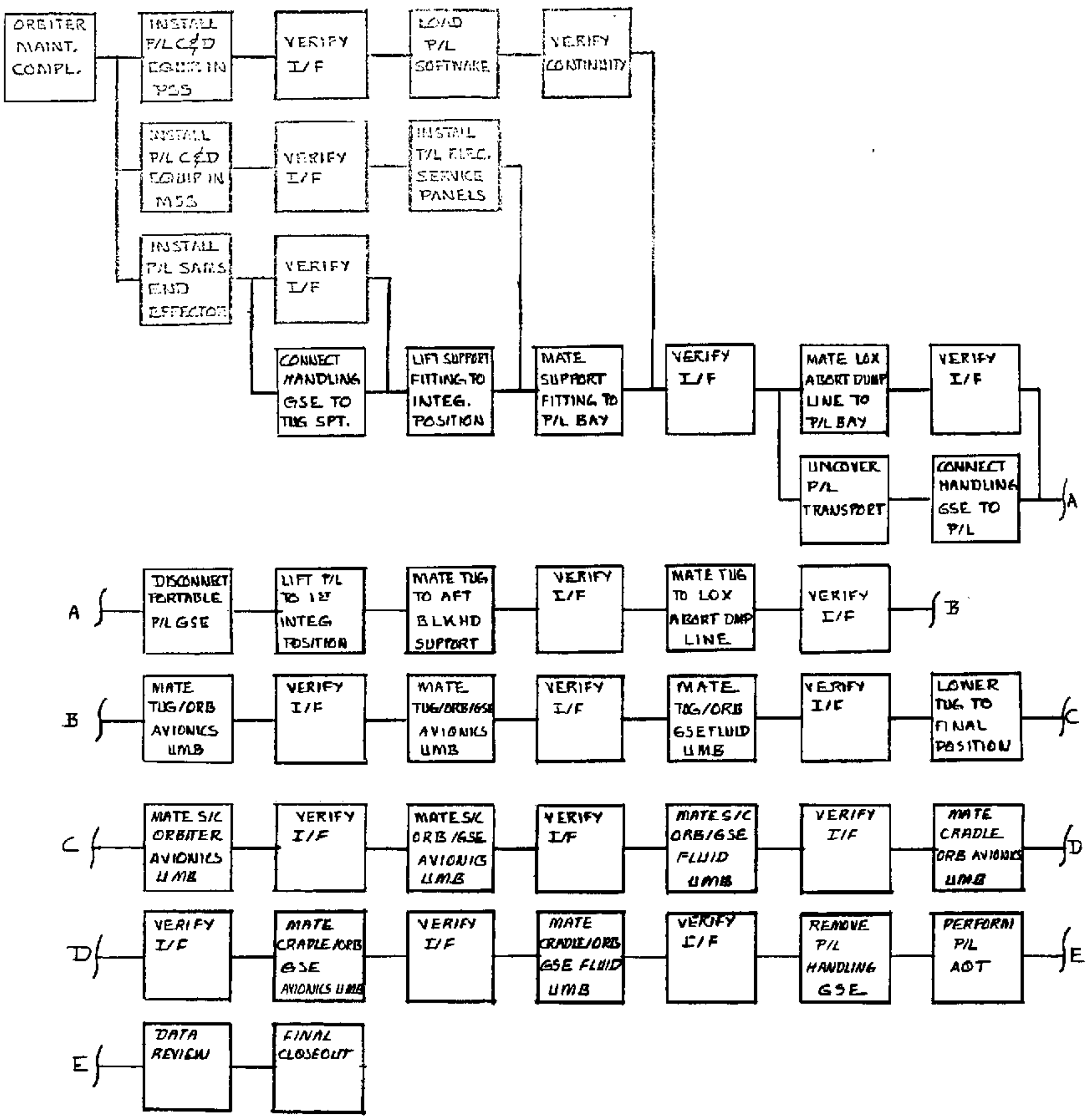
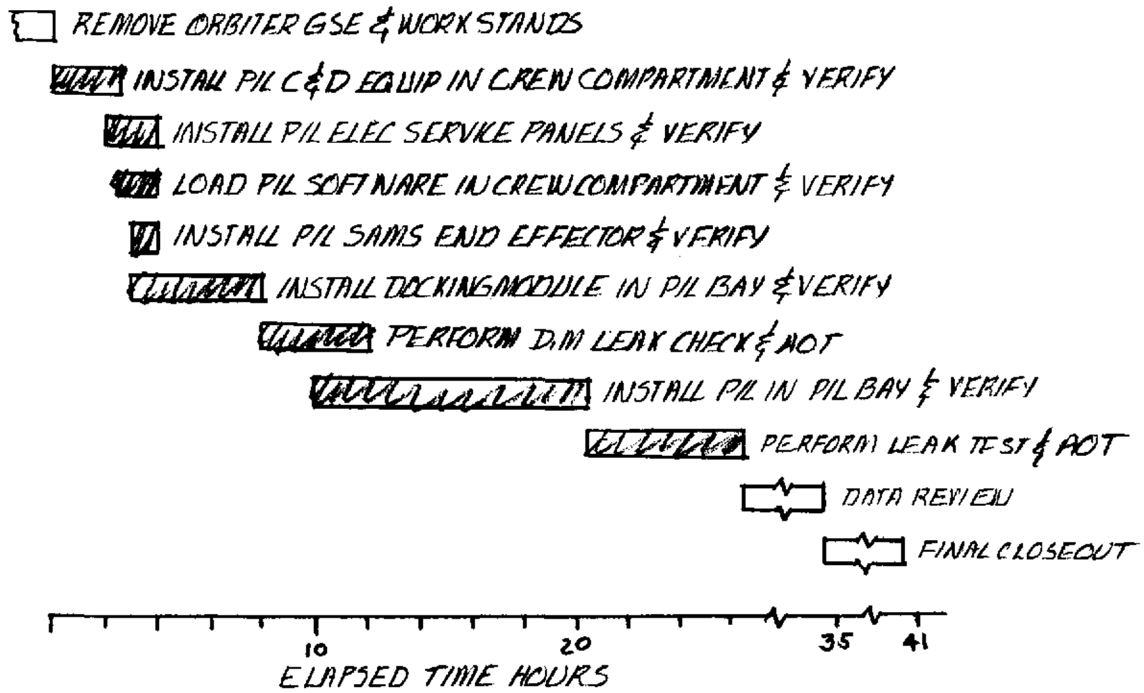


FIGURE A-8

CLASS IV PAYLOAD/ORBITER INTEGRATION TIMELINE HORIZONTAL IN THE MCF



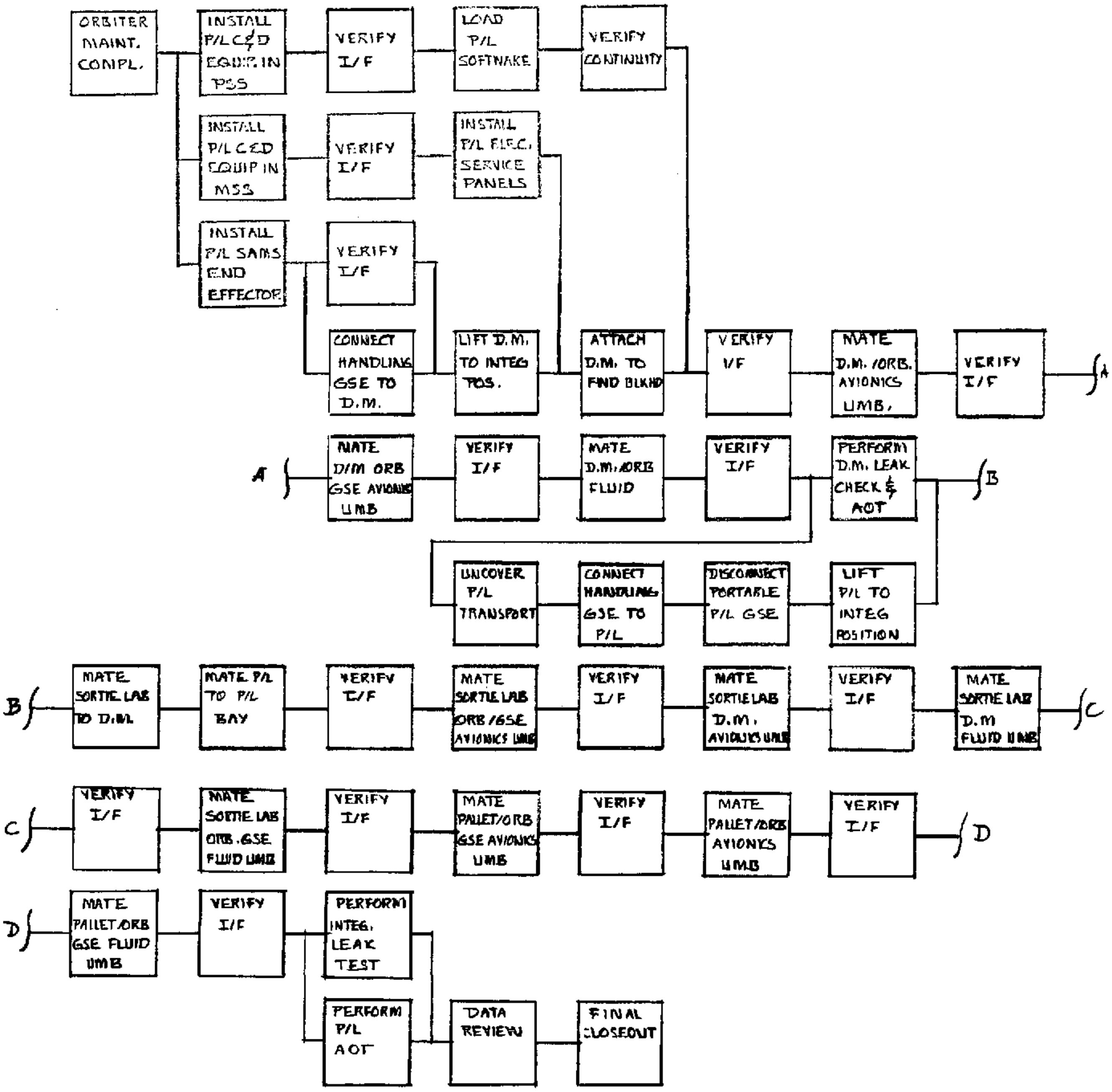
A. Install flight support equipment in P/L bay
   1. FSE/Orbiter avionics umbilicals
   2. FSE/Orbiter/GSE avionics umbilicals
   3. FSE/Orbiter fluid umbilicals
   4. FSE/Orbiter structural mechanical interface

B. Install payload in P/L bay
   1. Payload/Orbiter structural/mechanical interface
   2. Payload/FSE structural/mechanical interface
   3. Payload/FSE fluid umbilicals
   4. Payload/Orbiter avionics umbilicals
   5. Payload/Orbiter/GSE avionics umbilicals
   6. Payload/Orbiter/GSE fluid umbilicals

C. Post installation payload avionics operational test
D. Installation of payload peculiar SAMS end effector
E. Integration of payload C&D equipment in crew compartment
F. Integration of payload software in Orbiter

FIGURE A-9

CLASS IV PAYLOAD/ORBITER INTEGRATION FUNCTIONAL FLOW HORIZONTAL IN THE MCF



The required payload/Orbiter integration time of 22 to 26 hours potentially impacts the baseline 18 hour MCF allocation of 4 to 8 hours. In order to remain within the allocated integration time, it is recommended that because of the nature of the initial and final payload integration functions that, where possible, payload and Orbiter operations be performed in parallel on a non-interference basis.

A.7 VERTICAL INTEGRATION

In developing the integration flows and timelines for vertical integration at the launch pad, it was assumed that the integration process would be performed utilizing standard Shuttle provided payload changeout equipment located at the launch pad as depicted in JSC 07700 Payload Accommodations document. This equipment consists of a rail mounted manipulator capable of maneuvering the payload in three orthogonal planes. This manipulator must also be capable of rotating the payload with respect to the payload bay vertical centerline for Class II payloads in order to accommodate manned access for the connection of Tug flight support equipment.

Additionally, it was assumed that, after the payload is transported to the launch pad from the PSA and installed on the manipulator in the launch pad environmental shelter, an abbreviated five hour payload AOT would be performed. This test serves to verify the functional integrity of payload systems after the major transportation and handling operations required to prepare the payload for integration with the Orbiter.

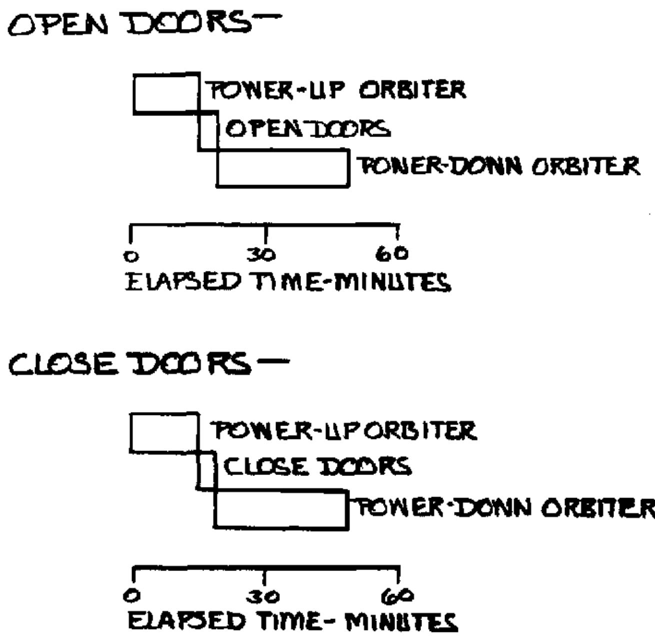
Considerations included in the development of on pad integration functional operations were the requirements to extend, condition, and retract the launch pad environmental enclosure to and from its Orbiter interface. It was assumed that the enclosure exhibits the following characteristics:

Extension time -- 2 hours
Conditioning time -- 1 hour
Retraction time -- 1 hour

An additional consideration was the Orbiter payload bay door operational characteristics while in the vertical position. These characteristics are illustrated in Figure A-10.

FIGURE A-10

ORBITER PAYLOAD BAY DOOR OPERATIONS (VERTICAL)*



* PAYLOAD INTEGRATION SPECIAL EMPHASIS STUDY NO. 14; APRIL 3, 1973

The functional flows and timelines developed for each payload class generally follow the scenario presented in Figure A-11 and are shown in Figures A-12 through A-17. It was assumed that for on pad payload integration that all required payload flight support equipment had been previously installed in the orbiter payload bay and that at the launch pad, the Orbiter completely ready to accept the payload.

As in the case of horizontal integration at the MCF, development of integration functional flows revealed that payload/Orbiter integration time and functional requirements are essentially independent of payload class and requires between 24 hours and 26 hours of on pad operations. Of this time, between 12 and 14 hours of Orbiter payload bay access is required to install payload in P/L bay.

A. Payload/Orbiter structural/mechanical interface
B. Payload/FSE structural/mechanical interface
C. Payload/FSE fluid umbilicals
D. Payload/Orbiter avionics umbilicals

FIGURE A-11

40297

ON-PAD PAYLOAD/ORBITER INTEGRATION OPERATIONS

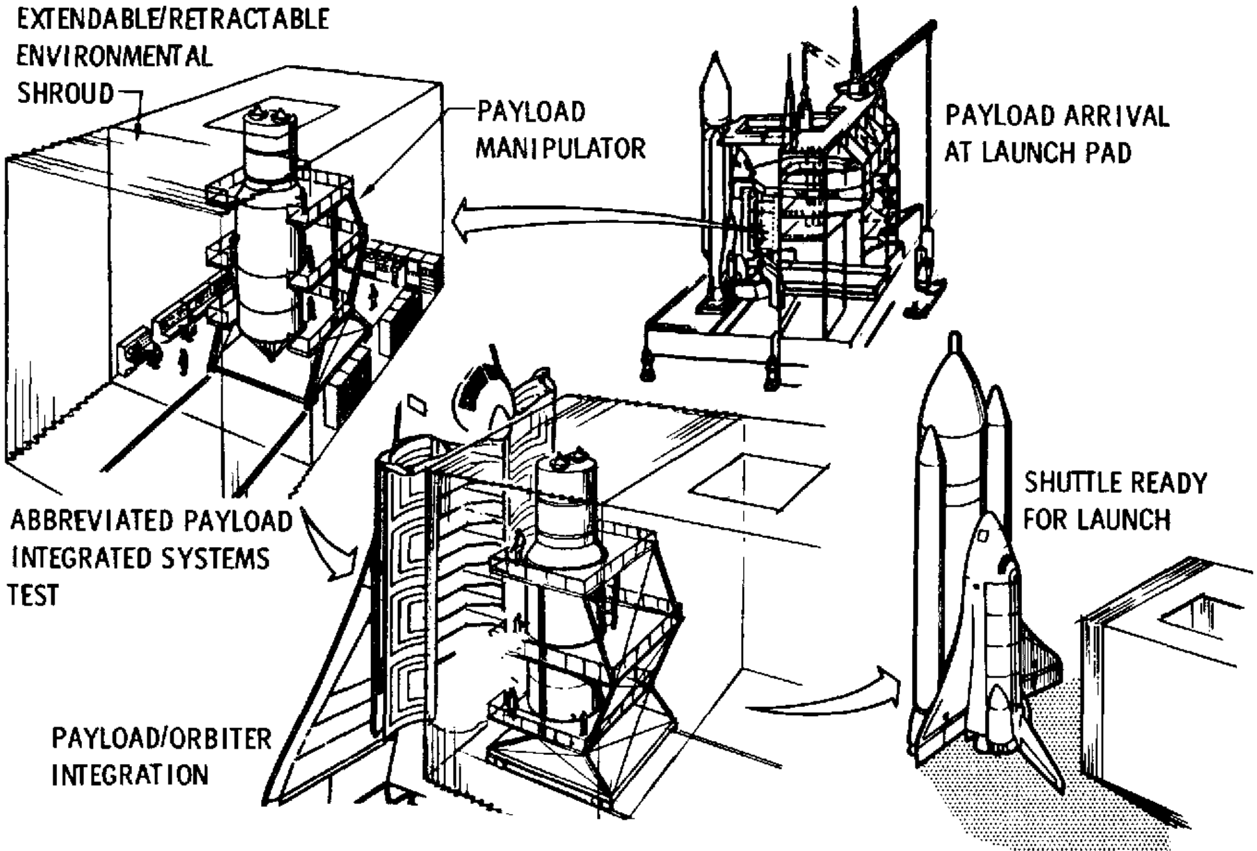


FIGURE A-12

CLASS I & III PAYLOAD/ORBITER INTEGRATION FLOW VERTICAL ON LAUNCH PAD

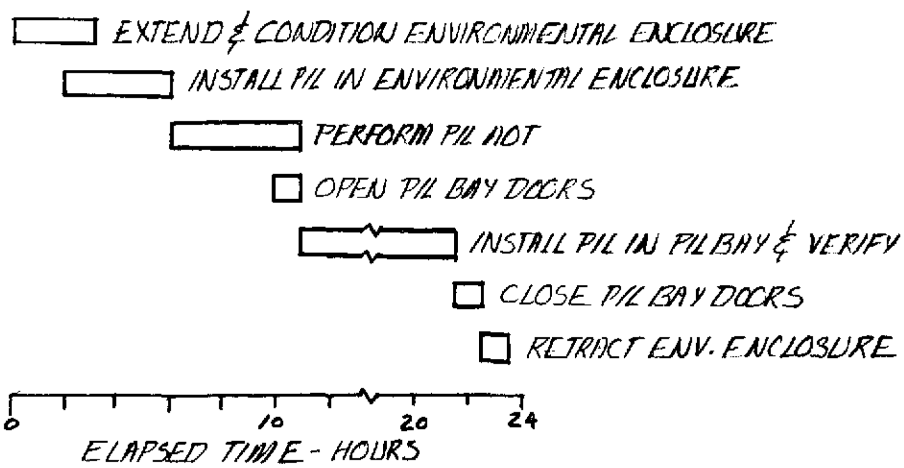


FIGURE A-13

ALTERNATE ON-PAD CLASS IV PAYLOAD/ORBITER INTEGRATION FLOW

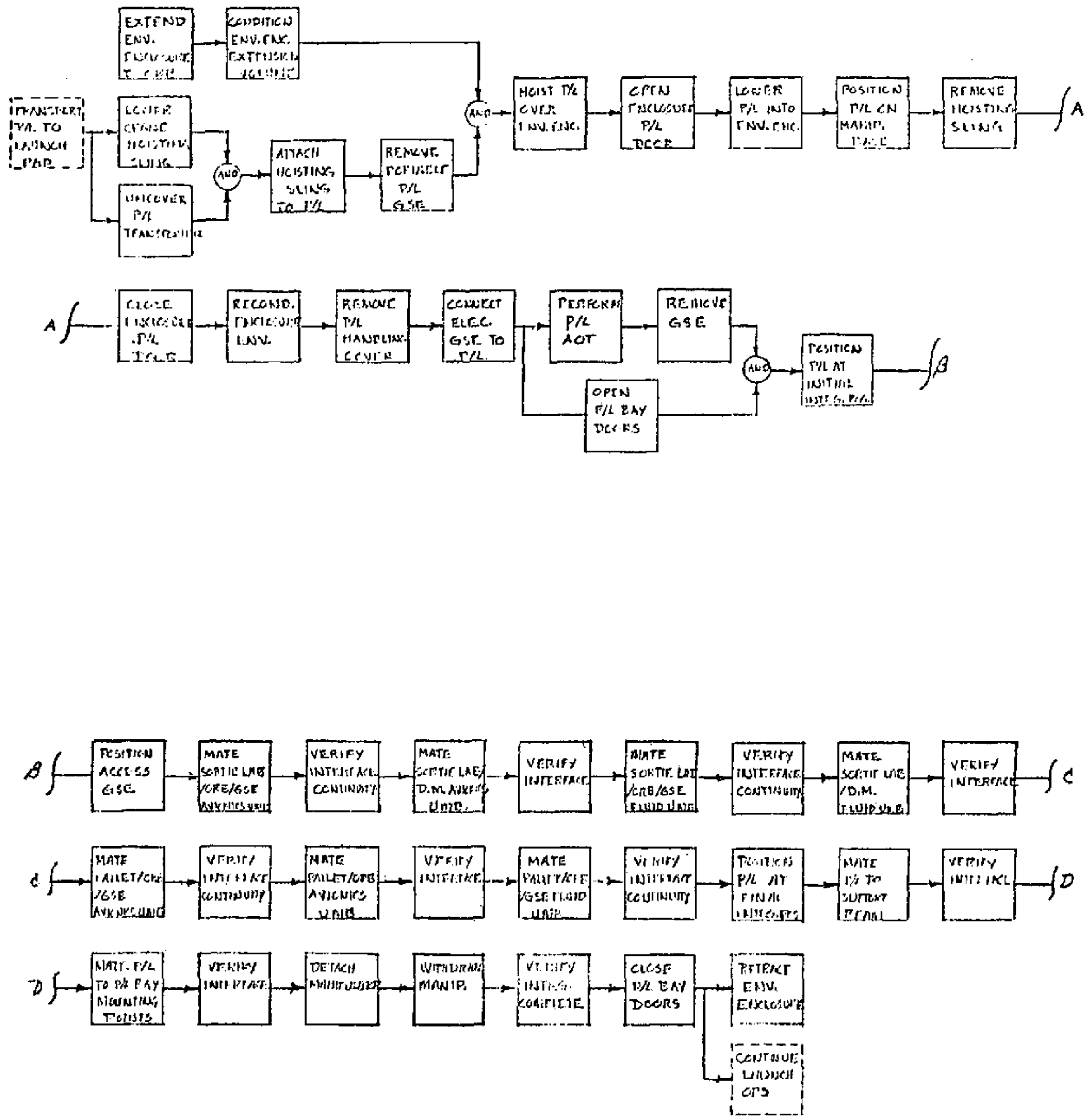
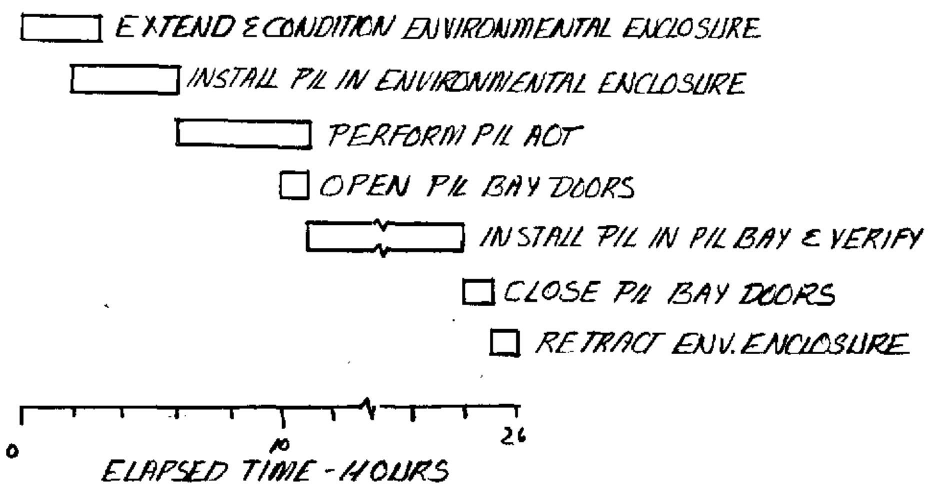


FIGURE A-14

CLASS II PAYLOAD/ORBITER INTEGRATION FLOW
VERTICAL ON LAUNCH PAD



E. Payload/Orbiter/GSE avionics umbilicals

F. Payload/Orbiter/GSE fluid umbilicals

The required in-bay access time of 12 to 14 hours impacts the baseline 8 hour on pad access allocation by 4 to 6 hours. It is believed, however, that this impact can be resolved for the following reason.

As indicated above, it was assumed that the necessary payload flight support equipment is installed in the payload bay while the Orbiter is located at the MCF in a manner similar to that of horizontal integration. These installation operations require between 6 and 12 hours as indicated in Figure A-18. Since the Orbiter baseline allocated 18 hours for these operations, Orbiter operations in the MCF can be shortened by 6 hours and on pad operations can be increased by 6 hours thus eliminating the potential 6 hour on pad access impact and still remaining within the overall Orbiter turnaround time of 231 hours.

A.8 INFLUENCE OF ORBITER ORIENTATION AND LOCATION

Orbiter orientation during the payload integration process has a relatively

FIGURE A-15

ALTERNATE ON-PAD CLASS II PAYLOAD/ORBITER INTEGRATION FLOW

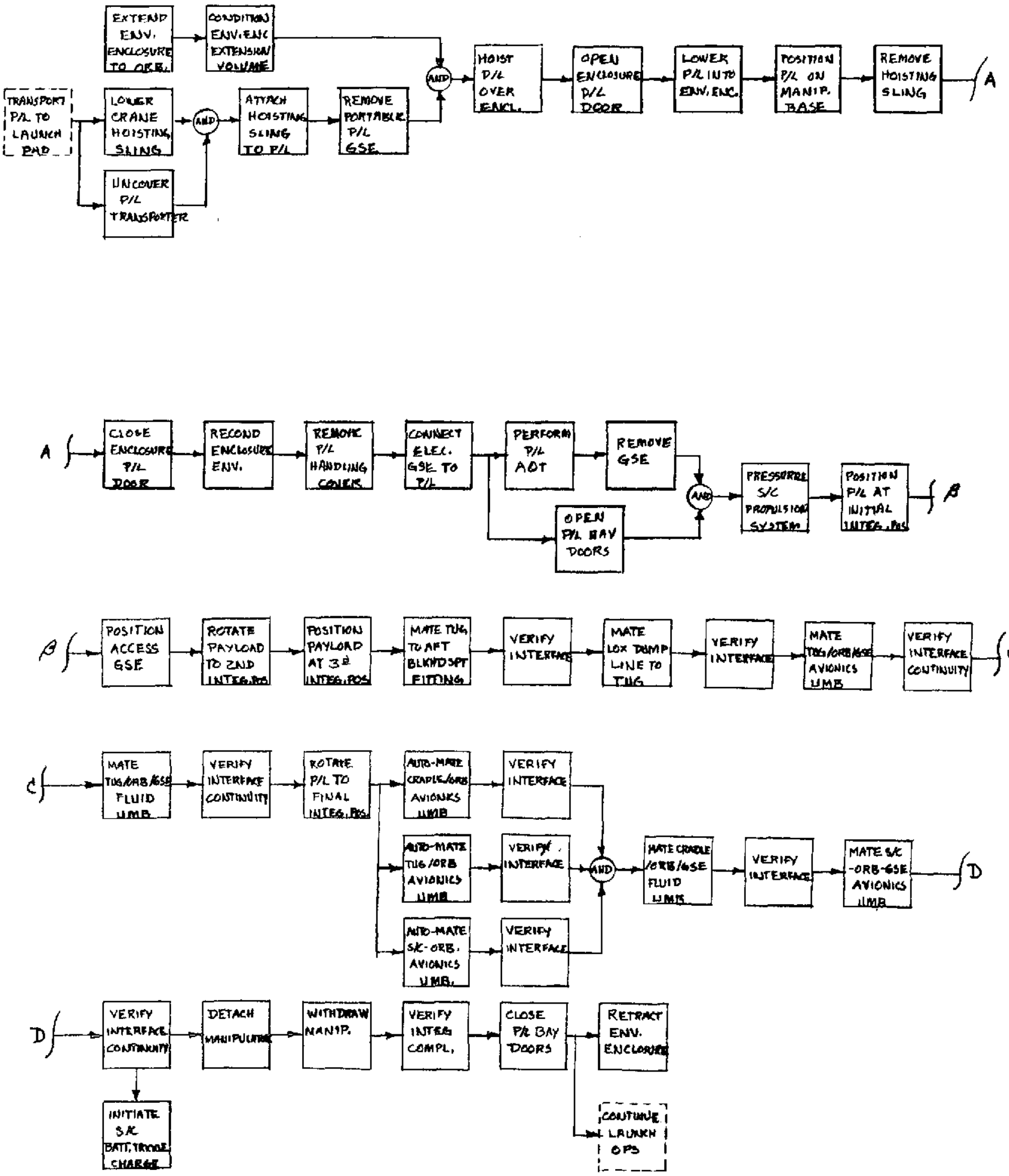
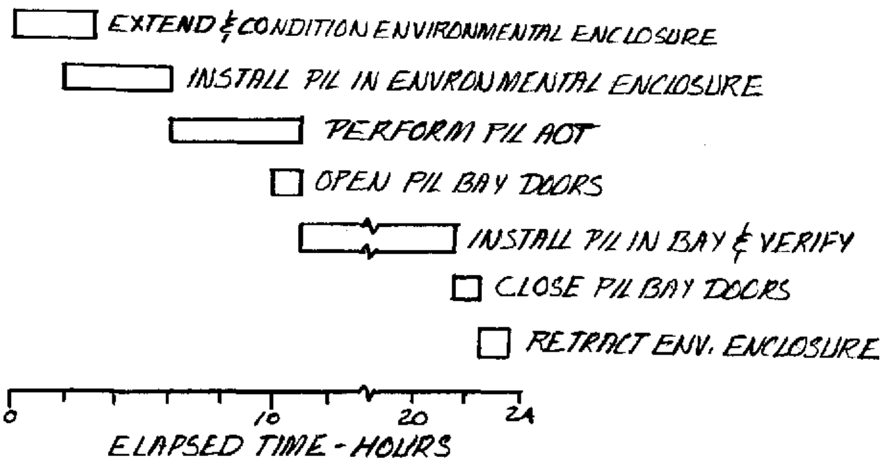


FIGURE A-16

CLASS IV PAYLOAD/ORBITER INTEGRATION FLOW
VERTICAL ON LAUNCH PAD



minor influence on the payloads. Class I and Class II, which employ hydrazine propulsion systems, require payload unique orientations in the payload bay such that catalyst material within the spacecraft thrusters will be prevented from migrative to and clogging the thruster injectors while in the horizontal position. This unique orientation requirement imposes potentially complex payload/Orbiter umbilical interface requirements.

Vertical installation of payload classes requires special access GSE which is compatible with the launch pad payload manipulator device in order to permit mating of payload/Orbiter and payload/flight support equipment interfaces. The specific configuration of the manipulator device has not yet been defined, however, it is believed that manned access to the payload bay with the device in place at the payload bay will be extremely difficult.

Because of the configuration and physical location and orientation of the PSS and MSS consoles in the crew compartment, installation of payload control and display equipment and software at these stations is preferred while the Orbiter

FIGURE A-17

ALTERNATE ON-PAD CLASS I & III PAYLOAD/ORBITER INTEGRATION FLOW

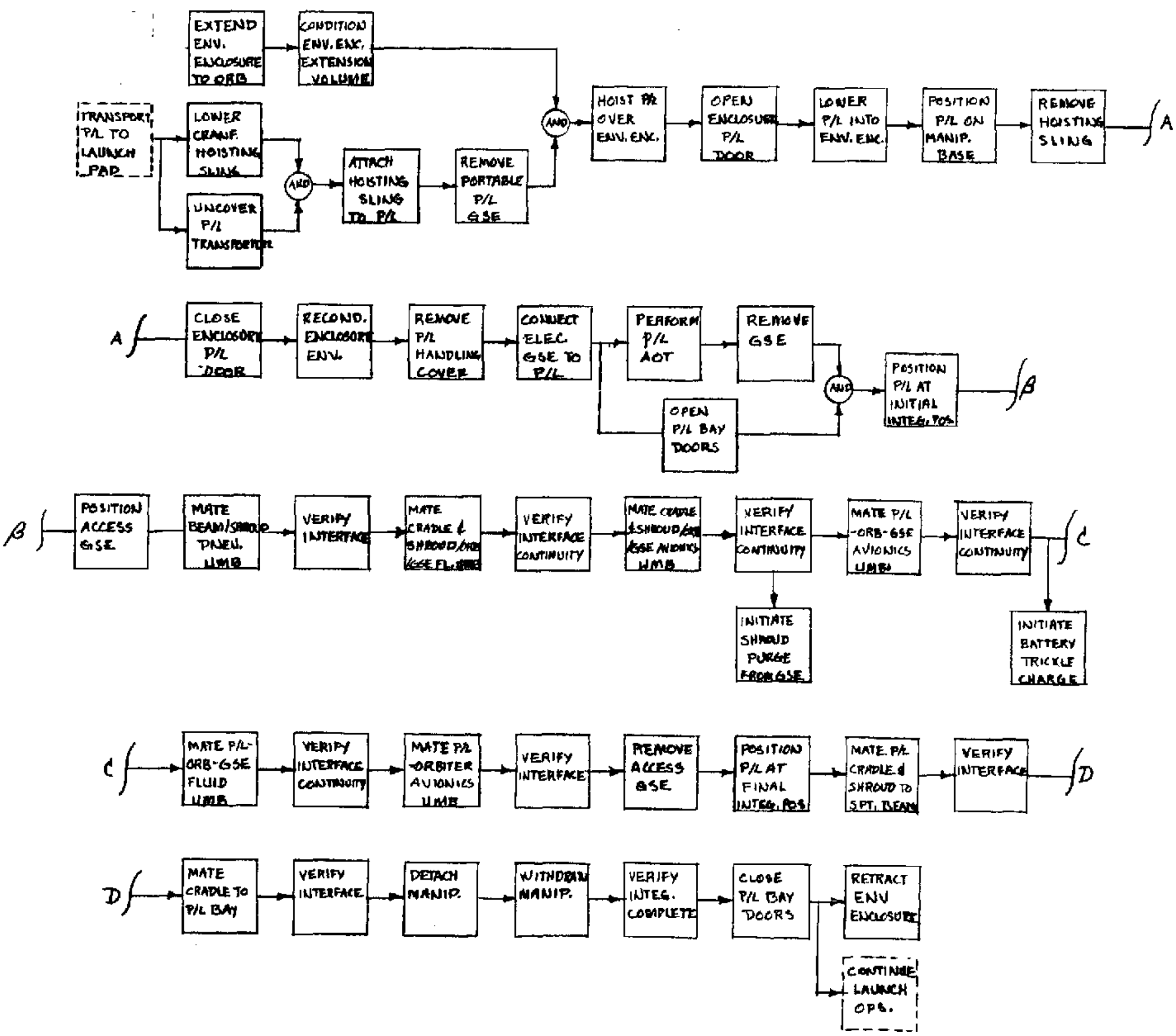
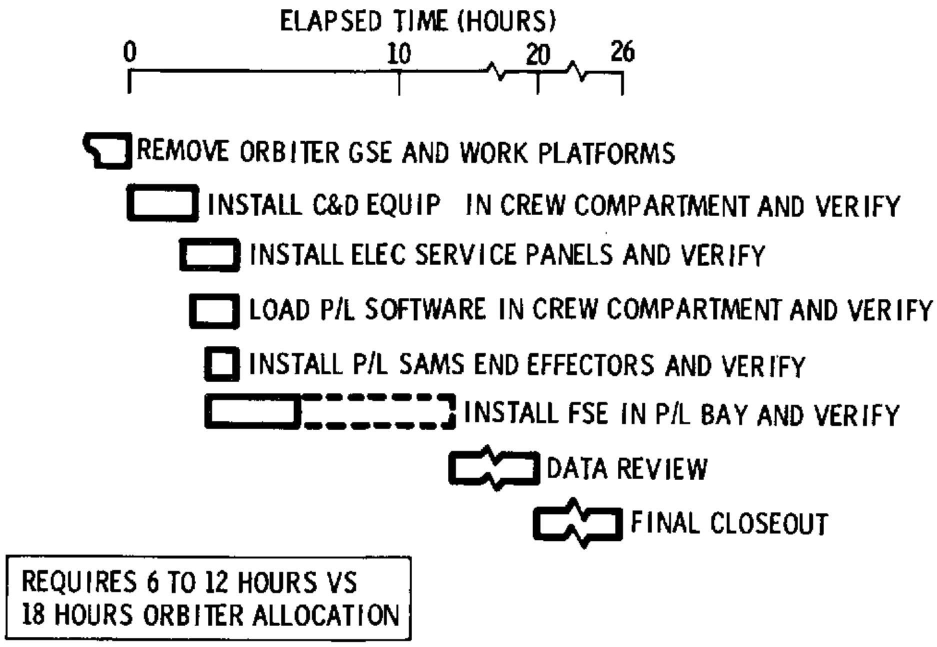


FIGURE A-18

MCF P/L OPERATIONS REQUIRED AS A RESULT OF PAD INTEGRATION

40433



is in the horizontal position. For either the horizontal or vertical payload/ Orbiter integration method, this equipment and software installation is recommended to occur at the MCF.

The influence of Orbiter location (MCF vs pad) on the payloads is significant. For Class II payloads which involve a Tug vehicle, installation location plays a major role in sizing the Tug fleet required at the launch site. Information developed for the cryogenic Tug study being performed at MDAC and presented in Figure A-19 indicates that for the potential Class II payload launch rates at KSC, installation of payloads at the launch pad two days prior to launch, reduces the fleet size by one Tug.

Installation of all payload classes at the MCF approximately 8 days prior to launch imposes significant access constraints on the payloads.

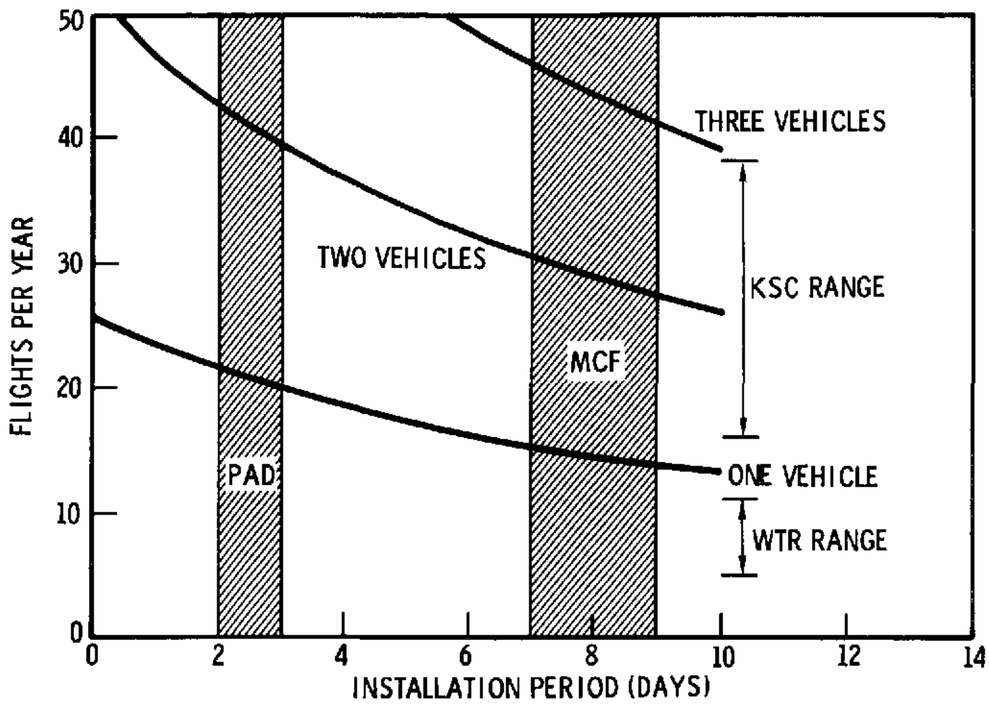
In the case of Class IV Sortie Lab payloads, installation of time critical equipment must occur at the launch pad thus impacting on pad payload access time constraints. If Class IV payloads are installed at the launch pad however,

FIGURE A-19

TUG FLIGHT ARTICLES REQUIRED

INSTALLATION PERIOD SENSITIVITY

40427



time critical equipment can be installed just prior to payload/Orbiter integration while the Sortie Lab is still in the environmental enclosure with no impact to access time constraints.

In addition, after completion of payload/Orbiter integration, the payload bay doors are closed and the payload is effectively isolated during post integration Orbiter operations until the entire Shuttle arrives at the launch pad. This isolation period consists of approximatley seven days. Until the Shuttle arrives at the launch pad, there are several factors which are potentially undesirable from the payload point of view. These are:

A. There is currently no specified environmental control of the payload bay until arrival at the launch pad. Because of this, the payloads which are not shrouded will require that protective covers which are necessary to protect contamination and humidity sensitive equipment will have to remain installed until just prior to launch. All of the payloads require strict thermal control during launch site operations.

During Shuttle/launch pad roll-out operations, no thermal control of the payload bay is currently specified.

B. Spacecraft propulsion systems will probably be loaded and under a blanket pressure and payload flight batteries will be installed prior to integration. If payloads are installed at the MCF, safety monitoring and control equipment which is compatible with post integration Orbiter operations will be required. Additionally, should a spacecraft anomaly occur during these operations, it cannot be assessed without impacting the Orbiter turnaround schedule.

C. Since flight batteries are installed prior to integration, if the payloads are installed at the MCF, battery charging equipment which is compatible with post integration Orbiter and Shuttle operations will be required.

D. Post integration Orbiter operations in the MCF involve transfer of the Orbiter to the VAB, erection, mating to the external tanks, and transfer to the launch pad on the Shuttle mobile launch platform. From the point of view of the payload, these moves and operations are significant. After arrival at the launch pad, it is highly desirable to perform an avionics operational test. This test verifies the functional integrity of the payload systems after these major moves and require access to the payload. Access to the payload is also required to remove any non automatic protective covers and, if required on payloads of current design, to install inflight jumpers prior to launch.

These on pad operations require 16 hours as illustrated in Figure 8. Eight of these 16 hours involve payload access.

On pad installation of payloads circumvents all of the above undesirable factors which result from payload/Orbiter integration at MCF.

A.9 INFLUENCE OF PAYLOAD SERVICING AND CHECKOUT REQUIREMENTS

Payload servicing requirements influence the desired mode of payload/Orbiter integration. As discussed in the preceding paragraphs, no payload bay environmental control provisions are currently specified for VAB or Shuttle transportation operations. MCF payload integration requires additional Orbiter compatible environmental control GSE to maintain the payload bay within the cleanliness, humidity, and thermal requirements specified by the payloads during the 7 day transition period between the MCF and the launch pad.

It is assumed that the payload transporter which transfers the payload from the PSA to the MCF for horizontal integration or the launch pad for vertical installation will provide the environmental and cleanliness control specified by the payloads as recommended in the SOAR II study results.

Also, as discussed above, if payload installation occurs at the MCF, additional GSE will be required to perform the necessary safety monitoring and control and spacecraft battery trickle charging functions. This equipment must be compatible with Orbiter erection and external tank mating operations as well as with the Shuttle mobile launch platform.

The remaining payload servicing requirements are insensitive to the method of payload/Orbiter integration. Class I and II spacecraft hydrazine propellant servicing is greatly simplified if propellant is loaded prior to payload/Orbiter integration. This operation includes loading the payload to flight levels with hydrazine and maintaining a blanket pressure of 30 to 50 psia on the propulsion system until arrival at the launch pad where the system is pressurized to flight pressure (about 600 psia).

These spacecraft employ relatively small amounts of hydrazine (200-300 lb) and until current launch rate safety studies have been completed, KSC safety personnel have indicated that propellant preloading is tentatively acceptable.

All high pressure vessel pressurization and cryogenic gas and liquid loading of payloads will occur at the launch pad and is thus independent of the payload installation adopted. For payloads of current design, Orbiter payload bay access is required to make the necessary GSE interfaces required to perform these pressurization and loading functions.

Payload post integration checkout requirements potentially impact the quantity of checkout GSE which is required.

Each payload class requires (highly desirable) an abbreviated avionics operations test after every major move or operation. This test is estimated to require about 5 hours to complete and verify the functional integrity of the payload systems after each physical move.

If payload integration occurs at the MCF, an abbreviated AOT is required after transportation to the MCF from the PSA and payload/Orbiter integration and again after Orbiter transfer to the VAB, Orbiter erection and transportation to the launch pad.

If payload integration occurs at the launch pad, only one post integration AOT is required and the requirement for GSE necessary to support this test in the MCF is eliminated.

A.10 PAYLOAD CONTINGENCY REMOVAL/CHANGEOUT OPERATIONS

An additional consideration of the study analyses was that of contingency on pad payload removal and changeout operations.

Removal and changeout functional flows and timelines were developed for these operations for the case of a "matched set" of payloads and are presented below in Figures A-20 through A-24. Removal and subsequent installation of different payloads at the launch pad was not analyzed since the scope of such an analysis is beyond the capability of this study. The analysis of matched set payload changeout operations did however reveal that at least 32 working hours would be required to offset the changeout.

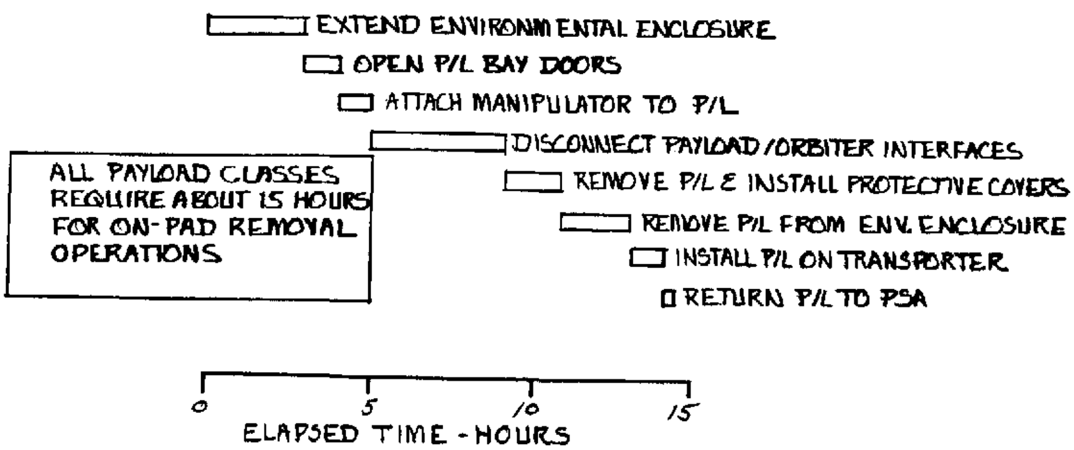
A-11 CONCLUSION

The results of this Pad vs MCF Installation analyses indicate that payloads are capable of being integrated with the Orbiter at either location. It is concluded however that payloads prefer vertical installations at the launch pad for the following reasons:

- Allows continuous access to payloads through launch minus 2 days
- Reduces Tug fleet size for Class II payloads by one (1) Tug
- Reduces payload time from notification to launch preps by 7 days
- Simplifies payload/Orbiter interfaces for Class I and II payloads
- Reduces payload integrated systems test requirements.

FIGURE A-20

ON-PAD PAYLOAD REMOVAL OPERATIONS



This conclusion also supports the conclusion presented in the SOAR II study results which recommended that vertical integration at the launch area be adapted as the nominal Shuttle baselined plan. This recommendation was based on the following factors.

The rationale for MCF installation has been reported to be to reduce the probability of launch impacts late in the prelaunch operations. It is not apparent that the baselined schedule meets this objective. Historical data on the unmanned spacecraft shows that two of the major elements contributing to anomalies are moving equipment around and subjecting the equipment (for an extensive period of time) to conditions other than those for which it was primarily designed. For the element involving spacecraft motion, direct access to the payload should be provided as late as possible in the launch flow. For condition exposure, the payload ground operation would certainly benefit from installation into the bay as late as possible in the flow. Both of these factors favor late installation of the payload into the Orbiter payload bay. Also, many of the anticipated problem sources associated with "late flow" installation will

FIGURE A-21

ON-PAD CLASS I & III PAYLOAD REMOVAL
FUNCTIONAL FLOW

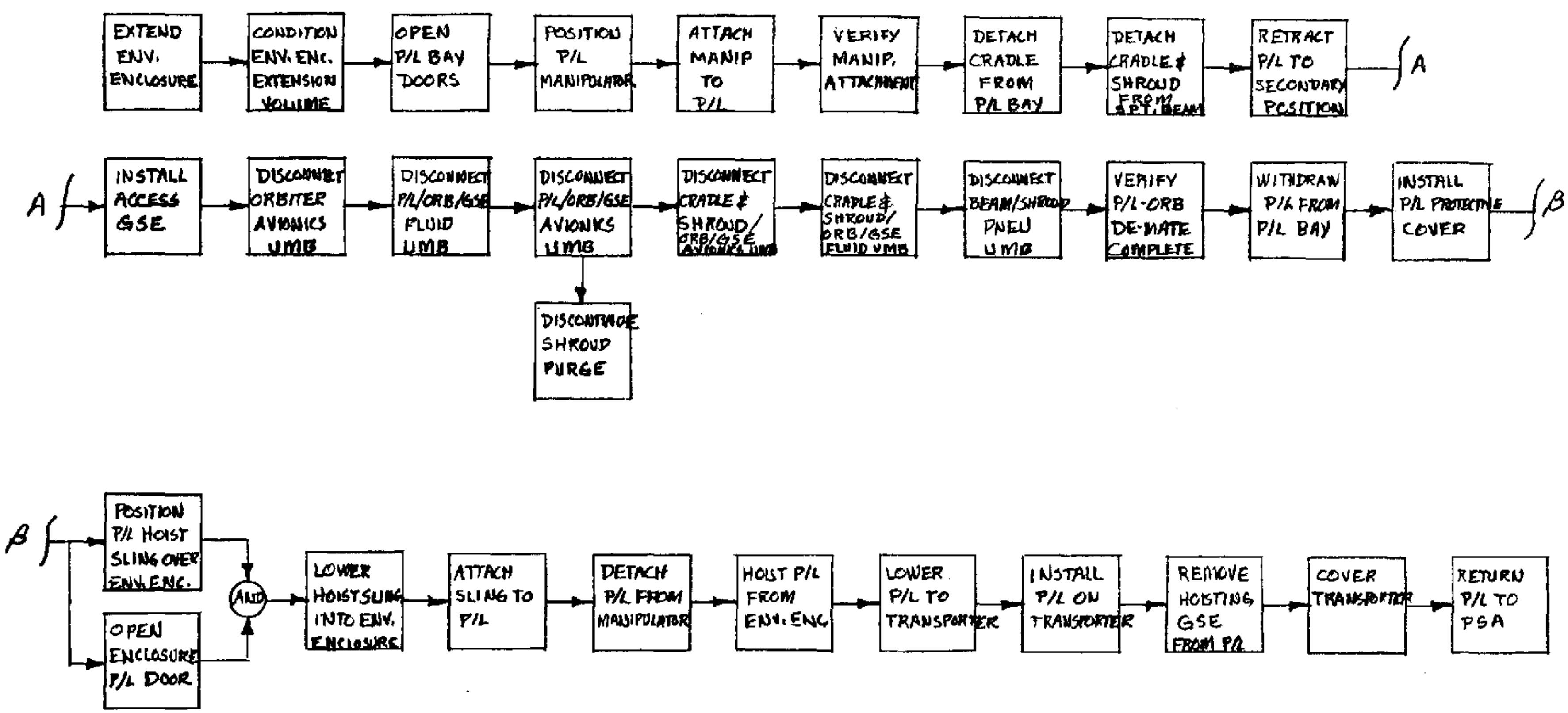


FIGURE A-22

ON-PAD CLASS II PAYLOAD REMOVAL FUNCTIONAL FLOW

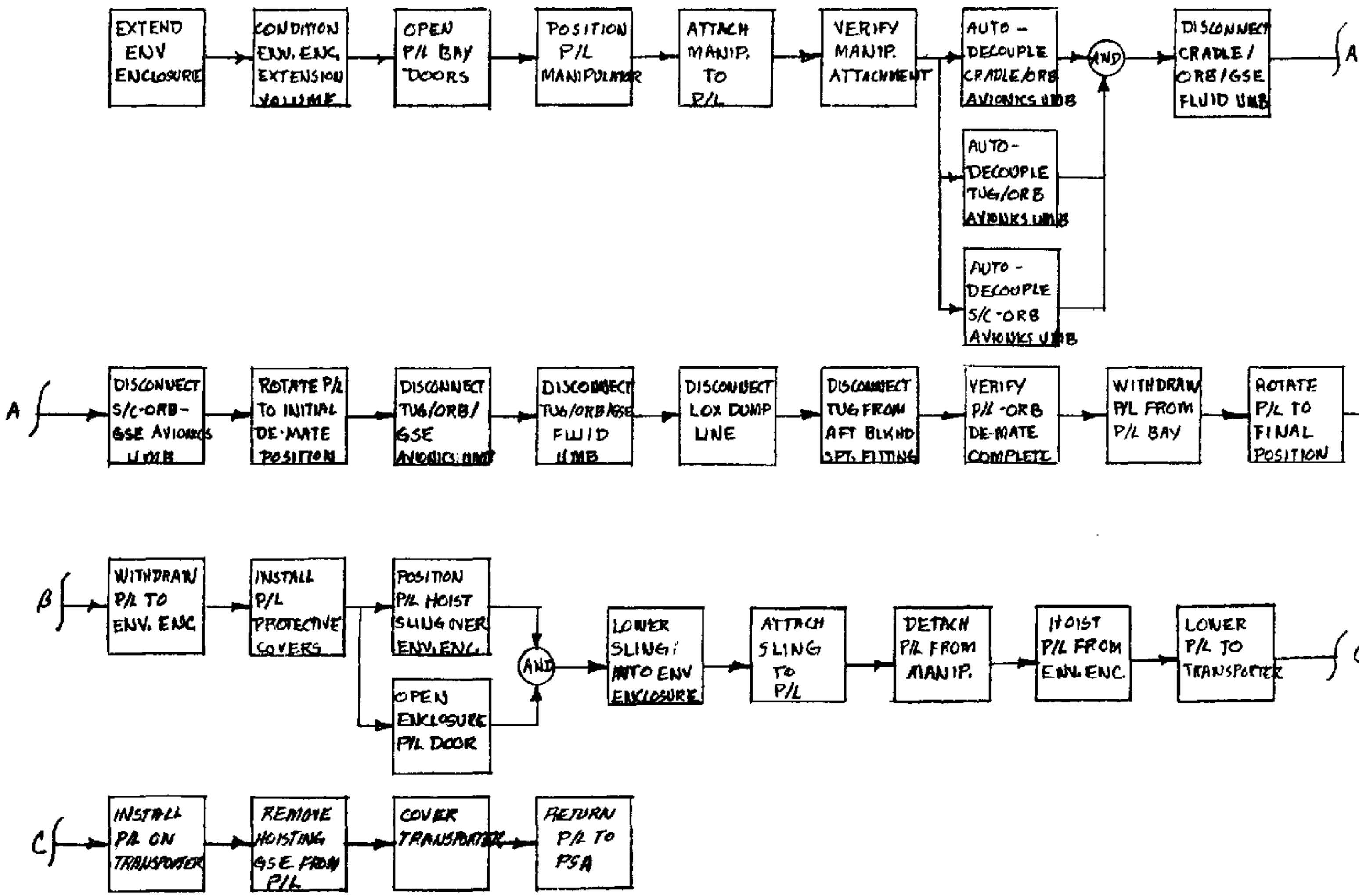


FIGURE A-23

ON-PAD CLASS IV PAYLOAD REMOVAL FUNCTIONAL FLOW

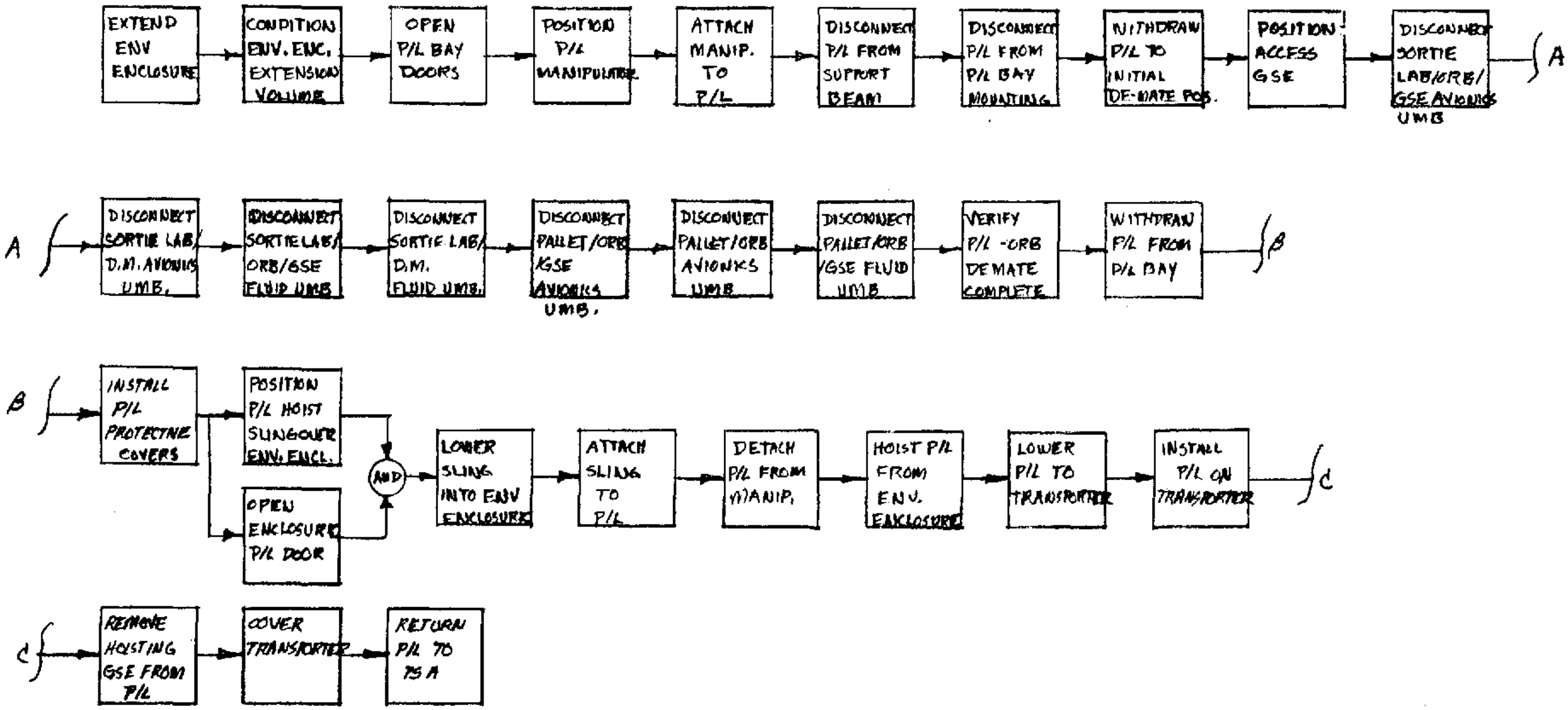
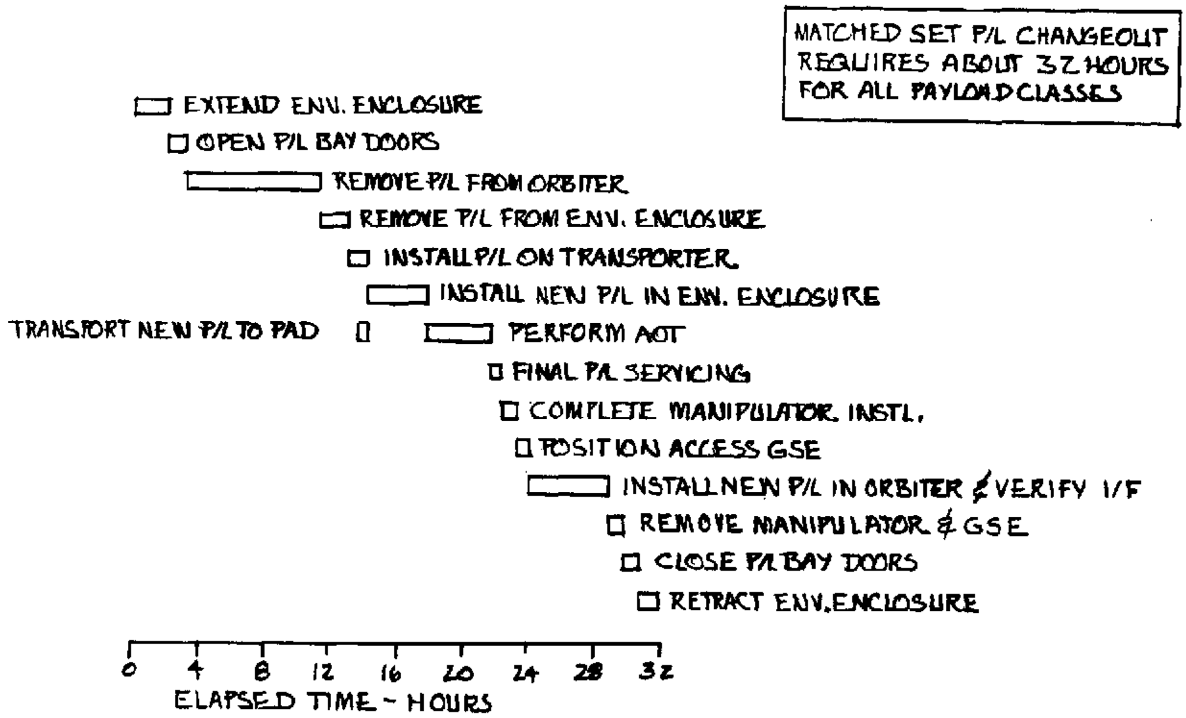


FIGURE A-24

ON-PAD PAYLOAD CHANGEOUT OPS. (MATCHED SET)



be solved through the use of the Shuttle SIF and EAU's during the prelaunch payload operations.

Another factor which should be considered is payload recovery from the returning Orbiter. Several payloads desire recovery from the Orbiter as soon as possible after Orbiter landing. Certainly Tug turnaround phasing with the Orbiter can be enhanced by early recovery of the Tug at the Safing Facility (the KSC/Tug Study has recommended this early recovery of the vehicle). If this operational procedure is baselined in the Shuttle flow the transfer of the payload installation function to the pad area would eliminate the requirement for payload handling equipment and support equipment in the MCF.

Additionally, the baselined launch pad payload installation would inherently provide for the manned access at the pad.

A final factor involves the years of experience of the KSC personnel in launch pad installation of the payload (presently the nominal procedure at KSC) with the delivery vehicle. The problems (and costs) associated with the development of this type of baseline installation have already been solved, and changing from MCF installation to pad installation represents "returning to the normal mode" rather than perturbing established procedures.

Appendix B

PAYLOAD CHECKOUT/CONTROL REQUIREMENTS ANALYSIS

B.1 REQUIREMENTS

An analysis was performed on the study mission model to determine the control and monitor requirements for each payload based on satisfaction of STS safety criteria (caution and warning) and provision of sufficient additional control and monitor capability during all phases of the mission profile to accomplish prelaunch preparation of the payloads, provide payload performance evaluation during flight and provide conditioning of payloads for deployment and/or emergency or normal return-to-Earth activities.

B.1.1 SOAR-II Summary

Results of the SOAR-II Study provided the general caution and warning (C&W) requirements and system noted in Table B-1. More explicit C&W information was generated by the SOAR-II special emphasis tasks for DSCS-II and Tug. Reference SOAR-II, Volume III, MDC G4473, pp. 77 through 79.

SOAR-II results for checkout operations during the STS mission profile are contained in the Appendix of SOAR II, Volume V, MDC G4475, and essentially offers generalized checkout sequence and philosophies for the SOAR II mission model.

B.1.2 Safety

The various payloads and FSE (Flight Support Equipment) were surveyed on a conceptual basis) to establish candidate caution and warning (C&W) functions. This survey coupled with published SOAR-II data provided the system and hazard identifications shown in Table B-2, which are essentially candidate C&W functions.

The following are the criteria that were generated and utilized to evaluate the candidate functions for inclusion on a composite C&W list.

A. All pressure vessels shall be monitored for pressure and temperature on a C&W basis.
B. All other systems shall be assessed using a hazard analysis type approach wherein a system/component fail operational-fail safe

TABLE B-1
CAUTION AND WARNING

OPTION	ADVANTAGES	DISADVANTAGES
• INTEGRAL PROCESSOR & PANELS, SIGNAL DISTRIBUTOR	DECREASED UNIT COMPLEXITY	MAX. SYSTEMS PARTS COUNT
* • CENTRAL C&W PROCESSOR, DEDICATED PANELS	MINIMUM COST, CONTROL CENTRALIZATION	SYSTEM DEPENDANCY ON SINGLE UNIT
• ALL C&W HARDWIRED	RELIABLE, SIMPLE	MAX. WEIGHT INSTALLATION COMPLEXITY
• ALL C&W HARDWIRED WITH COMPUTER BACKUP	MAX. RELIABILITY ALLOWS RANGE VARIATION	MAX. COST
* • ALL WARNING HARDWIRED	MAX. RELIABILITY WHERE NECESSARY	MEDIUM COST, COMPLEXITY AND WEIGHT
ALL C&W COMPUTER PROCESSED	INTERFACE SIMPLIFICATION ALLOWS RANGE VARIATION	
* • ADJUSTABLE CONTROLS WITH LOCKS ON PROCESSOR	MINIMUM CHANGE TIME	LOWER RELIABILITY
• HARDWIRE/COMPONENT CHANGES	NONE	WEAR, CHANGE TIME, MAX. COST
• ANALOG CIRCUITRY	SIMPLE	GREATER COST
* • DIGITAL CIRCUITRY	SMALL SIZE	NOT CONSTANT WITH HARDWIRE/ APPROACH
* • OVERLAY LEGENDS	CHEAP	TIME CONSUMING
• PROGRAMMABLE LEGENDS	— — — — —	REQUIRES PROGRAMMING

CONTROLS: 1. CHANNEL SELECT (1-N)
2. OFFSET ADJUST
(PROCESSOR) 3. RANGE ADJUST
4. LIMIT SELECT "LOW"
5. LIMIT SELECT "HIGH"
(CONTROLS) PUSH-TO-TEST
(PANEL) ABORT (COMMANDER/PILOTS STATION)

DISPLAYS: LIGHTS

*INDICATES CHOICE

MEASUREMENTS AND ASSIGNMENTS

	Spacecraft									
Subsystem	BRM	HEAO C	LST	LDE	DSCS-II	SMS	ATSH-1	MJS-77	EOS	S/EOS
Power	3	9	9	0	8	4	4	12	4	6
Comm/Data	3	9	2	0	14	5	11	5	3	3
Ordnance	0	0	0	0	2	2	6	16	0	0
Attitude Cont.	3	37	15	0	2 5	3	4	9	6	13
Sep. /Deploy	1	0	0	0	2	1	4	3	4	4
Other	2	1	1	0	0	0	0	1	0	0
C&W Assignment										
Mission Spea.	3	2	2	0	6	5	12	21	6	6
Payload Spea.	12	56	27	0	28	15	29	46	17	26

TABLE B-2

CANDIDATE C&W FUNCTIONS

SYSTEM/FUNCTION	HAZARD
1. Command System	
a. Uplink signal present	Potential of ultimate actuation of deployment devices or injection of contaminants into payload bay and/or Tug engine ignition.
b. Command execute	Potential of actuation of deployment devices or injection of contaminants into payload bay and/or Tug engine ignition.
c. Input power	Same as 1.a and 1.b.
2. Ordnance System	
a. Arm	Potential of firing ordnance devices.
b. Fire relay status	Same as 2.a.
3. ACS Mode	Potential of injecting contaminants into payload bay.
4. Momentum Devices	Potential damage due to device fragmentation.
5. Propulsion System	
a. Pressures	Potential tank rupture.
b. Temperatures	Potential tank rupture.
c. Leaks	Contamination in payload bay.
6. Thruster Temperature	Indicative of contaminant injection into payload bay.
7. Separation Switches	Potential of sequencing satellite deployment systems.
8. Deployment Switches	Potential of damage from loose hardware.
9. Sequencer Status	Same as 7.
10. Dump Lines Status	Potential of dumping contaminants into payload bay.
11. Vent Lines Status	Potential of venting contaminants into payload bay.
12. Electrical Umbilical Status	Loss of payload control by orbiter.
13. Propulsion Umbilical Status	Loss of propulsion system control.
14. Tilt Table Status	Same as 8.
15. Power Systems	
a. Pressures	Potential of source rupture.
b. Temperatures	Potential of source rupture.
c. Voltages	High voltage arcing.
d. Currents	Potential of short circuits.
16. Transmitters' Outputs	Possible actuation of ordnance devices.
17. Engine Ignition Inhibit	Potential engine ignition in payload bay.

characteristic is sufficiency for rejections of a candidate C&W function.

Evaluation by these criteria resulted in the C&W function list shown in Tables B-3 through B-6 for the study mission classes and the FSE.

No ordnance firing functions are included in the C&W list. This omission is based on the premise that the safety and arming approach recommended by SOAR-II for ordnance circuitry safing will be integrated into Shuttle era satellite circuits for C&W rejection via item two of the aforementioned criteria. Additionally, battery temperature and pressure are omitted based on the premise that incorporation of an impact resistant battery cover and facilities to absorb KOH (within the case) are included in satellite design as recommended by the MDAC DOD payload interface study.

Designation of a particular C&W function as a caution or a warning item utilizes the SOAR-II criterion wherein urgency is associated with warning functions and immediate corrective action is required; caution functions are associated with

TABLE B-3
CAUTION AND WARNING-SATELLITES

MISSION CLASS

FUNCTION	I (EOS)	II (ATS/SMS/DSCS)	III (LST)	ASSIGNMENT	ANNUNCIATORS
ORDNANCE SAFE-ARM	•	• • •(2)	•	WARNING	2
PROPELLANT/GAS PRESSURE	•(2)	• • •(2)	•	CAUTION	1
PROPELLANT/GAS TEMPERATURE	•(2)	• •(2) •(2)	•	CAUTION	
DEPLOYMENT SWITCHES	•	• • •(2)	•	WARNING	2
DUMP LINES STATUS	•	• • •(2)	-	WARNING	2
VENT LINE STATUS	•	• • •(2)	-	WARNING	2
LEAK DETECTION*	•	• • •(2)	-	WARNING	2

*LEAK DETECTION IS DERIVED FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

JUL 73 P253

TABLE B-4
CAUTION AND WARNING-TUG

FUNCTION	ASSIGNMENT	ANNUNCIATORS
TANK PRESSURES (6)	CAUTION	1
TANK TEMPERATURES (6)	CAUTION	
ACCUMULATOR PRESSURES (2)	CAUTION	1
ACCUMULATOR TEMPERATURES (2)	CAUTION	
FUEL CELL PRESSURES	CAUTION	1
FUEL CELL TEMPERATURES	CAUTION	
DUMP LINE STATUS (2)	WARNING	2
VENT LINE STATUS (2)	WARNING	2
ELECTRICAL UMBILICAL STATUS	WARNING	1
TUG LATCH STATUS	WARNING	1
ENGINE IGNITION INHIBIT	WARNING	1
COMMAND SYSTEM INHIBIT	WARNING	1
*LEAK DETECTION (6)	WARNING	6

*LEAK DETECTION FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

TABLE B-5
CAUTION AND WARNING-FLIGHT SUPPORT EQUIPMENT

40450-3

FUNCTION	MISSION CLASS I (EOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)	ASSIGNMENT	ANNUNCIATORS
HOLDING TANK PRESSURE (OPTION)	•	•	•	•	-	-	CAUTION	1
HOLDING TANK TEMPERATURE (OPTION)	•	•	•	•	-	-	CAUTION	
TILT TABLE LATCH STATUS	-	•	•	•	-	-	CAUTION	1
C&W POWER SOURCE NO. 1	•	•	•	•	•	•	CAUTION	
C&W POWER SOURCE NO. 2	•	•	•	•	•	•	CAUTION	1
MSS/PSS CONTROL POWER	•	•	•	•	•	•	CAUTION	
*LEAK DETECTION (OPTION)	•	•	•	•	-	-	WARNING	1
TIE DOWN STATUS	•	-	-	•	•	•	WARNING	1

*LEAK DETECTION FROM COMPUTER PROCESSING OF SYSTEMS' PRESSURES AND TEMPERATURES

TABLE B-6
CAUTION AND WARNING-SORTIE LABORATORY

40450-4

FUNCTION	ASSIGNMENT	ANNUNCIATORS
*OXYGEN TANK PRESSURE (2)	CAUTION	
*OXYGEN TANK TEMPERATURE (2)	CAUTION	
*HYDROGEN TANK PRESSURE (2)	CAUTION	
*HYDROGEN TANK TEMPERATURE (2)	CAUTION	1
*NITROGEN TANK PRESSURE	CAUTION	
*NITROGEN TANK TEMPERATURE	CAUTION	
*FUEL CELL STACK TEMPERATURE	CAUTION	
DOCKING MODULE PRESSURE	CAUTION	
COMPARTMENT OXYGEN	WARNING	
COMPARTMENT CO_2	WARNING	
*FUEL CELL STACK TEMPERATURE	CAUTION	
H_2O QUALITY	WARNING	
*ELECTRIC POWER	WARNING	1
COMPARTMENT PRESSURE	CAUTION	
COMPARTMENT TEMPERATURE	CAUTION	
*CLOCK	WARNING	1
*COMPUTER (FAILURE)	WARNING	1
*LEAK DETECTION (7)	WARNING	7

*INDICATES FUNCTIONS TO SHUTTLE INTERFACE a condition or trend having the potential to ultimately present a hazard to the Shuttle either through persistence or combination with subsequent planned activities.

B.1.3 C&W Control and Display Requirements

The following approach shall be utilized for C&W function detection and display and is in consonance with the interpretation of C&W philosophy to be utilized for Shuttle systems.

A. Primary C&W indications shall be derived from a dedicated hardwired detection circuit/system.

B. Backup for the primary system shall be provided through management of payload telemetry information (data management system). Where backup information is not available via data systems, visual observation (via TV or direct) is a suitable substitute.

C. Caution functions may be logically grouped into a single annunciator. Determination of the out of tolerance parameter shall be accomplished via the data management system.

D. Warning functions shall require a dedicated annuciator for each function.

E. Electrical control required for corrective action related to occurrence of a warning function shall be provided by a dedicated, hardwired, manual control circuit. Redundant control may be provided by available computer systems in conjunction with payload command decoder subsystems.

F. C&W out of tolerance conditions shall be indicated by both aural and visual means. Warning indications shall be easily differentiated with respect to caution indications.

Table B-7 presents the C&W related control functions required to provide corrective action when necessary.

40368

TABLE B-7
CAUTION AND WARNING RELATED CONTROLS

FUNCTION	MISSION CLASS I (EOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)
SATELLITES						
ORDNANCE SAFE-ARM	●	●	●	● (2)	●	-
PROPELLANT DUMP	●	●	●	● (2)	-	-
PROPELLANT VENT	●	●	●	● (2)	-	-
N_2 TANK VENT	●	●	-	-	●	-
TUG **SORTIE LAB**						
HYDROGEN TANK PRESSURIZE	-	●	●	●	-	●
HYDROGEN TANK DUMP	-	●	●	●	-	●
HYDROGEN TANK VENT	-	●	●	●	-	●
OXYGEN TANK PRESSURIZE	-	●	●	●	-	●
OXYGEN TANK DUMP	-	●	●	●	-	●
OXYGEN TANK VENT	-	●	●	●	-	●
COLD HE TANK VENT	-	●	●	●	-	-
AMBIENT HE TANK VENT (2)	-	●	●	●	-	-
FUEL CELL CONTROL (2)	-	●	●	●	-	●
N_2 TANK VENT	-	-	-	-	-	●
PAYLOAD BAY						
HOLDING TANK VENT (OPTIONAL)	●	●	●	●	-	-
HOLDING TANK DUMP (OPTIONAL)	●	●	●	●	-	-
HOLDING TANK PRESSURIZE (OPTIONAL)	●	●	●	●	-	-

B.1.4 Orbital Readiness Tests (ORT)

Each class of satellite mission was examined to determine an ORT sequence to be performed during the mission delivery flight profile. For purposes of this discussion, ORT is defined as a planned in-flight checkout operation performed with the payload attached to Shuttle wherein a system response to a specific commanded stimulus is evaluated through the observation of data. Therefore, activities such as deployment preparations, health monitoring, etc., are separated from ORT.

The broad classifications of payload systems that are candidates for Shuttle attached ORT are summarized below.

Reaction Control Systems (RCS)

Command/Data Systems

Sensor Systems (gyros, star trackers, sun sensors, earth sensors)

Power Systems

Momentum Devices

Experiments

It is recommended that RCS thrusters be tested subsequent to payload release from Shuttle for the following reasons.

A. Thruster derived moments from cold gas systems are probably undesirable while the payload is in the Shuttle and/or attached to the Shuttle by the RMS.
B. Actuation of hydrazine or mercury ion thrusters in the payload bay is prohibited by safety and/or contamination criteria.

Momentum devices generally require 4-8 hours for spin-up and have been identified as hazard items (Table B-2). It is therefore generally recommended that these devices should remain inactive when payloads are in or in close proximity to Shuttle. An exception to this general recommendation will be noted in the case of the LST.

The remaining candidate ORT systems are discussed in the following material by mission class.

B.1.4.1 Mission Class I (EOS)

With the exception of the systems noted in the previous discussion, it is recommended that the remaining systems of power, command data, sensors and experiments be tested prior to release from Shuttle. This selection was based on the fact that ground station contact times are severely restricted as noted in Figure B-1 and Table B-8, and that hardwired checkout essentially circumvents the high EOS experimental data rates (31 MBPS) and the limitations of the Shuttle downlink capability (256 KBPS interleaved). It is suggested that the aforementioned systems can be effectively tested during an integrated test operation. A typical operational sequence follows:

A. Shuttle orient EOS toward Earth
B. Payload bay doors open
C. Raise EOS to vertical position
D. Deploy solar arrays

FIGURE B-1

EOS GROUND STATION CONTACT TIME

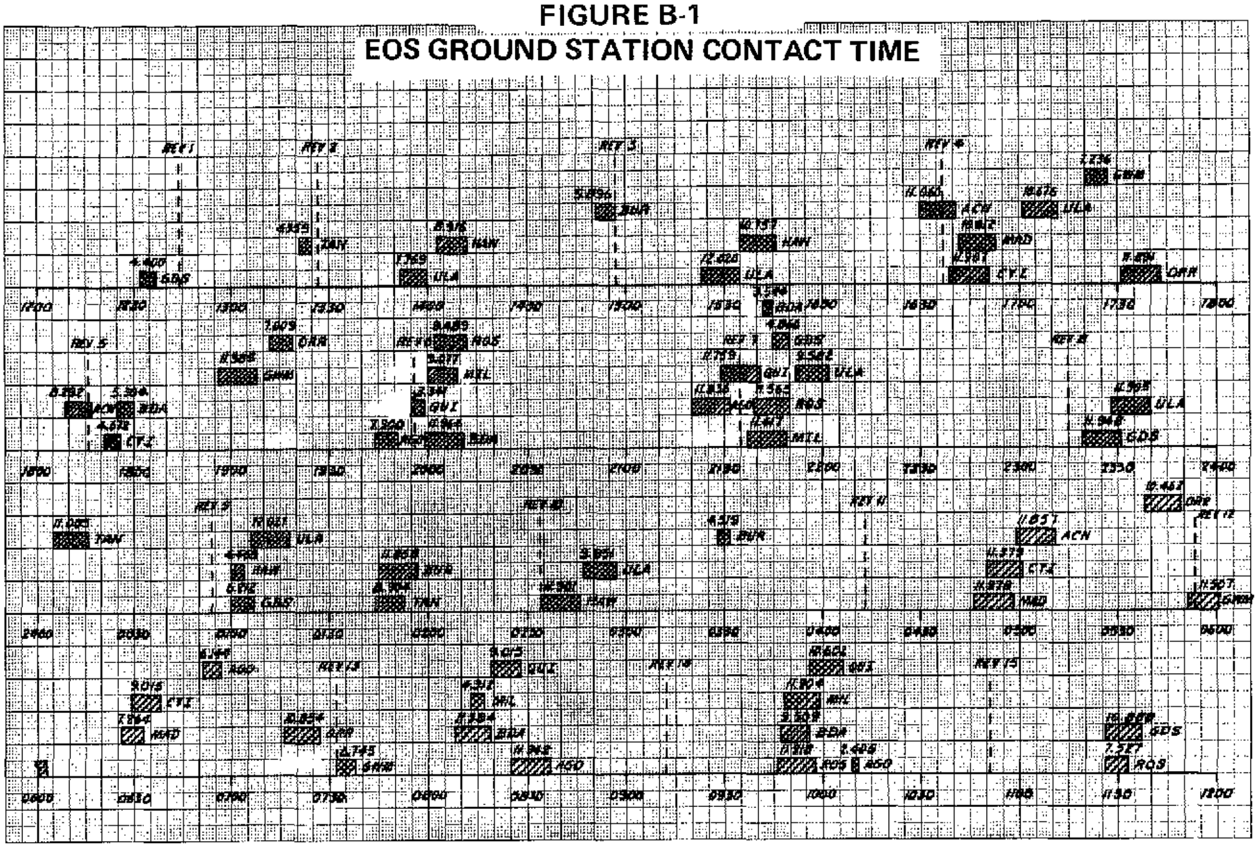
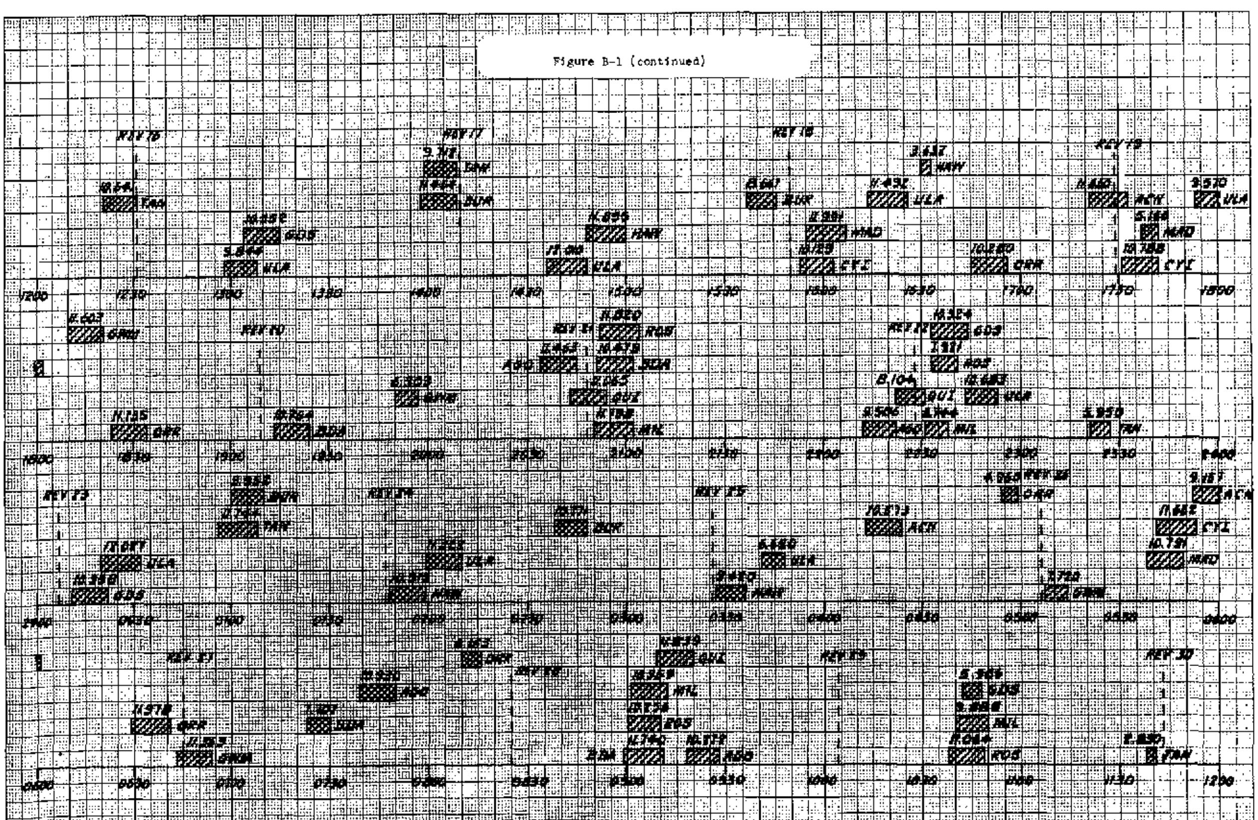


Figure B-1 (continued)



SHEET 2

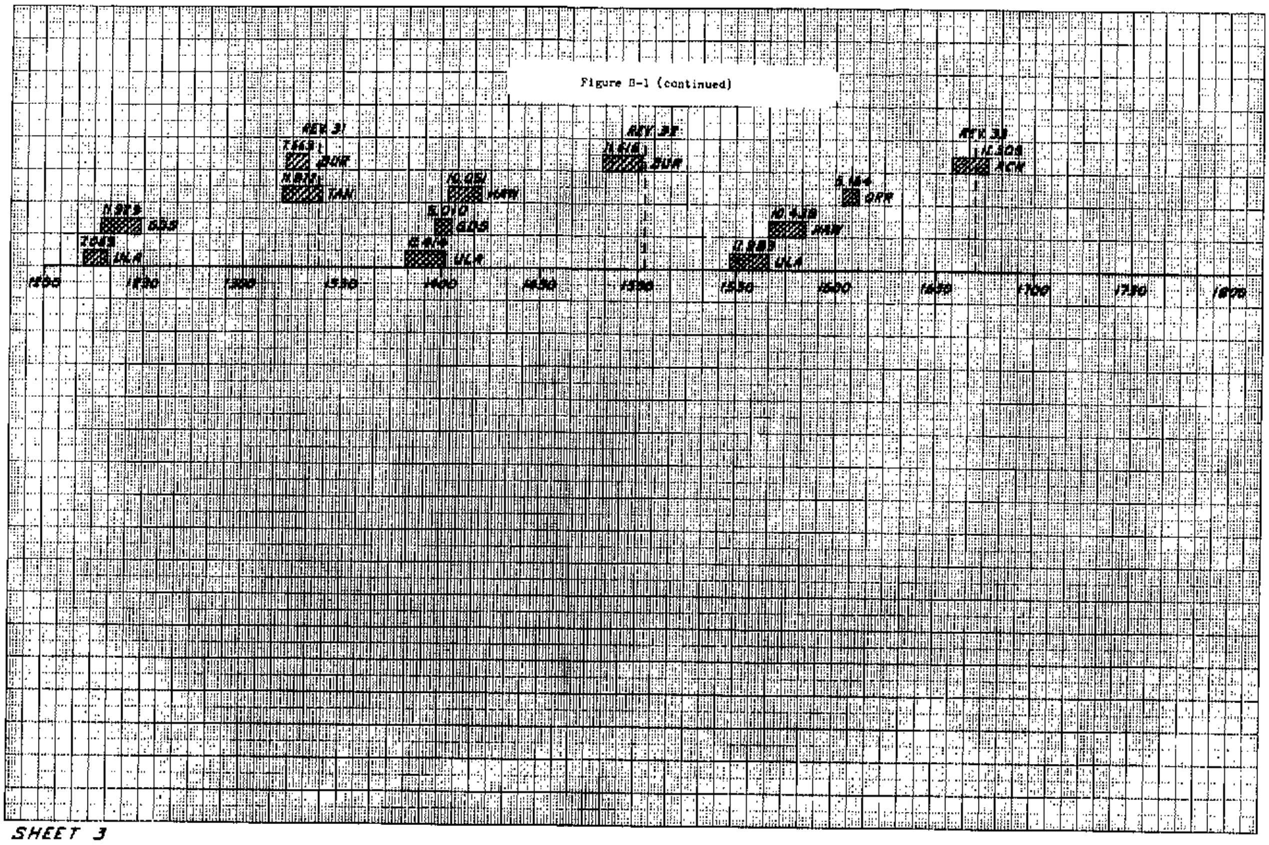


Figure B-1 (continued)

SHEET 3

TABLE B-8
EOS GROUND STATION CONTACT SUMMARY

STATION	T_1 (Min)	T_2 (Min)
Tamanarive	8.5	2.8
Alaska	10.4	6.7
Hawaii	9.2	3.6
Johannesburg	9.4	4.5
Acenscion Is.	10.2	7.6
Madrid	9.8	5.2
Guam	9.1	6.3
Orroral	9.3	5.0
Canary Is.	10.2	4.7
Bermuda	8.8	3.5
Quito	9.4	3.3
Cape Kennedy	10.9	4.3
Rosman	10.2	7.5
Goldstone	8.9	4.9
Santiago	9.1	2.4

Maximum time with no contact 71.2 min. between Alaska and Goldstone during seventh and eight orbits.

Percent of time in contact during repetition cycle 26%

Cumulative average station contact time per day 364.6 min

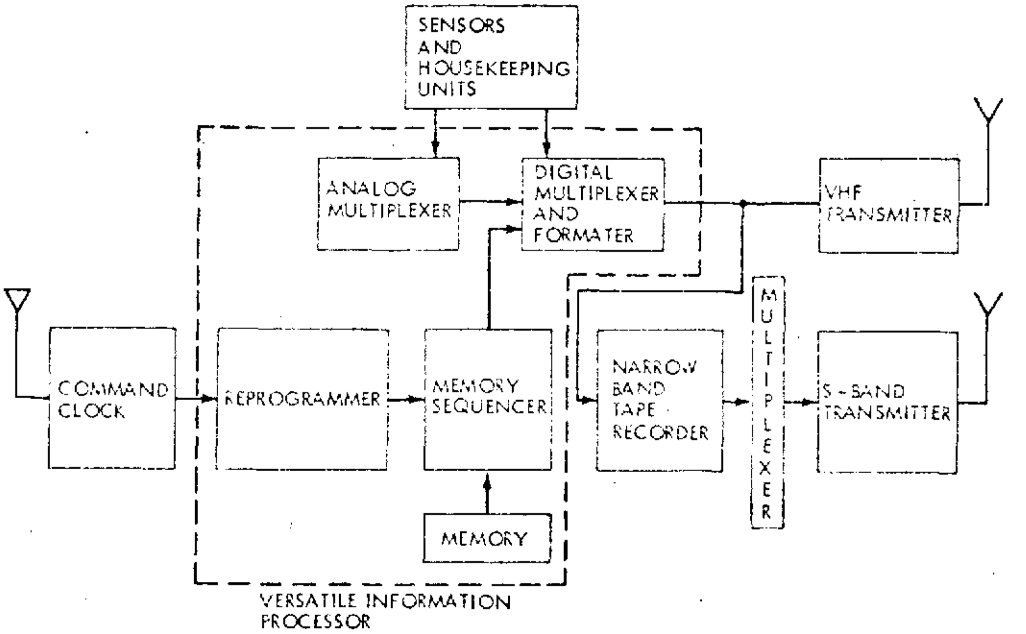
Average station contact time per orbit 25.6 min.

Minimum station contact time in repetition cycle 2.4 min. with Santiago in 14th orbit.

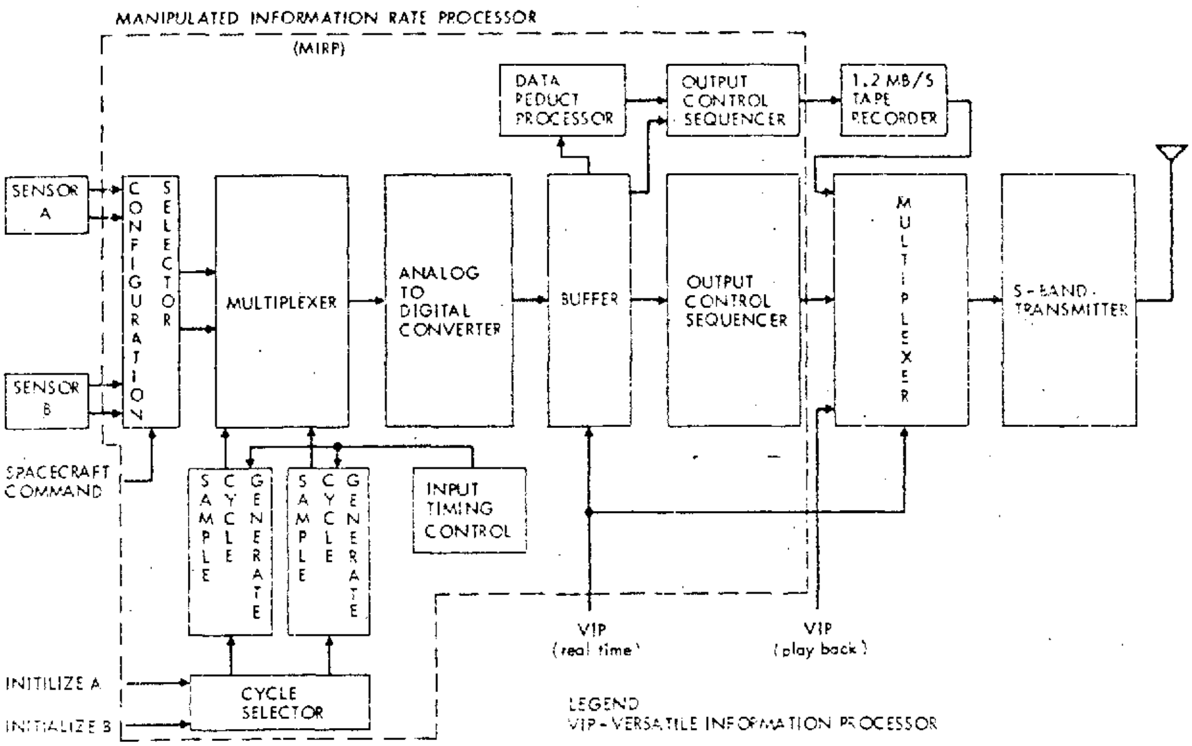
T_1 = Average station contact time per orbit

T_2 = Minimum station contact time in repetition cycle

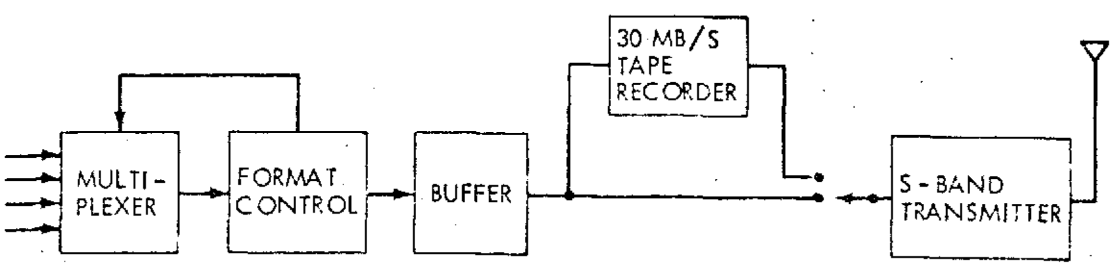
FIGURE B-2
EOS DATA SYSTEMS



Versatile Information Processor (VIP)



Manipulated Information Rate Processor (MIRP)



Multi-Megabit Operation Multiplexer System (MOMS)

E. Deploy sensor bays

F. Perform experimental measurements (power from Shuttle or satellite - may be split to checkout solar arrays and/or batteries).

G. Retract solar arrays and sensor bays in preparation for deployment.

The EOS-A and B experimental sensors and their characteristics are summarized in Tables B-9 and B-10. The experiment scanners require Earth pointing for measurement/calibration. It is assumed this orientation will be provided by Shuttle prior to opening of the payload bay doors.

The EOS high rate experimental data and housekeeping data systems are shown in Figure B-2. The experimental interface system suggested to measure sensor outputs prior to entry into the high data rate system is shown in Figure B-3. The indicated control functions are provided via hardwired command to the EOS utilizing the spacecraft command subsystem. Utilization of this experiment interface approach permits measurements of the EOS-A sensor outputs at the following maximum frequencies.

Sensor	Date Rate
Oceanic Scanning Spectrophotometer	4.6 KHz
Sea Surface Temperature Radiometer	9.2 KHz
Cloud Physics Radiometer	5.8 KHz
Upper Atmospheric Sounder	50 Hz
Atmospheric Pollution Sensor	8 Hz
Microwave Radiometer	400 Hz

For purposes of exercising the RF section of the command link, it is recommended that at least a portion of the control functions noted in Figure B-3 be provided through the Shuttle baseline RF command uplink (2KBPS max.).

B.1.4.2 Mission Class II (ATS/SMS/DSCS with Tug)

The mission flight profile for geosynchronous missions is presented in Table B-11. Shuttle attached ORT for geosynchronous missions is not recommended for the following reasons.

A. It is unfeasible/impossible to release deployable elements due to attachment to Tug and the inability to retract the deployed elements

TABLE B-9

EOS A SENSOR CHARACTERISTICS

EOS-A
Oceanography/Meteorology

Sensor	Wt. (lb.)	Power (Watts)	Description Orbit Adjust Not Required	Data Characteristics
Oceanic Scanning Spectrophotometer	45	60 (25 ave)	20 Channels (0.4 to 0.7 m) IPOV 2km, 19° scan angle	695 x 695 pixels, 8 bits/pixel 1 Frame/143 seconds, 4.6 KHZ noise bandwidth, 0.54MBPS Rate
Sea Surface Temperature Imaging Radiometer	45	30	5 Channels (0.5 to 11.5 m) IPOV 2km, 51° scan angle	2 5/HZ/IPOV, 10 bits/sample, 9.2 KHZ noise bandwith, 0.33 MBPS Rate
Cloud Physics Radiometer	70	40	5 Channels (0.75 to 2.125 m) IPOV 2.5km, 51° scan angle	2 5/HZ, 10 bits/sample, 5.83 KHZ noise bandwidth, 0.22 MBPS Rate
Upper Atmospheric Sounder	56	40	Non-scanner, 4 or more channels	10 KBPS
Atmospheric Pollution Sensor	30	10	FOV 5° x 5°	400 BPS
Passive Multichannel Microwave Radiometer	513	355 (105 ave)	freq. (gilz) / res. (km): 4.99 / 183; 10.69 / 88; 18.0 / 88; 21.5 / 88; 37.0 / 22; conical ± 45° scan	10 KBS Rate
Other	11	--	--	

TABLE B-10

EOS B SENSOR CHARACTERISTICS

EOS-B
Terrain Survey/Oceanography

Sensor	Wt. (lb.)	Power (Watts)	Description Orbit Adjust Required	Data Characteristics
Oceanic Scanning Spectrophotometer	45	60 (25 ave.)	Same	See EOS A
Sea Surface Temperature Imaging Radiometer	45	30	Same	See EOS A
Thematic Mapper	265	140 (40 ave.)	7 Channels, 66 rad resh	6 Channels 4200 x 4200 pixels (7 bits/pixel) 1 Channel 1300 x 1300 pixels (7 bits/pixel) (31 MBPS at 85% scan efficiency)
	70	(40 ave.)	Wide Band Video Tape Rec. 30 min. record time (30 mb/sec.)	
	50	50	Precision Altitude Determination System	
Upper Atmospheric Sounder	50	40		See EOS A
Other	115	25	To be selected	No Data

FIGURE B-3

EOS/PSS EXPERIMENT ORT INTERFACE

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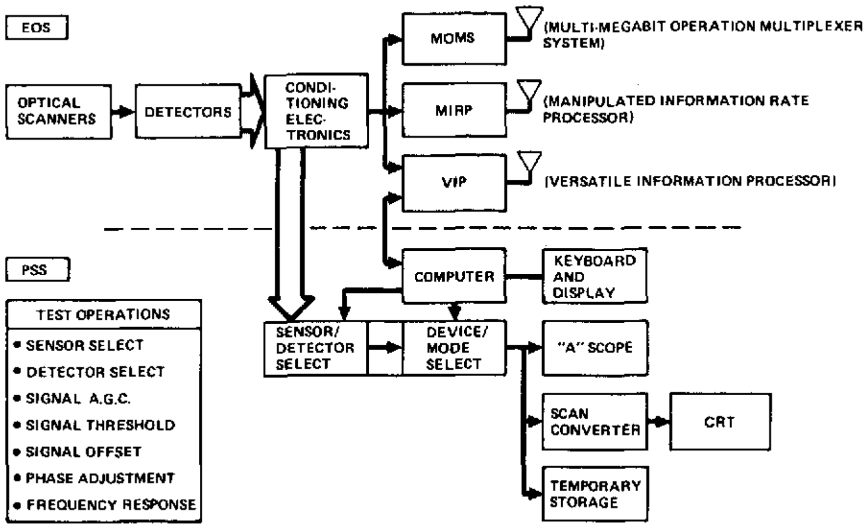

prior to release from Shuttle; i.e., existing satellite design prohibits deployment and retraction.

B. Low Earth orbit operations are somewhat time constrained due to the criticality of the departure time for geosynchronous ascent and thermal limitations of geosynchronous satellites.

C. The natural operational environment for the satellites is at geosynchronous station where ground station contact time is continuous and the satellite is in a fully operational condition.

It is recommended however that normal response of the Tug command system be demonstrated prior to release from Shuttle primarily from a Shuttle safety standpoint. An end-to-end check of this system requires RF command transmission from Shuttle to Tug. Options available are usage of an antenna hat on the Tug receiving antenna to accomplish an effective hardwired RF test or usage of the normal Shuttle RF uplink system with suitable attenuation. The latter option is selected primarily on the basis of avoidance of providing the in bay antenna hat and the attendant mechanisms for hat removal and stowage.

TABLE B-11

CLASS II, MISSION FLIGHT PROFILE

Phase	Time
1. Shuttle ascent to 50 nmi.	8.8 min.
2. Shuttle 50 x 100 nmi. transfer orbit	43.7 min.
3. Shuttle 100 x 100 nmi. intermediate orbit	88.3 min.
4. Shuttle 100 x 160 nmi. transfer orbit	44.7 min.
5. Shuttle 160 x 160 nmi. circularization	45.3 min.
6. Payload deployment (from Shuttle)	
A. Payload in release position (Umbilical connected)	
B. Payload in release position (Umbilical disconnected)	
*7. Free-flying payload 160 x 160 nmi. orbit	Variable
*8. Phasing orbit 160 x variable nmi.	Variable
9. Geosynchronous ascent 160 x 19,323 nmi.	318 min.
10. Synchronous orbit	
A. Satellite attached to Tug	
B. Satellite separated from Tug	

*Time varies dependent upon longitude of geosynchronous station.

TABLE B-12

LST SYSTEMS FOR ATTACHED ORT

- Communications/Data Handling
- Electrical Power and Distribution
- Attitude Control Sensors and System
- Navigation and Control System
- Deployables
  - Solar Arrays
  - Light Shield
- SIP Instruments (via LST self check logic)

It is therefore recommended that this test be performed subsequent to raising of the payload/tilt table to the 50 degree position to facilitate use of the baseline Shuttle uplink system and to avoid RF radiation in the payload bay. Testing in this posture requires a suitable payload-sun orientation via the Shuttle control system to provide a suitable thermal environment for the satellite(s).

B.1.4.3 Mission Class III (LST)

The recommended approach for Shuttle attached ORT of the LST is one of performing verification of the systems shown in Table B-12. These recommendations stem from the fact that a 150 hour orbital wait period is required for thermal stabilization of the LST optics. This period coupled with the normal activation/calibration time required for ground controlled completion of released ORT by orbital test plan exceeds the normal seven day stay time of the Shuttle. It is therefore recognized that an early assessment of LST systems performance is necessary to permit return of a malfunctioning LST to Earth via the delivery Shuttle.

It is also worthy of note that the latest planned Shuttle delivery trajectory for LST (Table B-13) requires addition of the OMS kit in the payload bay. This installation precludes installation of the docking module which prohibits on-orbit man repair of a malfunctioning LST by the delivery Shuttle unless EVA is utilized.

Testing of the LST is constrained for the first 48 hours of orbital life for outgassing completion. Checkout of the optics is not feasible since 150 hours are normally required for thermal stabilization prior to calibration. A typical sequence for the LST attached ORT is shown in Table B-14.

It is recommended that the attached ORT be controlled from the Shuttle via the same rationale used for EOS attached ORT. Ground station viewing time restrictions are not as severe as with the EOS mission but completion of the testing which would commence during the 31st orbit would require the interaction of numerous ground stations. The Shuttle controlled operation is recognized as an improved operation.

TABLE B-13

LST MISSION DELIVERY PROFILE

Altitude 330 nmi (611 km)

Inclination 28.5° (0.5 rad)

Phase	Time
Ascent to 50 nmi	8.8 min
Transfer orbit (50 x 100 nmi)	43.7 min
Intermediate orbit (100 x 330 nmi)	44.1 min
Transfer orbit (100 x 330 nmi)	46.3 min
Operational orbit (330 nmi) (611 km) two orbits for ephemeris data	194 min

TABLE B-14

LST ORBITAL OPERATIONAL SEQUENCE

On orbit arrival

EPS and distribution buses energized

OTA thermal system on

Open payload bay doors and erect LST

LST systems turn on

Attitude control systems checks (thrusters inhibited)

Erect sun shade

Deploy solar array

Power distribution and load check

Retract solar array

(48 hour wait for outgassing-REF orbital arrival)

Energize SIP; verify instruments and power supplies

Orient optics away from sun

Remove contamination covers

Confirmation of release readiness

Transfer LST to internal power (batteries)

Eject and stow electrical umbilical

Deploy LST with Shuttle RMS

- -

150 Hr. Wair period for thermal stabilization (Ref. orbital arrival)

ORT by ground station and orbital test plan

B.2 INTEGRATED OPERATIONS

Integration of attached ORT activities into representative pad and flight time lines is shown in Figures B-4 through B-6 for the study mission classes.

As a result of the payload Shuttle integration trades performed in Task 1, payloads will probably be installed in the vertical Shuttle at the launch site. Satellite propellant systems will have been loaded and pressurized and ordnance will have been installed prior to this integration.

B.2.1 Mission Class I (EOS)

The first activity subsequent to satellite installation in Shuttle is performance of a Shuttle payload functional interface test whose purpose is to demonstrate the complete electrical interface between Shuttle and the EOS. C&W and housekeeping data monitoring will be initiated at the same time and will remain active until the satellite umbilicals are demated in preparation for satellite release from Shuttle. Trickle charge will be supplied to the satellite batteries. Satellite power requirements will be satisfied by ground power until T-30 minutes at which time transfer will be made to Shuttle power.

The lift off configuration of the satellite is therefore one of quiescence with the exception of power to the hardwired C&W system, the telemetry system and the battery trickle charge. These conditions prevail until attached ORT is initiated at approximately T+50 hours. Subsequent to completion of ORT (T+65 hours) deployment preparations are initiated and the satellite is released. Deployment activities are summarized in Table B-15.

B.2.2 Mission Class II (ATS/SMS/DSCS with Tug)

The first integrated activity for the class II missions is performance of the interface functional test as described for the class I mission. C&W and housekeeping data monitoring are initiated at the same time and remain active until demating of the Tug electrical umbilical which immediately precedes payload release from the Shuttle. The AOT (Avionics Operational Test) is performed following the interface functional test and is dedicated to performing launch readiness confirmation of the Tug vehicle. Tug propellant loading is accomplished during the Shuttle countdown.

The lift off configuration of the payload is as follows:

A. Satellite

1. C&W system activated
2. Telemetry system activated
3. Trickle charge from Shuttle

B. Tug

1. Inertial guidance system on in navigation mode viz., IMU and GC are on
2. C&W system activated
3. Telemetry system activated
4. Trickle charge from Shuttle

These conditions prevail until the initiation of payload deployment activities at the 160 nautical mile orbit. Deployment activities are summarized in Table B-16.

B.2.3 Mission Class III (LST)

The integrated operations activities for LST are identical to the Class I EOS mission with the exception that attached ORT is estimated at 10 hours as opposed to 15 for the EOS.

Figures B-4, B-5 and B-6 provide the time lines for the previously integrated activities. Figure G-7 presents a summary of activities for the mission class payloads during the various phases of the flight profile.

TABLE B-15

CLASS I DEPLOYMENT ACTIVITIES

(Satellite in vertical position for attached ORT)

Retract solar arrays and sensor bays
Transfer satellite to battery power
Raise satellite to release position with RMS
Remove and secure electrical and propulsion umbilicals
Release satellite
Shuttle establish separation distance

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FIGURE B-4

MISSION CLASS I(EOS) SHUTTLE INTEGRATED OPERATIONAL PLAN

40451-1

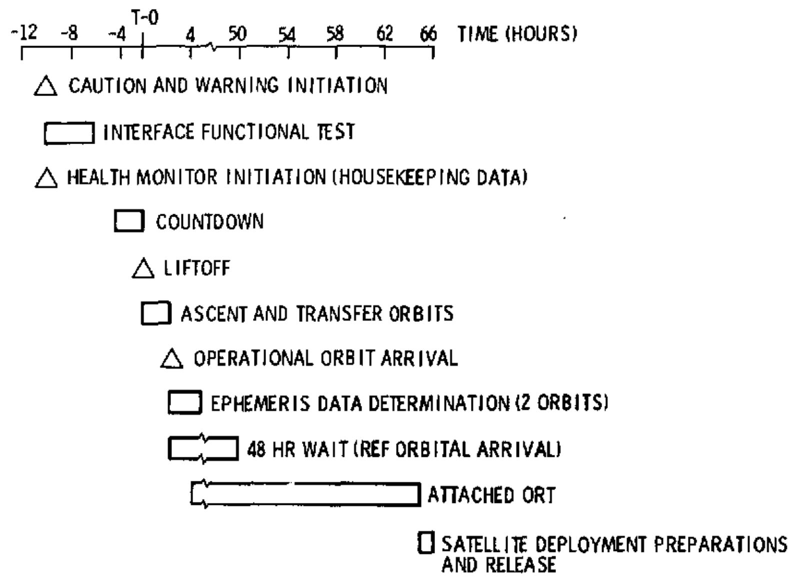

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FIGURE B-5

MISSION CLASS II SHUTTLE INTEGRATED OPERATIONAL PLAN

40451-2

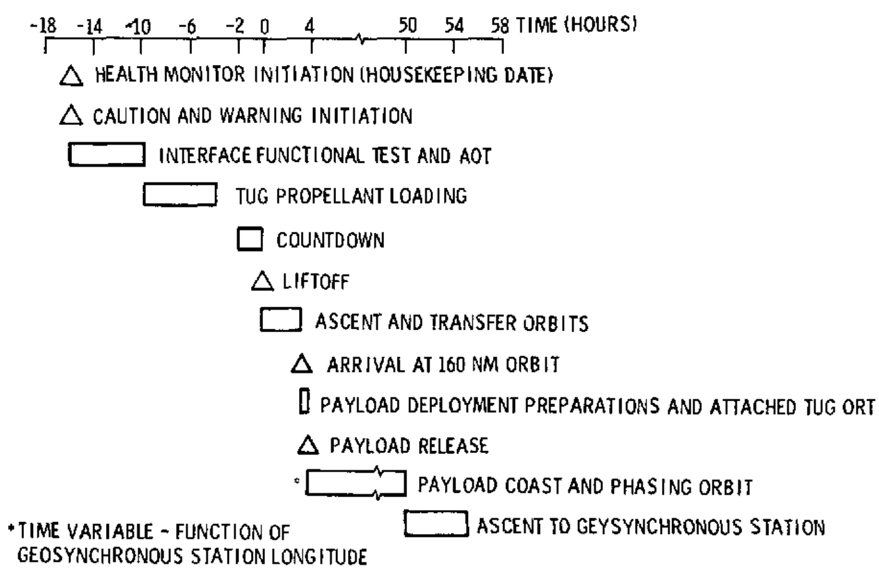


FIGURE B-6

MISSION CLASS III(LST) SHUTTLE INTEGRATED OPERATIONAL PLAN

40451-3

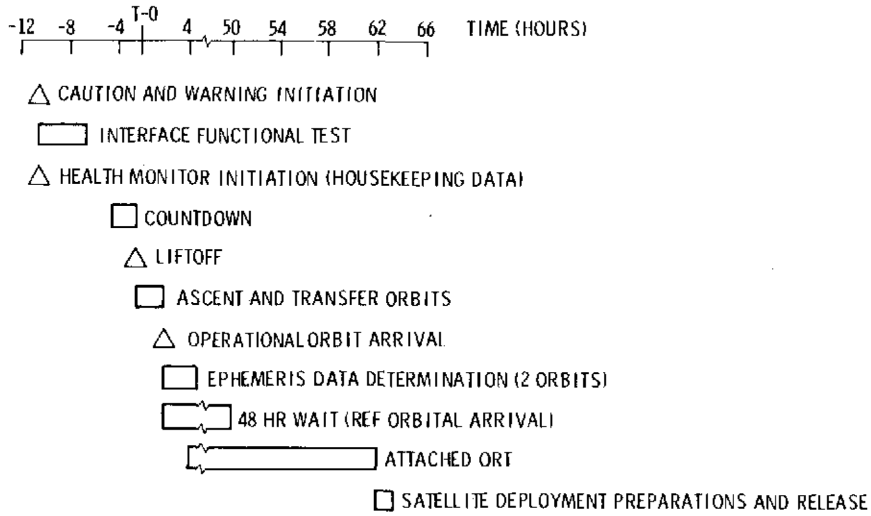


TABLE B-16

CLASS II MISSION DEPLOYMENT ACTIVITIES

Update Tug inertial guidance system with state vector data (attitude, position, velocity, time)

Raise tilt table to release position

Terminate battery trickle charge

Perform attached ORT - (Tug command system checkout)

Remove and secure electrical and propulsion umbilicals

Release payload

Shuttle establish separation distance

Tug perform automated self checks, initiate rotisserie flight mode

FIGURE B-7
CHECKOUT/ORT SUMMARY

40444

<table>
<tr><th rowspan="2">MISSION CLASS</th><th rowspan="2" colspan="2">PRELAUNCH (ON SITE)</th><th rowspan="2">ASCENT TO LOW EARTH ORBIT</th><th colspan="2">LOW EARTH ORBIT</th><th rowspan="2">GEOSYNC ORBIT</th></tr>
<tr><th>ATTACHED TO SHUTTLE</th><th>SEPARATED FROM SHUTTLE</th></tr>
<tr><td>I
(EOS)</td><td colspan="2">• INTERFACE TEST
• C&W MONITOR
• HEALTH DATA</td><td>• C&W MONITOR
• HEALTH DATA</td><td>• C&W MONITOR
• HEALTH DATA
• ORT (SHUTTLE CONTROL)
POWER
DEPLOY TEST
COMMAND/DATA
EXPERIMENTS</td><td>• ORT (ORBITAL TEST PLAN)
GROUND CONTROL
SHUTTLE ESCORT/ASSIST</td><td></td></tr>
<tr><td rowspan="5">II
(ATS/SMS/DSCS-TUG)</td><td>SATELLITE</td><td>TUG</td><td>SATELLITES AND TUG</td><td>SATELLITES AND TUG</td><td>TUG</td><td>SATELLITES</td></tr>
<tr><td rowspan="4">• INTERFACE TEST
• C&W MONITOR
• HEALTH DATA</td><td rowspan="4">• INTERFACE TEST
• C&W MONITOR
• HEALTH DATA
• AOT</td><td>• C&W MONITOR
• HEALTH DATA</td><td>• C&W MONITOR
• HEALTH DATA</td><td rowspan="4">• AUTO SELF CHECKS</td><td rowspan="4">• ORT (ORBITAL TEST PLAN)
GROUND CONTROL
TUG ESCORT</td></tr>
<tr><td>TUG</td><td>TUG</td></tr>
<tr><td>• NAVIGATION DATA</td><td>• FUEL CELL CHECKS AND ACTIVATION
• SYSTEMS TURN ON
• GUIDANCE UPDATE
• COMMAND/DATA
• INTERNAL TEST</td></tr>
<tr><td></td><td></td></tr>
<tr><td>III
(LST)</td><td colspan="2">• INTERFACE TEST
• C&W MONITOR
• HEALTH DATA</td><td>• C&W MONITOR
• HEALTH DATA</td><td>• C&W MONITOR
• HEALTH DATA
• ORT (SHUTTLE CONTROL)
ACS
CMG'S
DEPLOY TEST
POWER
COMMAND/DATA
EXPERIMENTS</td><td>• ORT (ORBITAL TEST PLAN)
GROUND CONTROL
SHUTTLE ESCORT/ASSIST</td><td></td></tr>
<tr><td>IV
(SORTIE LAB)</td><td colspan="2">• INTERFACE TEST
• C&W MONITOR</td><td>• C&W MONITOR</td><td>• C&W MONITOR
• EXPERIMENT OPERATION</td><td></td><td></td></tr>
</table>

ORT IS: OBSERVATION OF DATA RESULTING FROM A SPECIFIC SYSTEM INPUT (STIMULUS)

Tables B-17 and B-18 present the control and related monitor functions required for each mission class based primarily on operational considerations such as ORT, deployment, ground testing, etc. These tables in conjunction with the C&W requirements noted in Tables B-3 through B-7 provide the total payload discrete control and display requirements.

B.3 EQUIPMENT SELECTION (MODE VARIATIONS)

Table B-19 provides a summary of mandatory functions/capabilities that are required of on-board Shuttle equipment to provide in flight processing of payloads.

Figure B-8 presents the SOAR II equipment system which essentially satisfies the requirements in Table B-19 with the exception of experiment checkout capability. The purpose of the following is the generation of equipment selections based on the requirements generated in the previous section which are somewhat different from SOAR II results using the system shown in Figure B-8 as the baseline.

40499

TABLE B-17
SATELLITES AND SORTIE LAB CONTROL AND RELATED MONITORING FUNCTIONS

CONTROL	MONITOR	MISSION CLASS I (LOS)	II (ATS/SMS/DSCS)			III (LST)	IV (SL)
TIE-DOWN RELEASE	RELEASE/SECURE	●	-	-	●	●	-
COLD GAS VENT	OPENED/CLOSED	●	-			●	
HYDRAZINE VENT	OPENED/CLOSED	●	●	●	●		
HOLDING TANK DUMP (OPTIONAL)	OPENED/CLOSED	●	●	●	●		-
S&A SAFE-ARM	SAFE/ARMED	●	●	●	●	●	-
ELEC. UMBILICAL RELEASE	DISCONNECTED/CONNECTED	●	-	-	-	●	-
PROPULSION UMBILICAL RELEASE	DISCONNECTED/CONNECTED	●	●	●	●		
TRANSFER TO INTERNAL POWER	INTERNAL/EXTERNAL*	●	●	●	●	●	
EXTERNAL POWER	EXTERNAL/INTERNAL*	●	●	●	●	●	●
TRICKLE CHARGE (OPTIONAL)	ON-OFF	●	●	●	●	●	-
TELEMETRY SYSTEM	ON-OFF	●	●	●	●	●	●
TRACKING SYSTEM	ON-OFF	●	●	●	●	●	-
COMMAND SYSTEM	ON-OFF	●	●	●	●	●	-

* COMMON

40369

TABLE B-18
TUG CONTROL AND RELATED MONITOR FUNCTIONS

FUNCTION	CONTROL	MONITOR
IMU	ON-OFF	ON-OFF
IMU PREHEAT	ON-OFF	ON-OFF
GUIDANCE COMPUTER	ON-OFF	ON-OFF
TELEMETRY SYSTEM	ON-OFF	ON-OFF
TRACKING SYSTEM	ON-OFF	ON-OFF
COMMAND SYSTEM	ON-OFF	ON-OFF
POWER SYSTEM	INTERNAL-EXTERNAL	INTERNAL-EXTERNAL
POWER SELECT	BATTERY/FUEL CELL	INTERNAL-EXTERNAL
ELECTRICAL UMBILICAL	RELEASE	(STATUS)
PROPULSION UMBILICAL	RELEASE	(STATUS)
TILT TABLE TIE-DOWN	RELEASE	(STATUS)
TILT TABLE	RELEASE (TUG)	(STATUS)
FUEL CELL SHUT OFF VALVES (2)	OPEN-CLOSE	OPEN-CLOSE

FIGURE B-8

SOAR II PSS

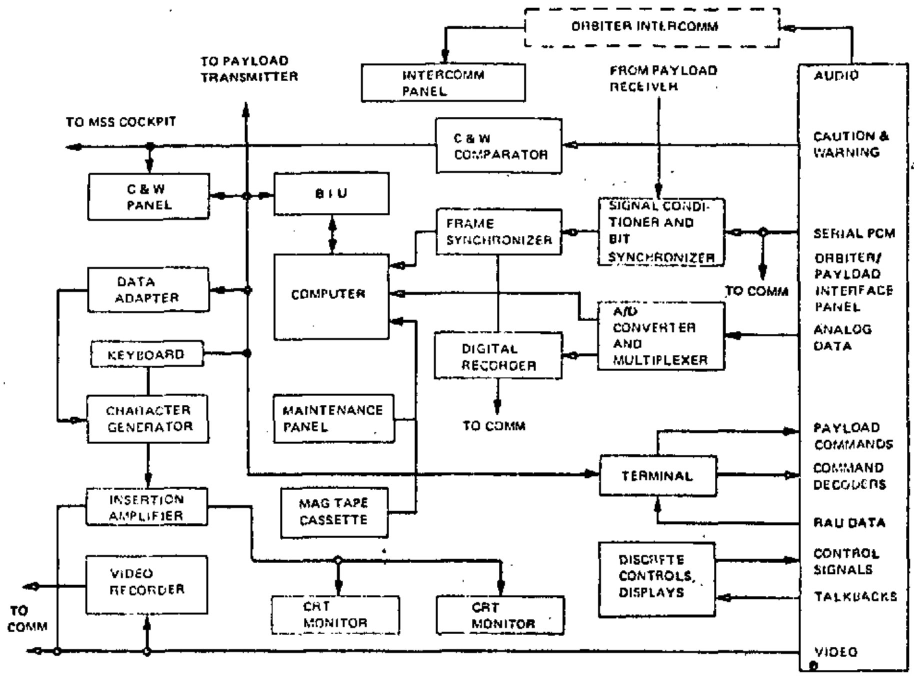


Table B-19

PAYLOAD EQUIPMENT REQUIREMENTS

- Caution and warning processing and display
- Caution and warning related control
- Telemetry signal processing and display
  - C&W backup
  - Housekeeping data
- Vehicle and flight support equipment control
  - Deployment
  - CRT
- Communications + audio
- Experiment checkout (mission class I and III only)

TABLE B-20
DATA REQUIREMENTS

40370

	MISSION CLASS I	II				III	IV
	EOS	**ATS	DSCS	SMS	TUG	LST	SORTIE LAB
DATA RATE (BPS)	*1K-12.5K	384	250	194	51K/ 1.6K	51.2K/ 1.6K	UNDF
BITS PER WORD	UNDF	9	8	9	UNDF	8/8	UNDF
MAIN FRAME PERIOD (SECS)	UNDF	9	1.024	2.97	UNDF	0.02/1	UNDF
FRAME SYNC (WDS)	UNDF	IN 1ST 16	1ST 4	1ST 2	UNDF	4/4	UNDF
MAIN FRAME (WORDS)	UNDF	368	32	64	UNDF	128/200	UNDF
DWELL MODE	PROBABLE	YES	PROBABLE	YES	UNDF	PROBABLE	UNDF
FORMAT	UNDF	BIØ-L	NRZ-L	UNDF	NRZ-L	UNDF	UNDF
SUBCOMMUTATION WORDS	UNDF	LAST 16 16 DEEP	64 & 128	32 & 64	UNDF	UNDF	UNDF

*VARIABLE - SELECTABLE BY PROGRAMMING; **ATS F&G; ATS H&I UNDEFINED

B.3.1 C&W Processing and Display

Caution and warning (C&W) primary monitor criteria (Section B.1.2) are satisfied by the conceptual system shown in Figure B-9 which provides a dedicated hardwired system including a display panel and aural indications. Backup for the hardwired system is provided via computer processing of the payload telemetry signal and CRT display. Table B-20 presents the characteristics of the satellite telemetry data by mission class which must be processed on board the Shuttle to satisfy C&W monitor backup requirements and to provide the capability to process and display payload health and test data. Figures B-10 and B-11 present the systems recommended to provide this capability. The DSCS system is somewhat different since data from two satellites must be processed and displayed which essentially adds the requirement for multiplexing and demultiplexing of the PCM telemetry hit streams in addition to the DOD communication security equipment.

Checkout of the systems for all mission classes and safety considerations discussed under ORT dictate that the capability to command each type of payload is required onboard the Shuttle. It is therefore deemed mandatory that command encoding equipment capable of controlling each mission model be installed in the Shuttle. RF equipment included in the baseline Shuttle is sufficient to provide verification of the housekeeping RF data link.

C&W related control (switching) requirements such as vent controls, dump controls, are ground ruled as dedicated hardwired circuits. These requirements as well as switching required for inflight operations such as deployment activities are conveniently satisfied by a dedicated discrete control panel which includes bi-level indications of switching status. These control and monitor requirements are summaried in Table B-21.

Recording capability is recommended for the payloads onboard the Shuttle for the following reasons:

A. Payload housekeeping data should be recorded so that a data sump can be made to ground stations to provide data to the controlling agency that was lost due to RF viewing constraints and to provide an historical record of payload in bay performance.

FIGURE B-9

CAUTION AND WARNING MONITOR SYSTEM

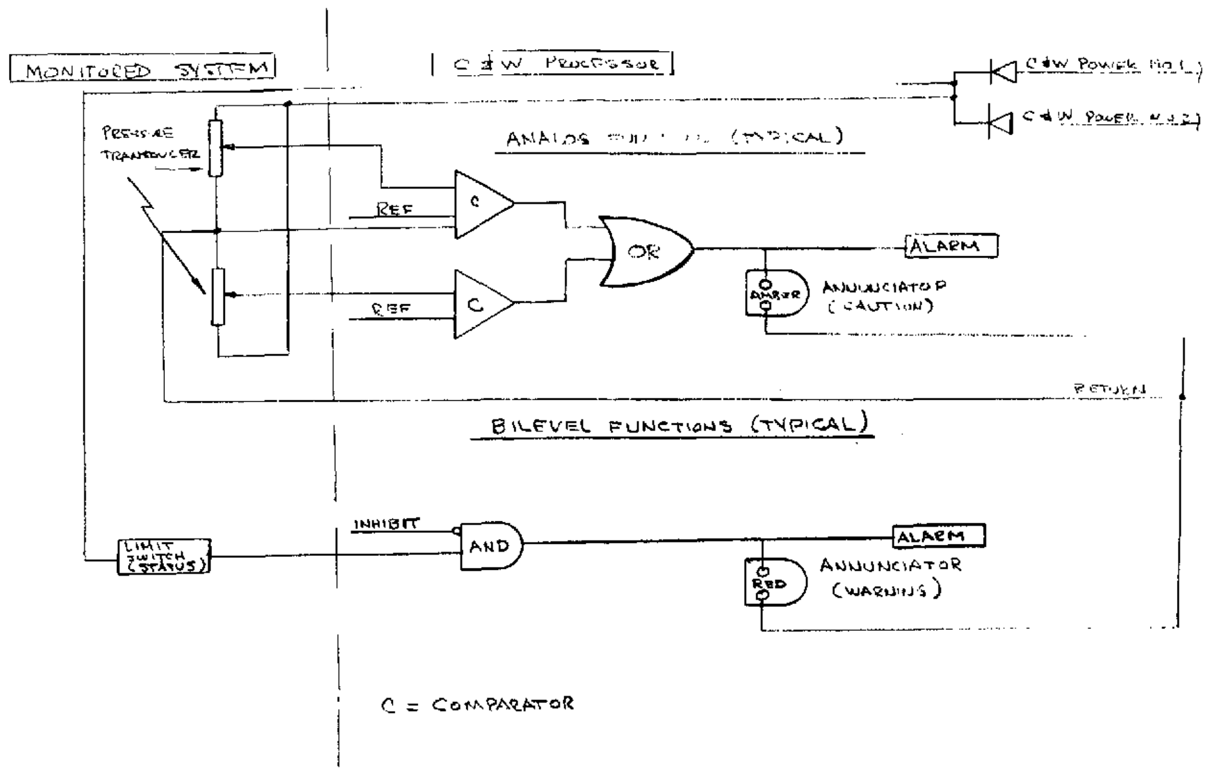


FIGURE B-10

DATA PROCESSING AND DISPLAY

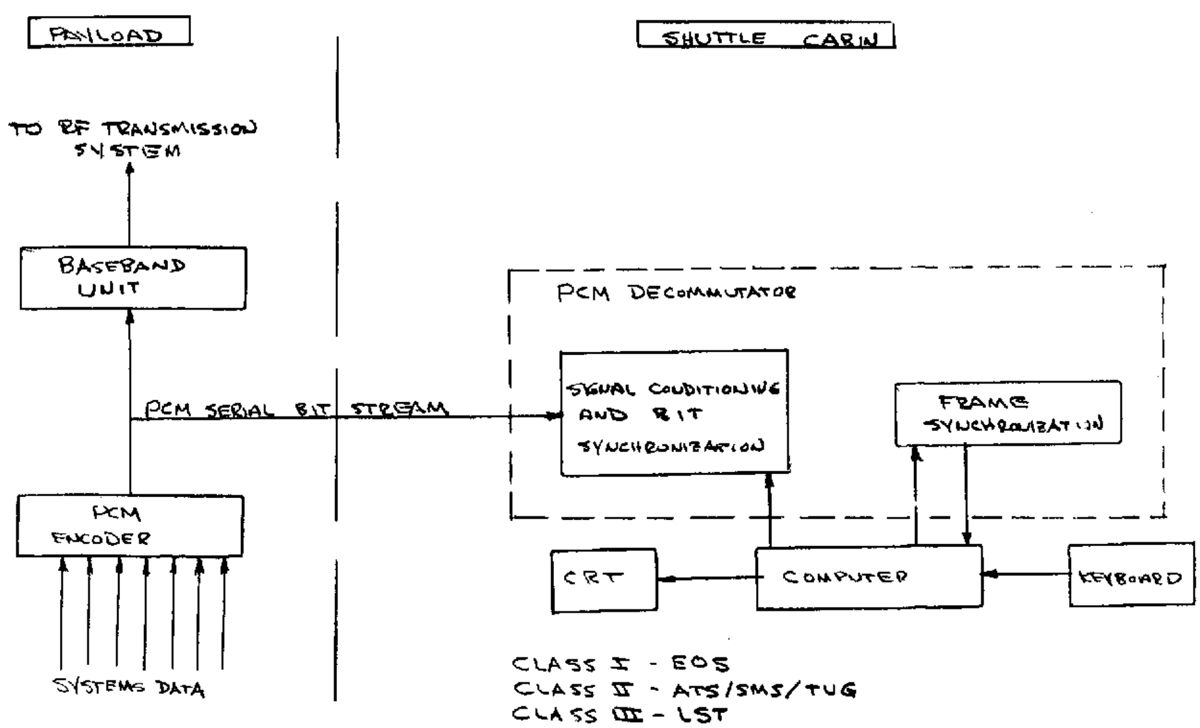


FIGURE B-11
DATA PROCESSING AND DISPLAY

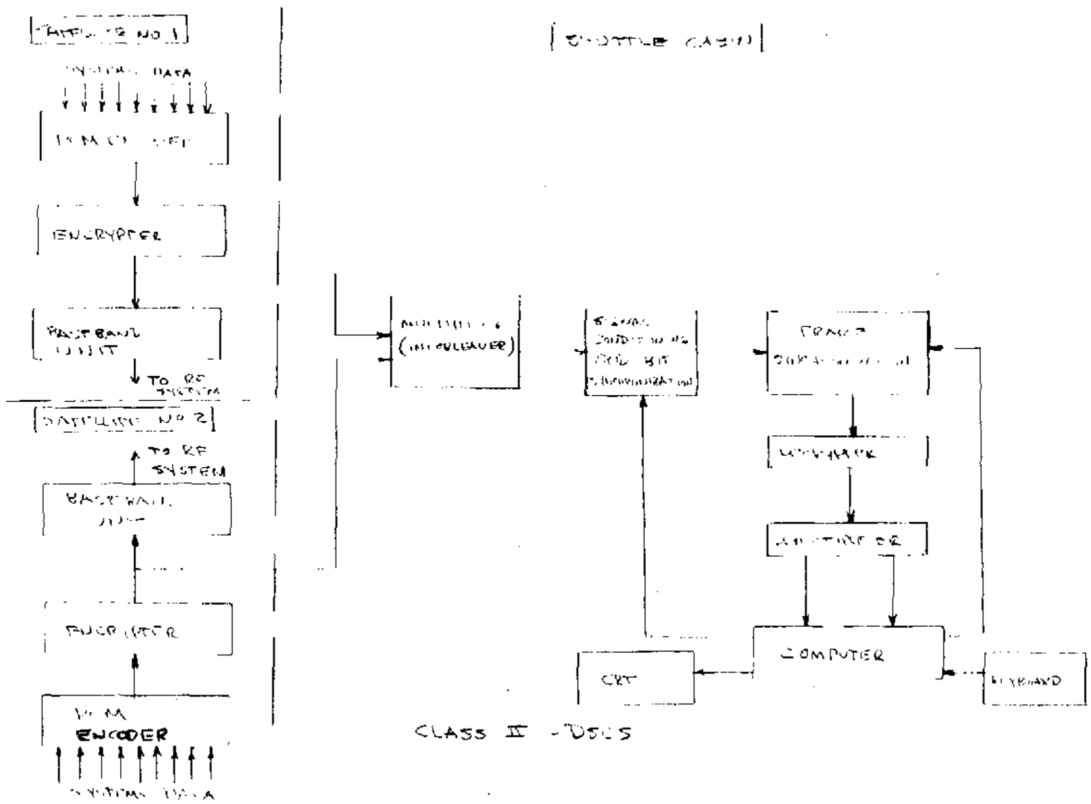


TABLE B-21
MSS/PSS FUNCTIONS

40371

	I (EOS)	II (ATS/SMS/DSCS/TUG)				III (LST)	IV (SORTIE LAB)
		ATS	SMS	DSCS	TUG		
CAUTION AND WARNING DISPLAY							
PAYLOAD							
FUNCTIONS	9	7	8	14	32	4	22
ANNUNCIATORS	6	6	6	12	17	3	11
*FLIGHT SUPPORT EQUIPMENT							
FUNCTIONS	7	7	7	8	7	4	4
ANNUNCIATORS	4	4	4	5	4	4	4
CONTROL PANEL							
CAUTION AND WARNING RELATED							
PAYLOAD	4	4	3	6	11	2	8
PAYLOAD BAY	3	3	3	3	--	-	-
OTHER (DEPLOYMENT, ETC.)							
FUNCTIONS AND ANNUNCIATORS	8	6	6	6	14	6	2

*INCLUDES OPTIONAL PAYLOAD BAY HOLDING TANK PRESSURE AND TEMPERATURE MONITOR AND LEAK DETECTION

B. A record of C&W events, C&W related switching actions and deployment switching activities is desirable.

C. Video recording capability is desirable to record video derived from deployment activities and to record data displayed on the CRT. It is also desirable to provide video recording capability in order to record surveillance related to C&W backup viewing of propulsion system lines, electrical umbilicals tie down systems, etc.

It is a foregone conclusion that computer facilities are required aboard the Shuttle to provide support for payloads. Table B-22 provides a summary of identified computer controlled operations by mission class.

CRT requirements are integrated closely with the noted computer operations in that housekeeping data display is accomplished via a CRT. CRT is also required to display cargo bay video data from inspection, deployment activities, etc. Some discussion has evolved concerning the option of one versus two CRTs for payload data display and video information display. This study recommends that two separate CRTs be provided for the aforementioned functions based on the following rationale.

A. CRT display is required for C&W backup data display and should therefore be available on a continuous basis for this purpose.

B. Payload personnel (MSS or PSS) should have unrestrained payload bay video access to determine/monitor the status of the payload at any time.

B.2.3.1 Commonality Assessment

The mission classes C&W control and monitor and other control requirements were surveyed to determine the total payload control and display requirements in Shuttle. These numbers are summarized in Table B-21. Analysis of these requirements leads to the following conclusions:

A. A satellite common C&W logic assembly and display panel is logical based on the numbers required for each satellite. The maximum number of annunciators is distorted by the two satellites-DSCS missions at 15. Common design dictates that the comparator section of the electronics be accessible and easily adjustable to provide a choice of threshold values. Changes in nomenclature can be readily handled via legend overlays.

B. The control panel provided for satellite C&W related switching and for other activities such as deployment preparations, evidences sufficient similarity to be classified as common. Variances in nomenclature can be handled by use of overlay legend assemblies.

C. The Tug C&W logic and related controls, and other controls should be provided as Tug peculiar equipment since there is virtually no similarity to spacecraft required equipment.

Table B-23 summarizes the recommendations related to classification of payload required equipment as GFE or user supplied.

Information related to the command encoding units for several of the study spacecraft is sparse. However, because of the wide diversity that generally exists in command systems, viz., rate, word length, encoding schemes, modulation, etc., and because of the requirement for security equipment for DOD missions (DSCS), it is recommended that command encoding equipment be supplied by the user until standardization of satellite command systems reaches a degree wherein it is feasible to become Shuttle Supplied GFE.

TABLE B-22

COMPUTER FUNCTIONAL REQUIREMENTS

- o CRT display control
- o Data limit checks - analog and discrete
- o Leak detection computation
- o Processing of navigation data
- o Guidance and navigation system updating
- o PCM data processing
- o Caution and warning limit checks
- o Uplink, downlink control

TABLE B-23

PAYLOAD FSE COMMONALITY ASSESSMENT

1. C&W processor (satellite) C&W display panel	GFE	Similarity in mission model requirements indicates usage of a common assembly is warranted. Nomenclaute variances handled by legend overlays.
2. C&W Processor (Tug)	GFE	Required for Class II Missions only. Classified as Tug peculiar item. Virtually no similarity between satellite and Tug requirements.
3. Control panel (satellites)	GFE	Similarity in mission model requirements indicates usage of a common assembly is warranted. Nomenclature variances handled by legend overlays.
4. Control panel (Tug)	GFE	Required for Class II Missions only. Classified as Tug peculiar item. Virtually no similarity between satellite and Tug requirements.
5. PCM decommutator	GFE	Required for all mission classes for processing of PCM data for C&W redundancy and acquisition of housekeeping data.
6. Payload computer/CRTS	GFE	Required for all mission classes for C&W redundant display housekeeping data display and display of payload bay video information.
7. Recorders		
Digital	GFE	C&W events (alarms and switching) should be recorded on all mission classes. Housekeeping data should be recorded to assist ground stations in data acquisition under ground station LOS conditions.
Wideband	GFE	Highly desirable to record deployment activities (video) for all mission classes and to provide capability to record experimental data for purposes of assisting ground stations during experimental orbital readiness tests by orbital test plan.
8. Command equipment	User	Wide diversity in encoding schemes and equipment by mission classes. DOD (DSCS) requires security equipment. Equipment should be user supplied until sufficient commonality exists to warrant GFE classification.
9. Special purpose equipment Experiment checkout equipment Encrypters, decrypter: Interleavers, demultiplexers	User	No mission commonality, program unique requirements.

B.2.3.2 Mission Specialist/Payload Specialist Operations

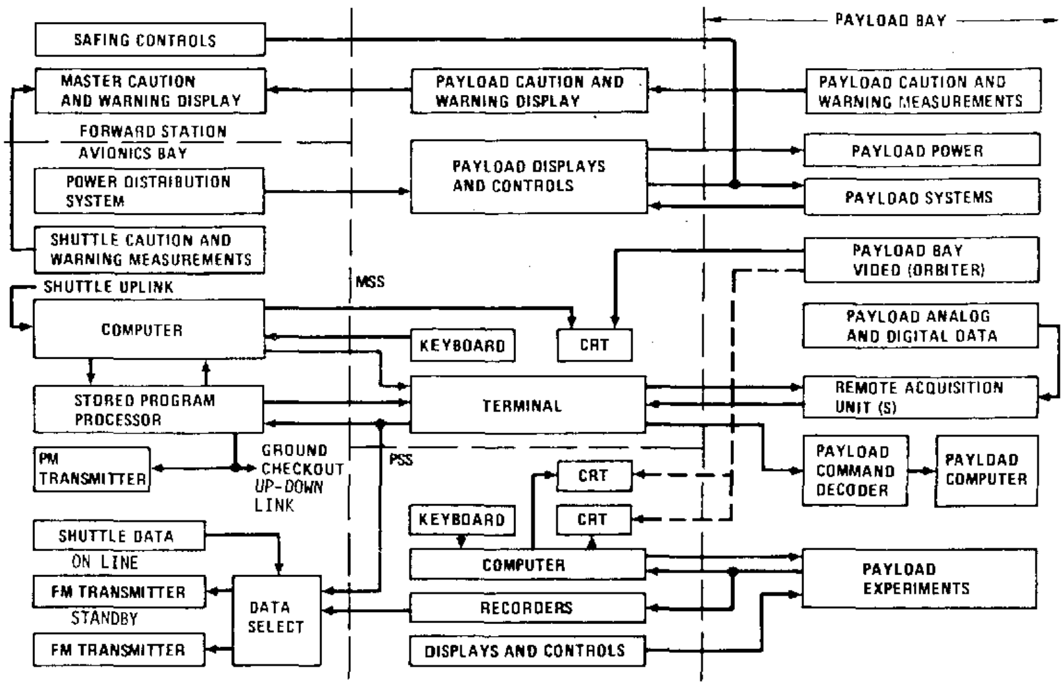
The representative timelines established for mission classes in-flight operations (Figures B-4, B-5 and B-6) were analyzed for purposes of determining the optimum allocation of equipment and responsibilities to the MSS and PSS.

The interpretation of the JSC allocation (Figure B-12) provides for primary control and monitoring of the satellite systems at the MSS. Experimental control and monitoring of the satellite were allocated to the PSS.

SOAR-II recommendations for the MSS and PSS capabilities differ from the JSC approach in that primary control and monitoring of the satellite was established at the PSS (Figure B-13).

FIGURE B-12

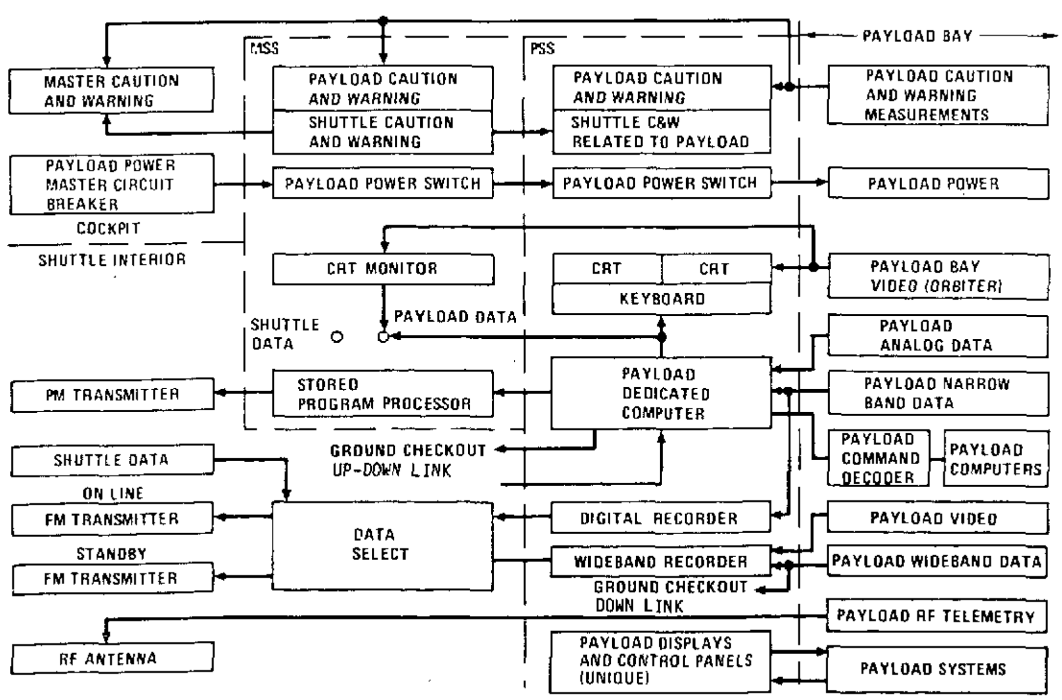
MSS/PSS CONFIGURATION*



* Reference JSC 07700 - March 20, 1973

FIGURE B-13

MSS/PSS CONFIGURATION - SOAR II



B.2.4 Class II Missions

The Class II missions were selected to provide an assessment of operator capabilities/responsibilities since it was judged to be the most taxing from an operator/equipment viewpoint due to multiple vehicle involvement. Figure B-14 presents a representative timeline for low Earth orbital operations for the Class II (geosynchronous missions) with the period of interest commencing at arrival at the 160 nmi. and continuing through payload release from Shuttle.

The selection drivers for the MSS/PSS operational responsibilities are the time constraints related to satellite thermal considerations and phasing for proper longitudinal station, the numbers of different activities that are in progress and an estimate of the skills that can be logically attributed to each operator, vix., MSS and PSS.

Activities during the noted period are generally expedited both prior to and subsequent to payload bay door opening due to satellite thermal considerations related to sun derived heating. (Class II satellite launches with expandable vehicles typically utilize a slow spin derived from the delivery vehicle during geosynchronous ascent to avoid exceeding satellite thermal limits.)

From inspection of Figure B-14, it is clear that the majority of preparatory activities are Tug related (and will require the full attention of Tug controller) and occur in parallel with housekeeping data monitoring and caution and warning monitoring activities for both the Tug and satellite(s). Because of the numbers of Tug activities that require performance in a relatively short period (Figure B-14) it is suggested that Tug activities should be managed from one station and that this station should be relieved of satellite related management activities.

Based on an assessment that the MSS operator would be well trained in both Shuttle and Tug systems, i.e., Tug is a component of the STS, it is recommended that Tug activities are most efficiently managed from the MSS. Relief for this station of satellite management activities is provided by assigning satellite management to the PSS. This assignment also appears logical since it is assumed the PSS operator would have a high degree of intelligence/training related to satellite systems.

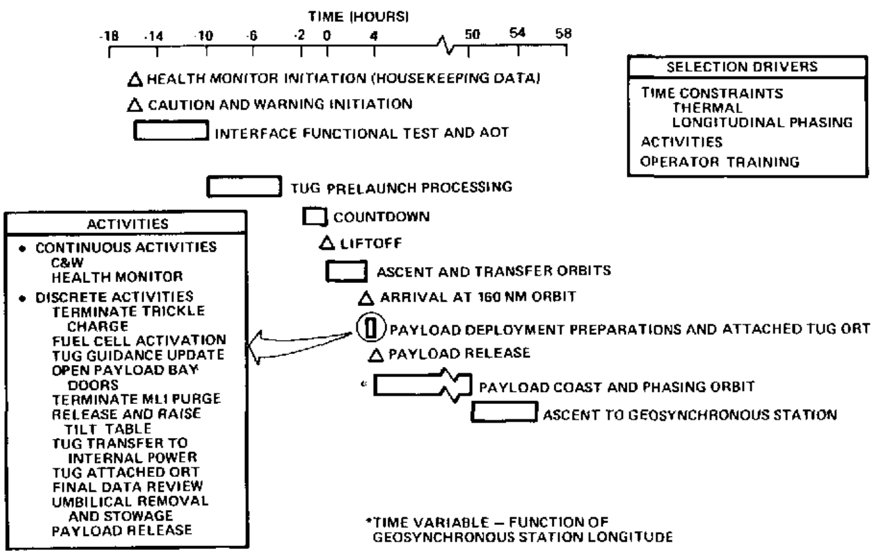
FIGURE B-14
EQUIPMENT ALLOCATIONS

40376

STATION/EQUIPMENT	MISSION CLASS I	II	III	IV
PSS	FUNCTIONS			
● BASIC CONTROL/DISPLAY PANEL COMPUTER/CRTS KEYBOARD DATA PROCESSOR C&W PROCESSOR POWER CONDITIONING DIGITAL RECORDER VIDEO RECORDER	SATELLITE CONTROL AND DISPLAY			EXPERIMENT CONTROL AND DISPLAY IF/AS REQUIRED
● UNIQUE COMMAND ENCODER ENCRYPTER DECRYPTER/DEMULTIPLEXER DSCS PANEL EXPERIMENT TEST EQUIPMENT INTERLEAVER	SPECIAL PURPOSE FUNCTIONS AND/OR USER SUPPLIED EQUIPMENT			
MSS ● BASIC (BASELINE SHUTTLE EQUIPMENT)	ORBITER SYSTEMS CONTROL AND DISPLAY MANAGEMENT OF PAYLOAD SERVICES			
● UNIQUE TUG MISSION MODULE CONTROL DISPLAY PANEL C&W PROCESSOR DATA PROCESSOR	N/A	TUG CONTROL AND DISPLAY	N/A	N/A

FIGURE B-15
MISSION CLASS II SHUTTLE INTEGRATED OPERATIONAL PLAN

40448



The following summarizes the PSS/MSS functional allocations based on the established division of management activities.

A. Prime control and monitoring of the Tug is accomplished from the MSS.

B. Prime control and monitoring of the satellite is accomplished from the PSS.

C. It is desirable to provide a parallel payload computer control by keyboard from both the MSS and PSS. This feature allows the PSS to assist the the MSS during anomaly derived diagnostic activity and also permits the PSS to operate either the computer (Tug or satellite) when the MSS is required for Orbiter vehicle activities.

As previously noted, this division of activities requires the MSS operator to be well versed in the Shuttle and Tug systems and the Orbiter payload interface and provides primary responsibility for the satellite to the PSS operator(s) with the attendant burden of satellite systems intelligence.

The degree to which the capabilities of the payload specialist console are exercised will depend upon the health of the satellites during predeployment. Should satellite status data, being continuously monitored during this period, evince a freedom from anomalies, the payload specialist will have a relatively passive role in on-orbit proceedings. However, the occurrence of an out-of-tolerance condition could result in consideralbe diagnostic activity in support of ground analysis. Whether contingencies of this nature require a fourth crewman will vary with the particular satellite being launched and the degree of training provided the copilot or commander in subsystem design and operation (assuming one or the other were to occupy the PSS station).

As a result of providing satellite systems management at the PSS for the driver Class II missions, and the previously performed equipment commonality assessment wherein it was shown a common block of FSE can satisfy basic satellite management requirements. It appears desirable from a minimum cost standpoint, and the need to maintain surveillance of Orbiter subsystems with the PSS, to manage satellite systems/activities from the PSS for all mission classes. Thus EOS and LST (Classes I and III respectively) are controlled via the PSS with the MSS providing management of Shuttle supplied services. A summary of equipment and functional allocation is provided in Figure B-15.

The SOAR-II version of the PSS shown in Figures B-16 and B-17 conceptually satisfies the requirements of the SOAR-IIS missions and provides the desired

38031

FIGURE B-16
PAYLOAD SPECIALIST STATION

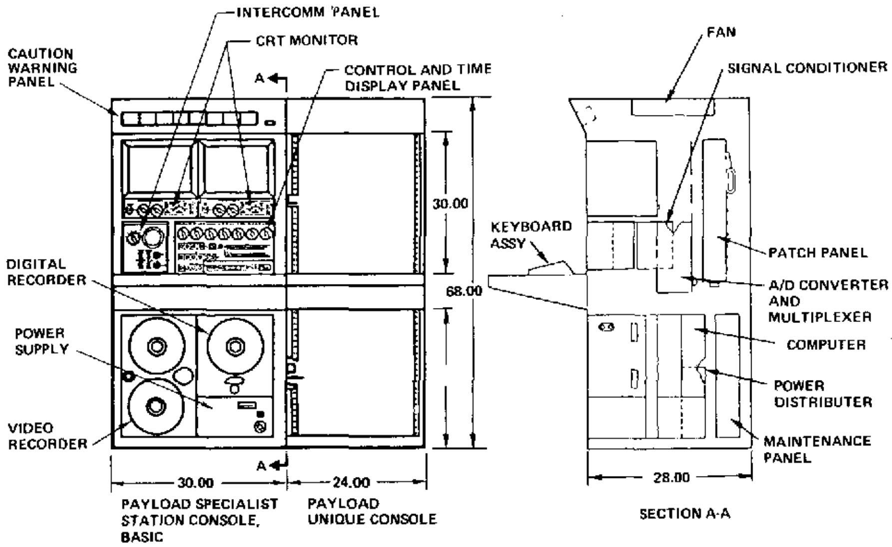


FIGURE B-17
BLOCK DIAGRAM - PAYLOAD SPECIALIST CONSOLE

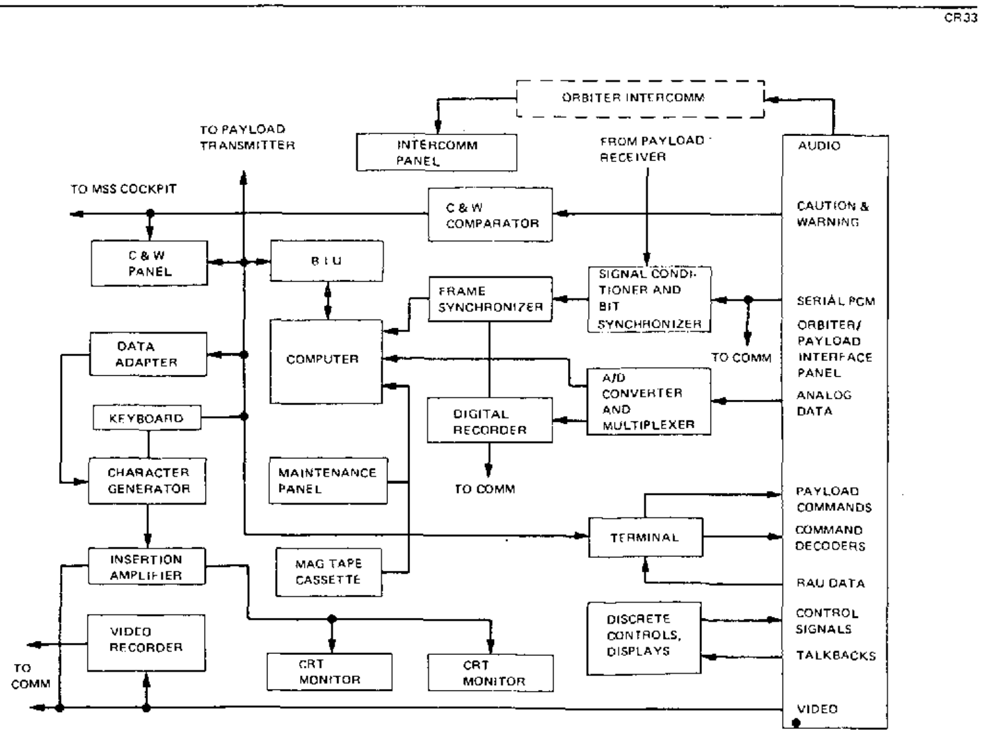


TABLE B-24

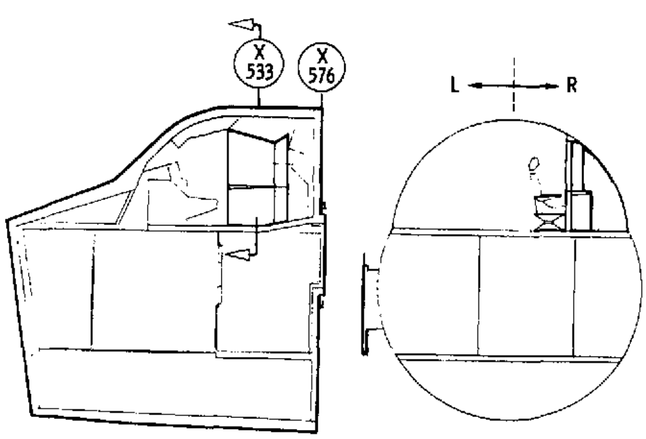
PSS EQUIPMENT CHARACTERISTICS

ITEM	POWER (Watts)	WEIGHT (Pounds)	VOLUME ($Inch^3$)	I.D. NO.
Basic				
CRT (2) Each	80	100	1,458	1
Keyboard	15	15	500	2
Display/Control Panel	15	15	168	3
Computer/Tape Recorder	150	50	768	4
Annunciator Panel	5	10	80	5
Intercomm Panel	6	6	150	6
PCM Simulator	5	10	160	7
Patch Panel	-	20	200	8
Power Conditioner	25	20	448	9
PCM Decommutator	50	20	400	10
C&W Processor	15	10	100	11
Digital Recorder	30	25	2,700	12
Video Recorder	100	40	2,700	13
A/D Converter	5	3	100	17
Special Purpose				
Wideband Recorder	50	22	650	15
Scan Converter	150	100	8,490	16
Decrypter/Demultiplexer	21	19	128	18
Encrypter	11	9	128	19
Command Encoder	5	10	128	20
DSCS-II Control & Display	35	20	420	21
A Oscilloscope	40	20	640	22
Multiplexer	10	10	128	23
* Thermal Generator Service Unit	15	290	17,280	14

* N/R for Study Mission Classes

FIGURE B-18
ORBITER CABIN ARRANGEMENT FOR PSS

40378



REF: R.I. VL70-003217 DTD 4-11-73
FLIGHT SECTION
MCR 200 BASELINE

allocation of activity responsibility related to the analysis performed on low Earth orbital operations, viz., PSS primary control/monitoring of the satellite.

Changes to the SOAR-II version of the PSS stem primarily from the improvement in definition of operational and design requirements and changes in the volumetric allowance in Shuttle for the PSS.

The equipment required to accomplish Shuttle processing of the mission class satellites is shown in Table B-24. The latest Rockwell International version of the Orbiter cabin arrangement for the PSS is shown in Figure B-18. An exercise was performed to determine the feasibility of installing the required equipment in the allotted volume.

Figure B-19 provides a typical equipment installation layout that includes not only the basic equipment but also includes the unique or special purpose equipment for <u>all</u> mission class satellites. The conclusion is therefore that the Shuttle cabin volume allotted to the PSS is sufficient to handle satellite FSE requirements and that no extraordinary geometric shapes are required for the FSE to be accommodated in the Shuttle profile shown in Figure B-19. Figure B-20 provides an illustration of the PSS console which demonstrates the wrap-around configuration of the console again showing the total equipment installation. Equipment locations in the two figures (Figure B-19 and B-20) are identical.

Assignment of Tug control to the MSS requires definition of Tug peculiar MSS equipment requirements. A basic assumption is made that the baseline Shuttle equipment such as computers, CRTS, keyboards and recorders are available for allocation to the Tug vehicle for geosynchronous missions. Under this assumption, Tug required equipment falls into the mission peculiar category wherein its installation is optional for missions other than those requiring a Tug. The Tug mission peculiar equipment is comprised of the following four items:

A. Control and Display panel
B. PCM simulator
C. PCM decommutator
D. Caution and warning processor

A typical installation of the above noted equipment is shown in Figure B-21 for purposes of demonstrating the volume required in the MSS for the Tug peculiar equipment.

FIGURE B-19

40379

PSS - PAYLOAD EQUIPMENT REQUIREMENTS

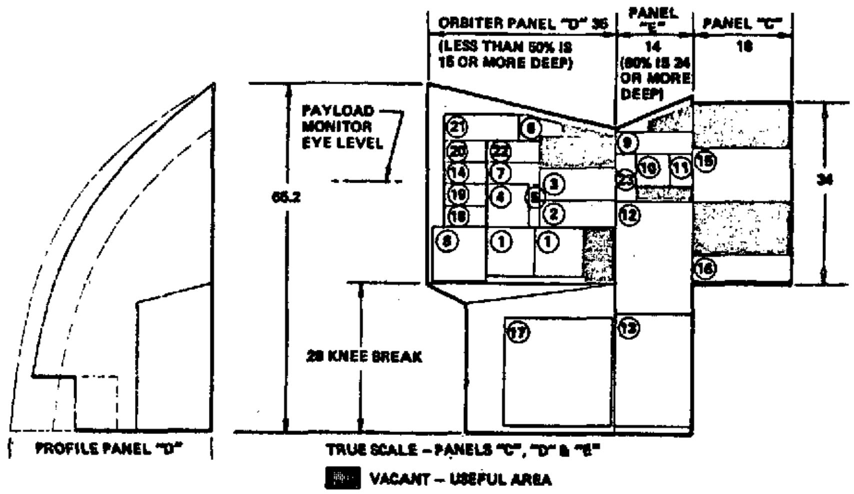


FIGURE B-20

40380

PAYLOAD SPECIALIST STATION

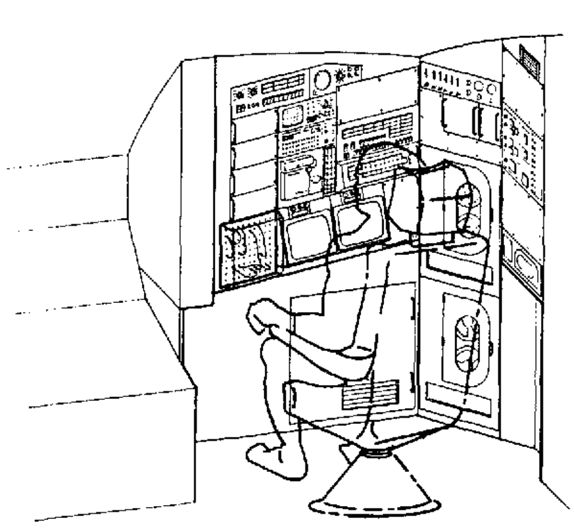
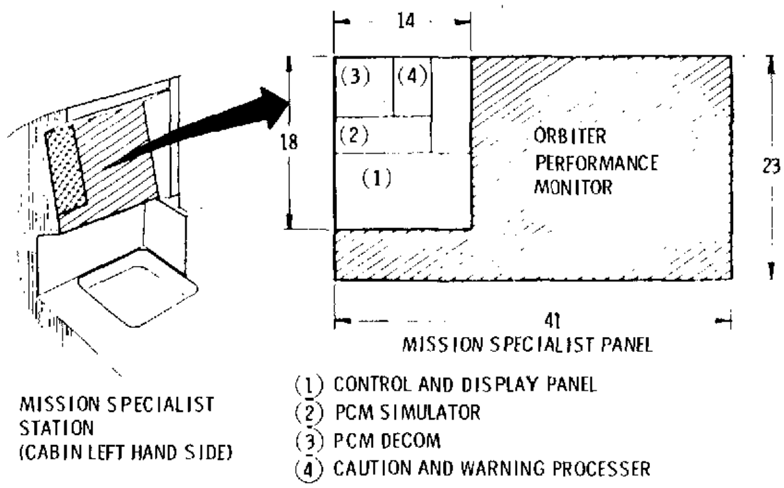


FIGURE B-21

MISSION SPECIALIST STATION - TUG NEEDS

40381



Payload equipment operating times were reviewed from the point of disconnection of ground power (T-30 minutes) until payload deployment from Shuttle for purposes of providing an estimate of average energy to be supplied by Shuttle for payload usage. FSE power requirements were derived from the equipment estimates shown in Table B-25.

B.2.5 Class I Missions (EOS)

The EOS mission requires 139 minutes for ascent to the 400 nmi orbit. The liftoff configuration requires 585 watts for the PSS/MSS consoles, 20 watts for EOS telemetry power and 18 watts for battery trickle charge. It is assumed this power requirement will be initiated at T-30 minutes when transfer is made from ground power to Shuttle power. With an 11 minute allowance for ground hold time, the duration for this load is three hours.

Subsequent to arrival at the 400 nmi operational orbit, experimental ORT will be conducted with the satellite hardwired to Shuttle (in payload bay - doors opened) after the 48-hour outgassing period. It is estimated that the time required for the testing is 15 hours. During this 15 hour period, the power demand increases by 340 watts for the experimental checkout equipment and an additional 276 watts for satellite experiment equipment operation.

EOS energy requirements are therefore summarized at 51 hours x 613 watts and 15 hours x 1,229 watts for a total of 49.8 KWH.

B.2.6 Class II Missions (Tug with ATS/SMS/DSCS)

It is assumed for the Class II missions that deployment from the Shuttle payload bay will occur as soon as possible after arrival at the 160 nmi orbit due to satellite thermal considerations.

With this assumption, the mission profile becomes common with regard to Shuttle power/energy requirements and the satellites need not be treated on an individual basis.

Ascent to the 160 nmi orbit requires 186 minutes. Transfer to Shuttle power from ground power should occur no later than T-30 minutes. With an allowance of 14 minutes for a ground hold, the ascent power load of 1,557 watts persists for 3.8 hours.

The power allowances for this phase are 662 watts for the PSS, 500 watts for the MSS, 320 watts for the Tug and 75 watts for the satellites.

Upon arrival at the deployment altitude of 160 nmi., deployment and attached Tug ORT activities will be initiated. Time allowance for this activity is 20 minutes. During this period fuel cell starting requires 800 watts for 15 minutes. Total energy requirements are therefore summarized at 4.4 hours at 1,557 watts and 0.25 hours at 800 watts for a total of 7 KWH.

B.2.7 Class III Mission (LST)

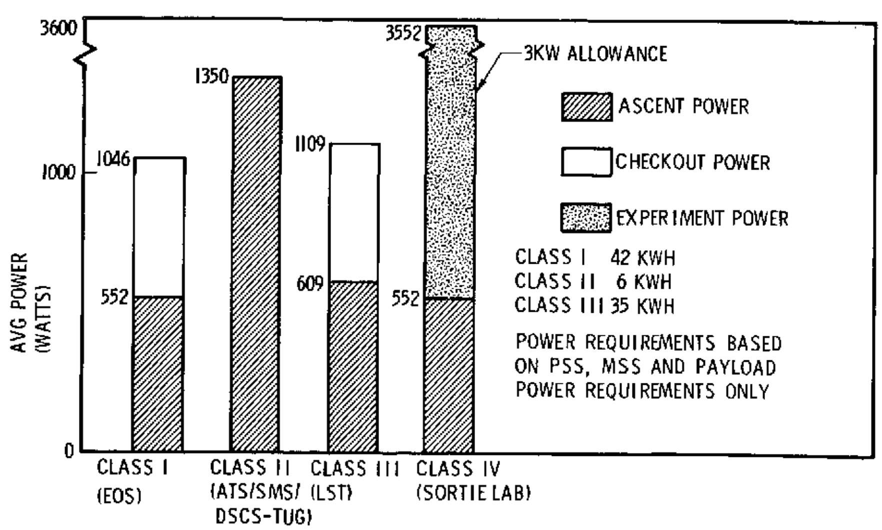
Ascent for the LST to the 30°nmi. operational orbit requires 142 minutes. With transfer to Shuttle power no later than T-30 minutes and an 8 minute hold allowance on Shuttle power, the time duration for the ascent power load is three hours. The ascent power load is comprised of 585 watts for the PSS/MSS consoles, 88 watts for the satellite telemetry system and 20 watts allowance for trickle charge of the satellite's six batteries at a rate of 0.1 amperes.

TABLE B-25
PSS - PAYLOAD EQUIPMENT REQUIREMENTS

ITEM	POWER (Watts)	WEIGHT (Pounds)	VOLUME (Inch^3)
Basic			
CRT (2) each	80	100	1,458
Keyboard	15	15	500
Display/Control Panel	15	15	168
Computer/Tape Reader	150	50	768
Annunciator Panel	5	10	80
Path Simulator	5	10	160
Patch Panel	-	20	200
Power Conditioner	25	20	448
PCM Decommutator	50	20	400
C&W Processor	15	10	100
Digital Recorder	30	25	2,700
Video Recorder	100	40	2,700
A/D Converter	5	3	100
Special Purpose			
Wideband Recorder	50	22	650
Scan Converter	150	100	8,490
Decrypter/Demultiplexer	21	19	128
Encrypter	11	9	128
Command Encoder	5	10	128
DSCS-II Control/Display	35	20	420
A Oscilloscope	40	20	640
Multiplexer	10	10	128

FIGURE B-22
PAYLOAD POWER/ENERGY REQUIREMENTS

40372



Subsequent to arrival at the LEO altitude, two orbits are allocated for determination of ephemeris data. During this period, initiation of limited checkout of the OTA and SIP is scheduled using the LST built-in self check logic. Checkout is limited due to the incomplete outgassing process which requires approximately 48 hours for completion. The total limited ORT for the LST is estimated to require 10 hours. Power requirements during this period are increased by 300 watt allowances each for the OTA and SIP.

Total energy requirements are therefore summarized at three hours at 693 watts and 10 hours at 1,293 watts for a total of 33.7 KWH. The payload power and energy requirements are summarized in Figure B-22. It should be noted that for Sortie Lab, the primary Shuttle energy requirement is derived from an allowance of 3 KW as specified in the literature.

It is important to note that the estimated EOS energy requirement at 50 KWH is at the exact value presently allocated to payloads by the Shuttle. A reiteration of SOAR-II recommendation to increase this allocation is therefore submitted in order to provide sufficient energy for on-orbit contingency holds and to compensate for additional energy requirements beyond those considered in the foregoing estimates that may be chargeable to the payloads.

B.2.8 Software-Computer Requirements

The payload computer (FSE) functional requirements are presented in Table B-26. The following presents estimates of machine sizing and characteristics to satisfy these requirements.

The Tug and satellite checkout software have basically the same requirements, with Tug having additional navigation requirements (e.g., state vector update of the navigation system and comparison of the Tug and Shuttle navigation data). Sizing for each computer was based upon worst case (W/C) requirements. The design requirements are described in the following table.

TABLE B-26

COMPUTER FUNCTIONAL REQUIREMENTS

- CRT DISPLAY CONTROL
- DATA LIMIT CHECKS - ANALOG AND DISCRETE
- LEAK DETECTION COMPUTATION
- PROCESSING OF NAVIGATION DATA
- GUIDANCE AND NAVIGATION SYSTEM UPDATING
- PCM DATA PROCESSING
- CAUTION AND WARNING LIMIT CHECKS
- UP-LINK, DOWN-LINK CONTROL

The operator interface with the systems consists of a keyboard and CRT display. Capability is provided to control/display PCM words, C&W parameters, navigation data and the baseline data base.

The prime difference between Tug and Satellite PCM data is main frame format and word size. The Tug has a fixed main frame format and word size, whereas the satellite has a variable main frame format and word size for each mission class payload. The size and timing estimates for the PCM decommutation processor are based upon worst case bit rates, word size and main frame as noted in Table B-27. PCM data will enter the computer by a DMA channel under interrupt control and decommutated in real time.

The operator response to a caution indication is selection of PCM words in groups. The selected group will be displayed and flagged with out-of-tolerance conditions.

The leak detector processor continuously monitors up to 20 pressure and temperature parameters. When an out-of-tolerance condition occurs, the data is automatically displayed. The pressure and temperature parameters to be monitored are included in the data base.

TABLE B-27

DESIGN REQUIREMENTS

PCM DATA	Tug	Satellite
Bit Rate (BPS)	51.2K (W/C)	51.2K (W/C)
Bits per word	8 (W/C)	9 (W/C)
Main Frame (words)	384 (W/C)	512 (W/C)
Format	Fixed	Variable
Variables (max.)	220 (W/C)	100 (W/C)
DISPLAY		
Type	CRT	CRT
Character Set	Alphanumeric	Alphanumeric
Code	ASCII	ASCII
Display Memory	Yes	Yes
KEYBOARD		
Character Set	Alphanumeric	Alphanumeric
Code	ASCII	ASCII
COMPUTER U/D LINK		
Bit Rage (BPS)	20K	20K
I/O	Parallel	Parallel

The processing navigation data is unique to the Tug system. The Tug FSE computer will be linked with the main Shuttle computer and Tug Flight computer. The main functions are to provide state vector update of guidance and navigation and to compare navigation data between Tug and Shuttle systems. The state vector update data is input by the operator via keyboard, then verified by displaying the update. To compare navigation data, the operator will select the required navigation parameters, which are then checked for out-of-tolerance conditions and displayed.

The estimate of software requirements necessary for the on-board Tug and satellite computers to satisfy processing requirements are shown in the Tables B-28 and B-29. It is concluded that the Tug and satellite data can be processed with a 16K, 16-bit word, 1 microsecond cycle-time machine wherein a 4K memory block exists for growth capability in both computers.

TABLE B-28
SATELLITE CHECKOUT SOFTWARE

40374

FUNCTION	INSTRUCTION	DATA BASE
EXECUTIVE	3795	360
CRT DISPLAY CONTROLLER	1200	600
DISCRETE AND ANALOG DATA PROCESSOR (LIMIT CHECK AND CHANGE)	900	80
LEAK DETECTION (PRESSURE AND TEMPERATURE)	400	360
ORBITER COMPUTER UP/DOWN LINK	450	75
SATELLITE COMPUTER UP LINK	525	75
PCM DATA PROCESSOR	520	1380
CAUTION/WARNING (LIMIT CHECK AND CHANGE)	465	45
TOTAL	8255	2975
TOTAL MEMORY SIZE	11,230	

TABLE B-29
TUG CHECKOUT SOFTWARE

40375

FUNCTION	INSTRUCTION	DATA BASE
EXECUTIVE	3795	720
CRT DISPLAY CONTROLLER	1200	600
DISCRETE AND ANALOG DATA PROCESSOR (LIMIT CHECK AND CHANGE)	900	80
LEAK DETECTION (PRESSURE AND TEMPERATURE)	400	360
NAVIGATION PROCESSOR (DATA COMPARISON)	200	100
GUIDANCE AND NAVIGATION SYSTEM UPDATE	200	40
ORBITER COMPUTER UP/DOWN LINK	450	75
TUG COMPUTER UP/DOWN LINK	450	75
PCM DATA PROCESSOR	600	1320
CAUTION/WARNING (LIMIT CHECK AND CHANGE)	465	45
TOTAL	8660	3415

TOTAL MEMORY SIZE - 12,075

Appendix B.1

GROUND STATION CONTACT TIMES

A computer evaluation of mission class ground station contact times was determined using a 15 station STDN network (for the NASA missions) projected for the late 1970's. The specified network is option 15-A of Network Integration Study, Part A, STDN No. 809, Networks Directorate, Goddard Space Flight Center, June 1972 and is comprised of the following stations:

Cape Kennedy (MIL)	Santiago (AGO)
Bermuda (BDA)	Rosman (ROS)
Canary Is. (CYI)	Alaska (ULA)
Ascension Is. (ACN)	Tanamariue (TAN)
Hawaii (HAW)	Johannesburg (BUR)
Goldstone (GDS)	Quito (QUI)
Orroral (ORR)	Guam (GWM)
Madrid (MAD)	

Contact time determination was performed in order to assess the effectiveness and/or need for Shuttle controlled checkout of satellites as an aid to ground controlling agencies (See checkout in Appendix B).

B.1.1 CLASS I MISSION (EOS)

The EOS delivery to the 400 nmi LEO at 98.4° uses the standard Shuttle trajectory (shown below) which was used to determine the noted contact times.

Ascent to 50 nmi
Transfer orbit (50 x 100 nmi) 1/2 orbit
Intermediate orbit (100 x 100 nmi)
Transfer orbit (100 x 400 nmi) 1/2 orbit
Operational orbit (400 x 400 nmi)

Table B.1-1 provides a summary of time parameters compiled from the computer data shown in Figure B.1-1.

B.1.2 CLASS III MISSION (LST)

The LST delivery to its operational orbit uses the standard Shuttle trajectory described for EOS with the operational orbit being 330 x 330 nmi at 28.5° inclination.

TABLE B.1-1

EOS CONTACT SUMMARY

AVERAGE CONTACT TIME PER STATION PER REF BY STATION:

STATION	AVERAGE CONTACT TIME PER STA. PER ORBIT	MIN. STA. CONTACT TIME IN REP. CYCLE
TAN	8.557	2.830
ULA	10.423	6.650
HAW	9.239	3.632
BUR	9.379	4.519
ACN	10.185	7.561
MAD	9.792	5.166
GWM	9.099	6.303
CRR	9.266	4.960
CYL	10.187	4.672
EDA	8.803	3.544
QUI	9.389	3.341
MIL	10.871	4.312
ROS	10.195	7.527
GDS	8.886	4.860
AGO	9.088	2.405

MAXIMUM TIME BETWEEN STATION COVERAGE:

71.17 Min. between ULA and GDS in orbits 7 and 8 respectively

PERCENT OF TIME IN CONTACT DURING REP (REPETITION) CYCLE: 25.8%

AVERAGE STATION CONTACT TIME PER DAY: 364.6 Min.

AVERAGE STATION CONTACT TIME PER ORBIT: 25.6 Min.

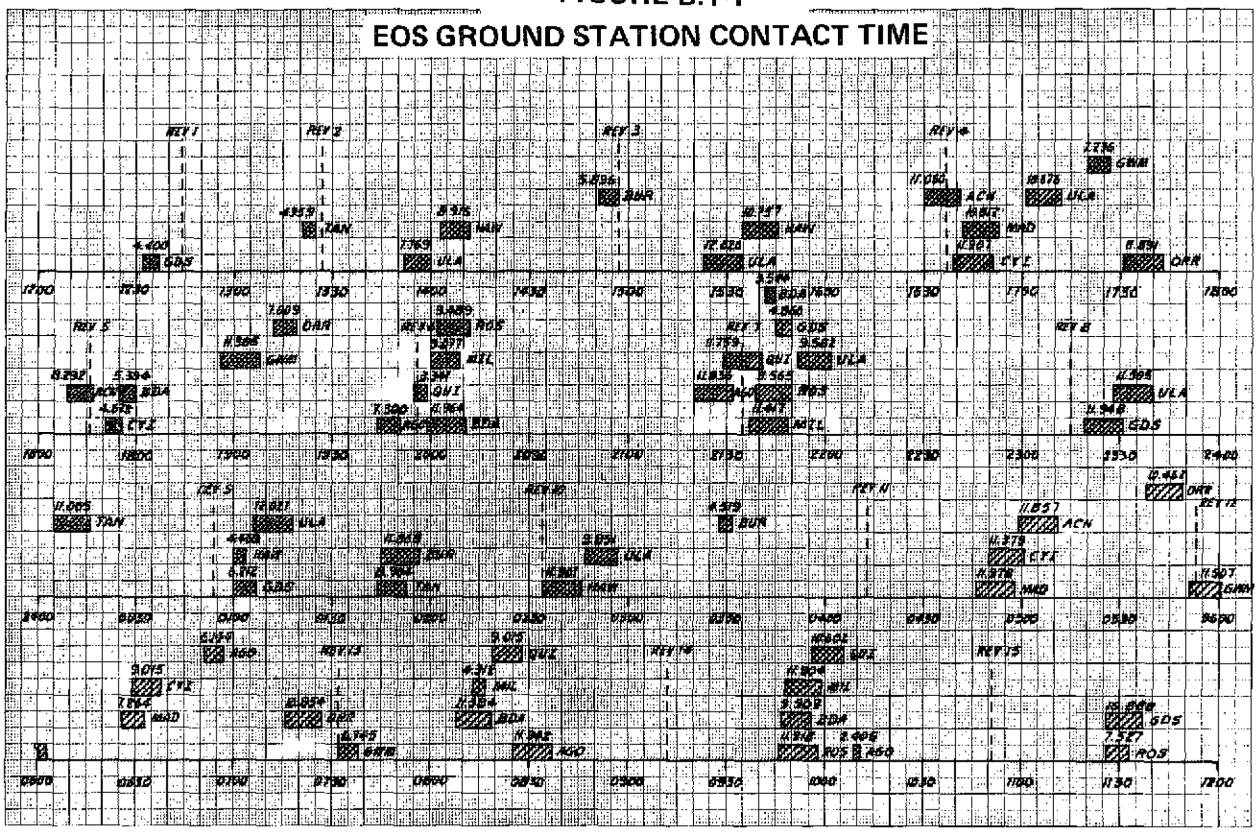
Table B.1-2 provides a summary of time parameters compiled from the data presented in Figure B.1-2.

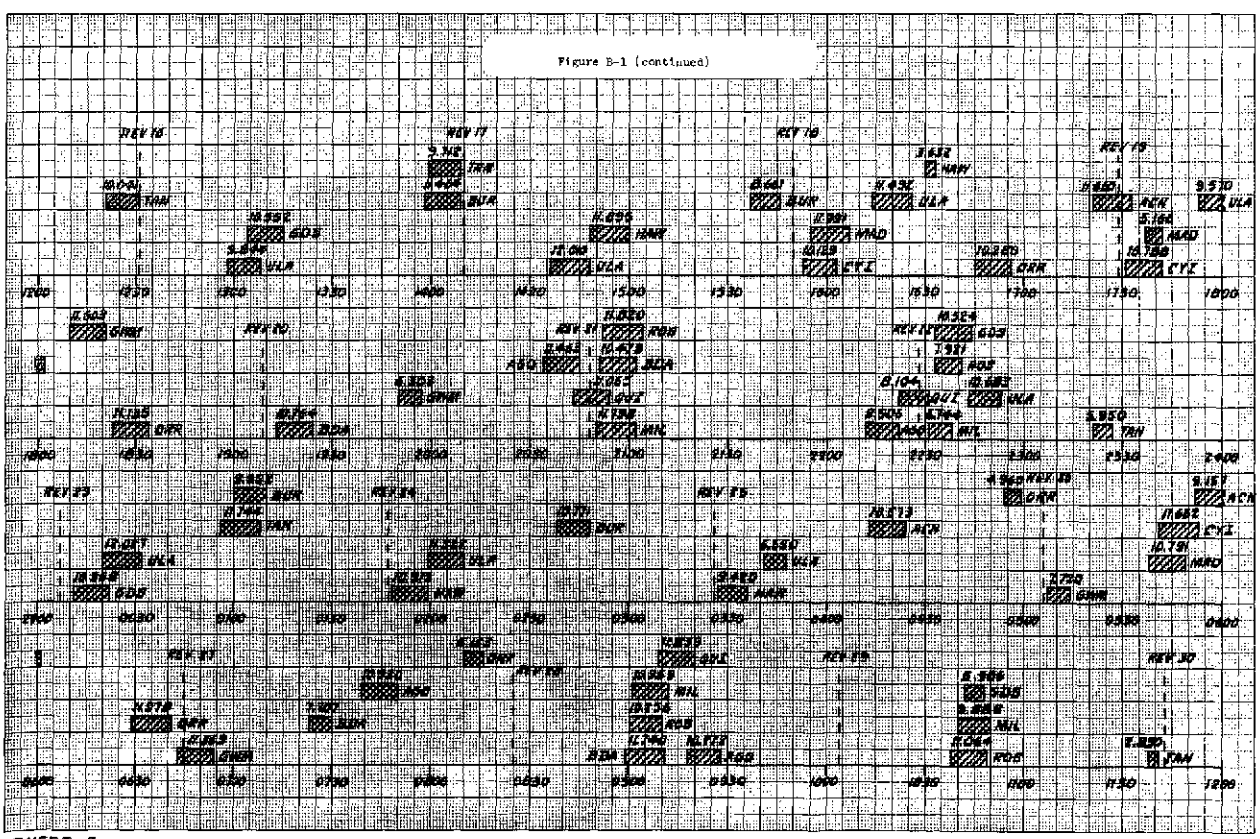
B.1.3 CLASS II MISSIONS

Class II missions (geosynchronous - ATS/SMS/DSCS) involve two totally different ground networks. ATS and SMS utilize the NASA STDN net and their contact times were therefore determined using the network specified for EOS and LST.

FIGURE B.1-1

EOS GROUND STATION CONTACT TIME





SHEET 2

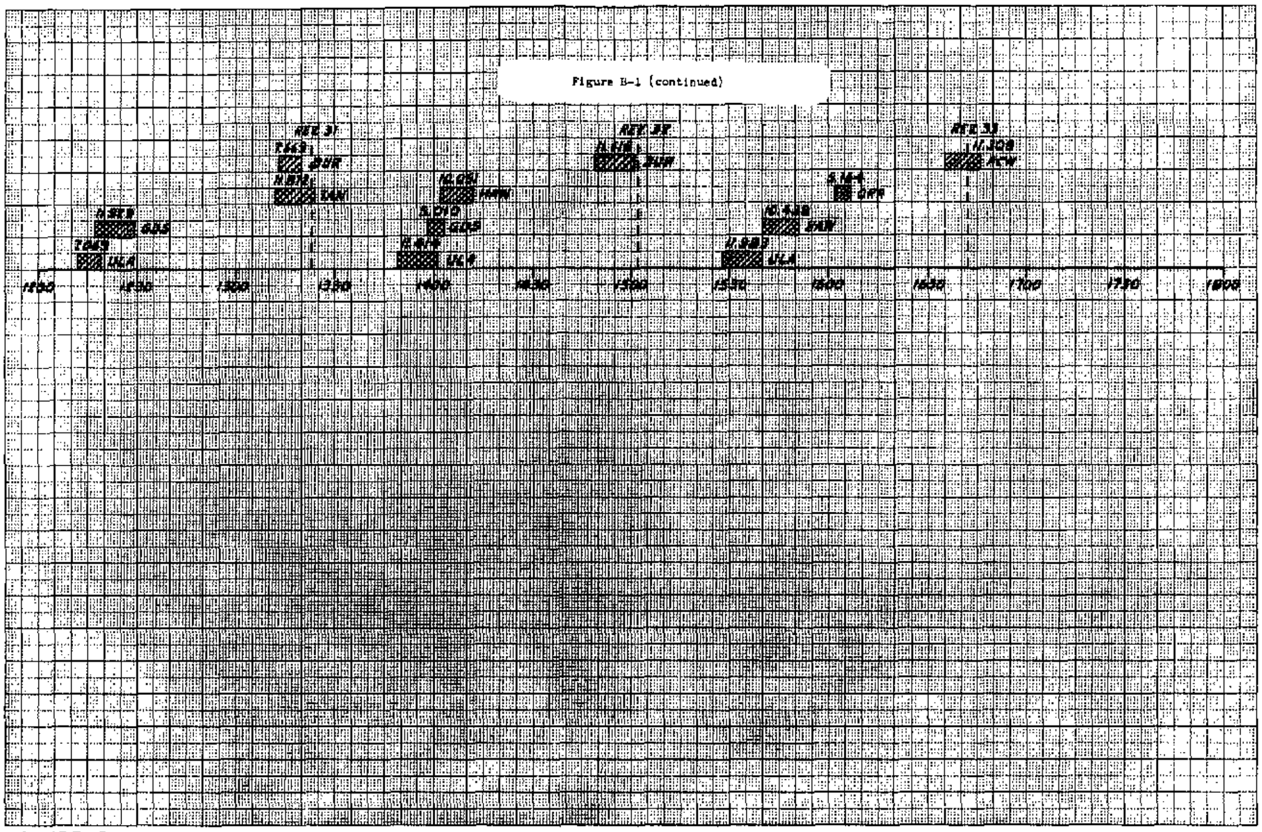


Figure B-1 (continued)

SHEET 3

The DSCS missions (DOD) utilizes the stations listed in Table B.1-3.

B.1.3.1 ATS/SMS

The ATS contact times are presented in Figures B.1-3 and B.1-4 for the geosynchronous longitudinal stations of 115°W and 140°W respectively.

SMS contact times are presented in Figure B.1-5 for the geosynchronous longitudinal station of 95°W.

B.1.3.2 DSCS

The DSCS delivery missions which were considered were the geosynchronous stations of 30°W and 175°E. Contact times are presented in Figures B.1-6 and B.1-7 respectively.

B.1.4 CONCLUSIONS

Significant results gleaned from evaluation of the contact data are summarized in Figure B.1-8.

EOS contact time restrictions are judged to be somewhat severe at 26 minutes (average) per orbit (99.7 minutes), although less severe than the coverage provided via the presently 6-7 station network stipulated in EOS phase definition documents.

LST contact time at 42 minutes (average) per orbit (97 minutes) provides obvious operational restrictions, but again, this time is increased over the coverage planned for the LST mission which is 25.7 minutes (average) utilizing a ground net comprised of CYI, ACN, ORR, GWM, HAW and GDS.

Geosynchronous mission coverage during operation at the 170 nmi departure orbit is typically represented at 30% for NASA missions (Figure B.1-8) and 11% for the DOD missions (DSCS) using the existing DOD facilities.

In the event that the envisioned TDRS system consisting of the TDRS and support ground stations (two or three) is established, full coverage is anticipated for all classes of missions with attendant elimination of operational restrictions.

FIGURE B.1-2

LST GROUND STATION CONTACT TIME

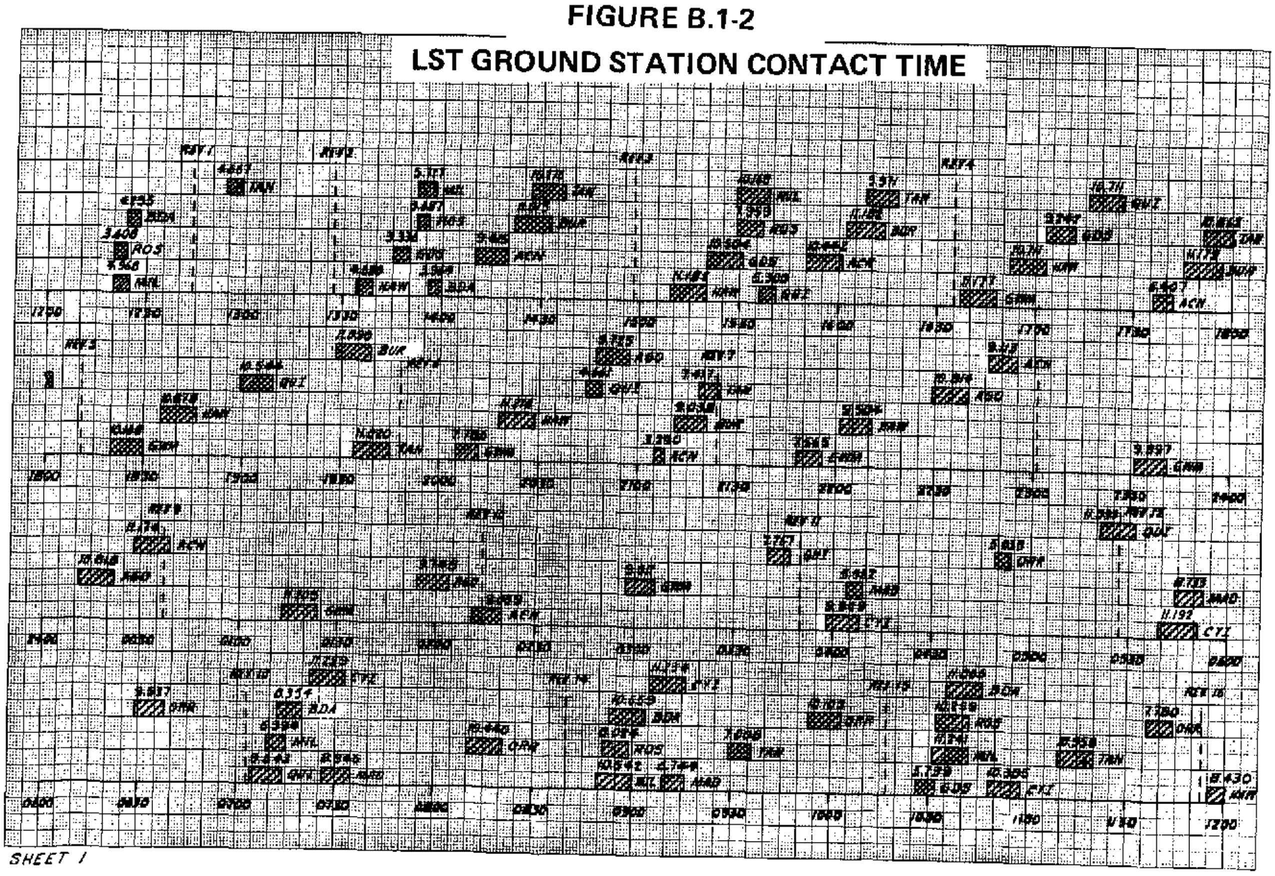


Figure B.1-2 (continued)

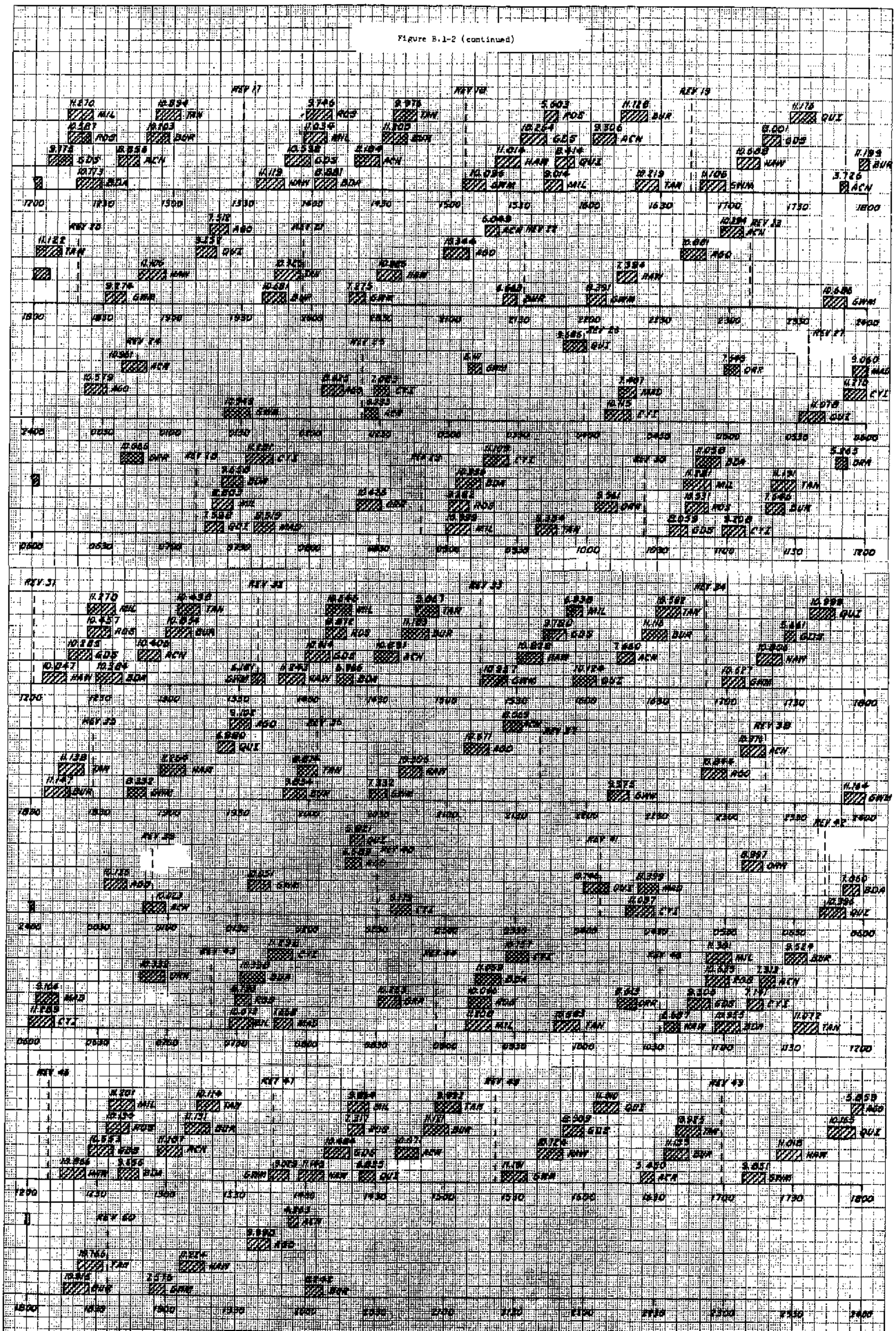


TABLE B.1-2

LST GROUND STATION CONTACT TIME

AVERAGE CONTACT TIME PER STATION PER ORBIT BY STATION:

STATION	AVERAGE CONTACT TIME PER STA. PER ORBIT	MIN. STA. CONTACT TIME IN REP. CYCLE
ROS	8.441	3.687
MIL	9.692	5.717
BDA	9.184	3.964
TAN	10.317	4.667
GDS	8.889	3.336
BUR	10.442	6.663
ACN	8.701	5.450
HAW	10.123	4.688
QUI	9.189	4.661
GWM	9.397	6.111
AGO	9.741	6.589
MAD	8.014	5.562
ORR	8.861	5.035
CYI	10.316	7.083

MAXIMUM TIME BETWEEN STATION COVERAGE:

73.57 Min. between CYI and QUI in Rev. 40

PERCENT OF TIME IN CONTACT DURING REP (REPETITION) CYCLE: 44.2%

AVERAGE STATION CONTACT TIME PER DAY: 628.9 Min.

AVERAGE STATION CONTACT TIME PER ORBIT: 42.1 Min.

TABLE B.1-3

DOD GROUND STATIONS

DUAL TRACKING STATIONS	SINGLE TRACKING STATIONS
NHS-New Hampshire (Manchester, New Hampshire)	KTS-Kodiak (Kodiak, Alaska)
VTS-Vandenberg (Lompoc, California)	IOS-Indian Ocean (Mahi, Seychelles)
HTS-Hawaii (Kaena Point, Hawaii)	GTS-Guam (Guam)

FIGURE B.1-3
ATS GROUND STATION CONTACT TIME

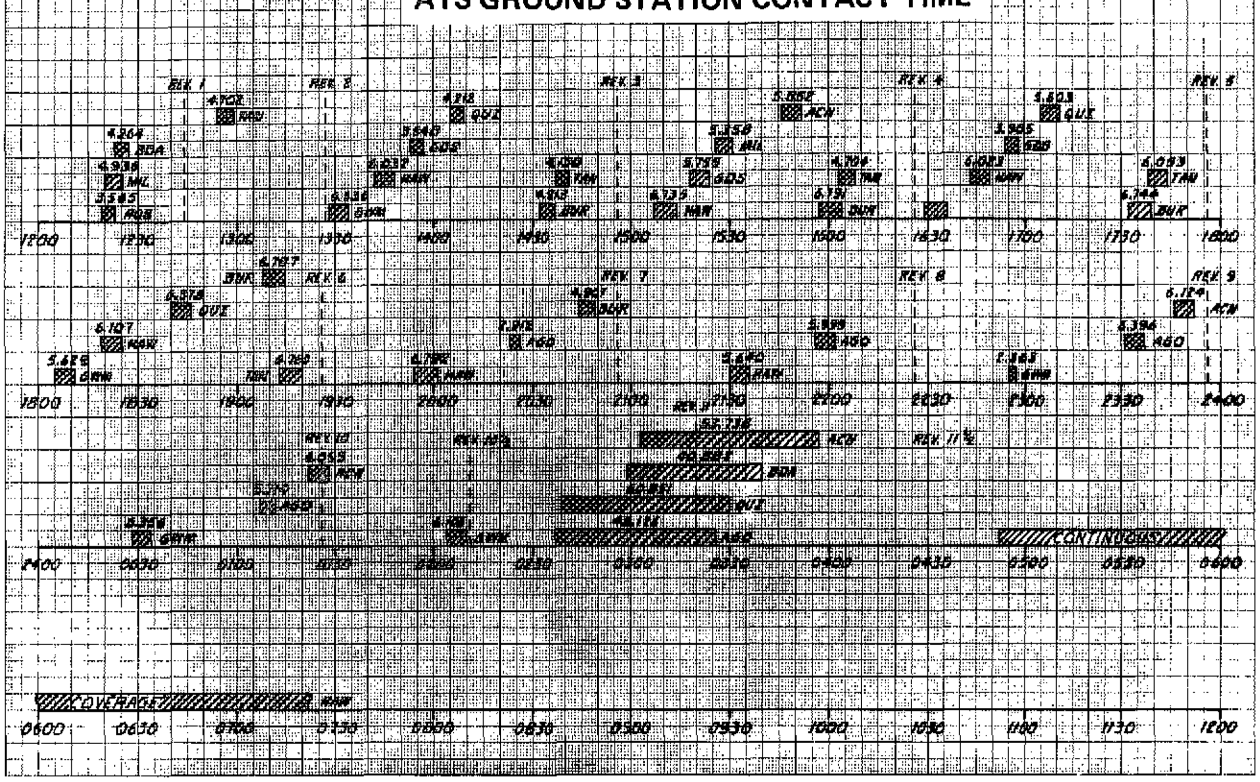


FIGURE B.1-4
ATS GROUND STATION CONTACT TIME

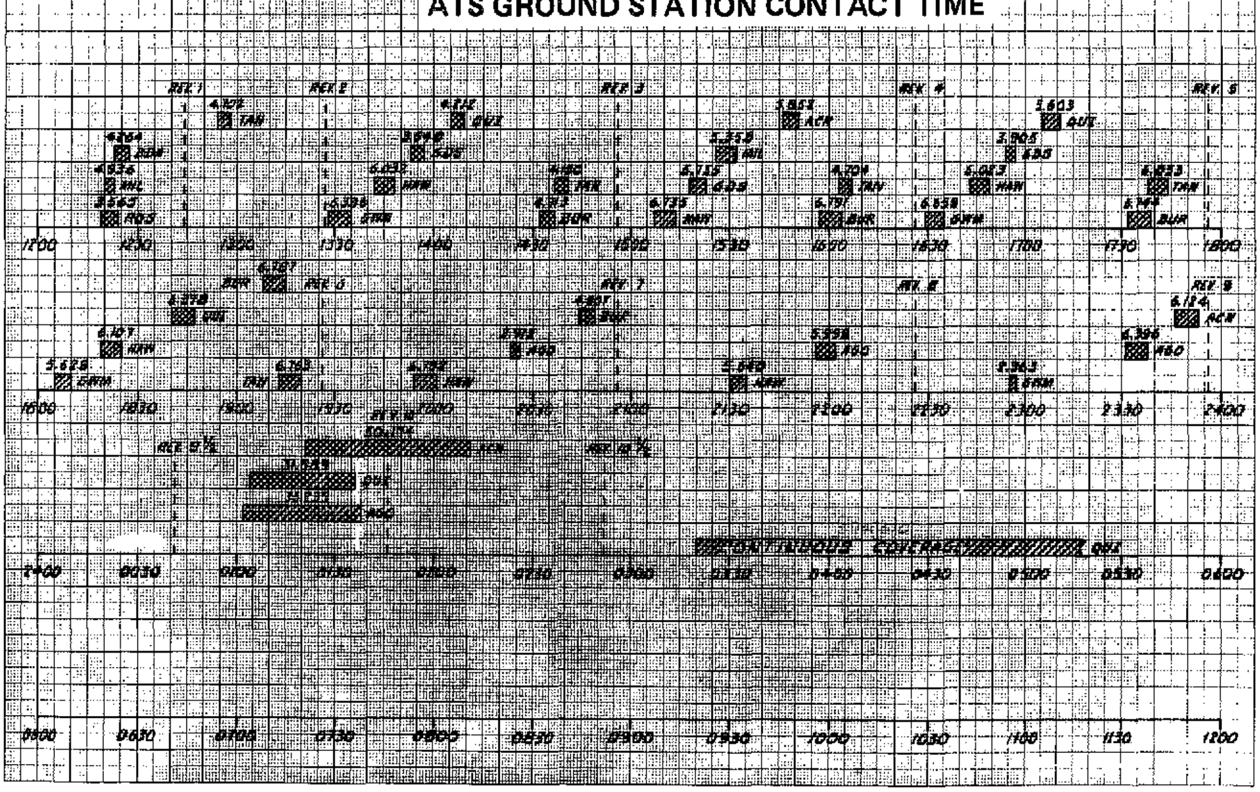


FIGURE B.1-5

SMS GROUND STATION CONTACT TIME

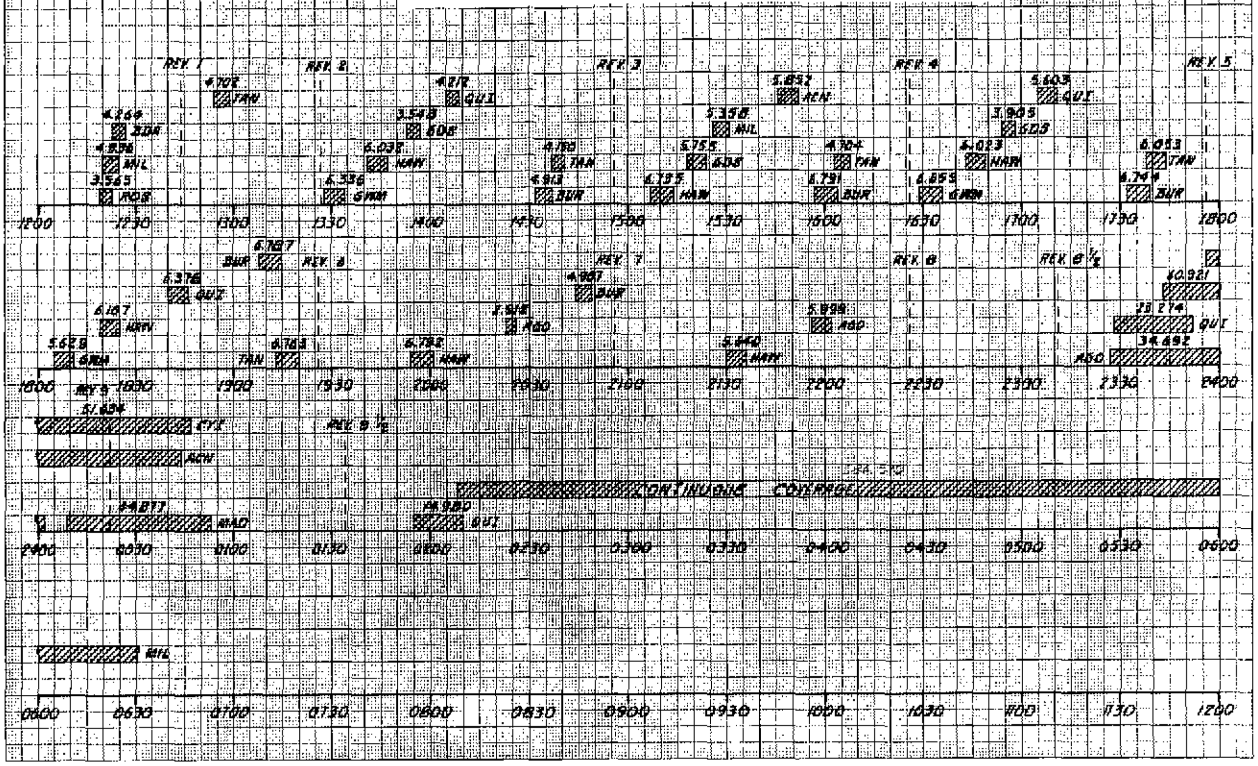


FIGURE B.1-6

DSCS GROUND STATION CONTACT TIME

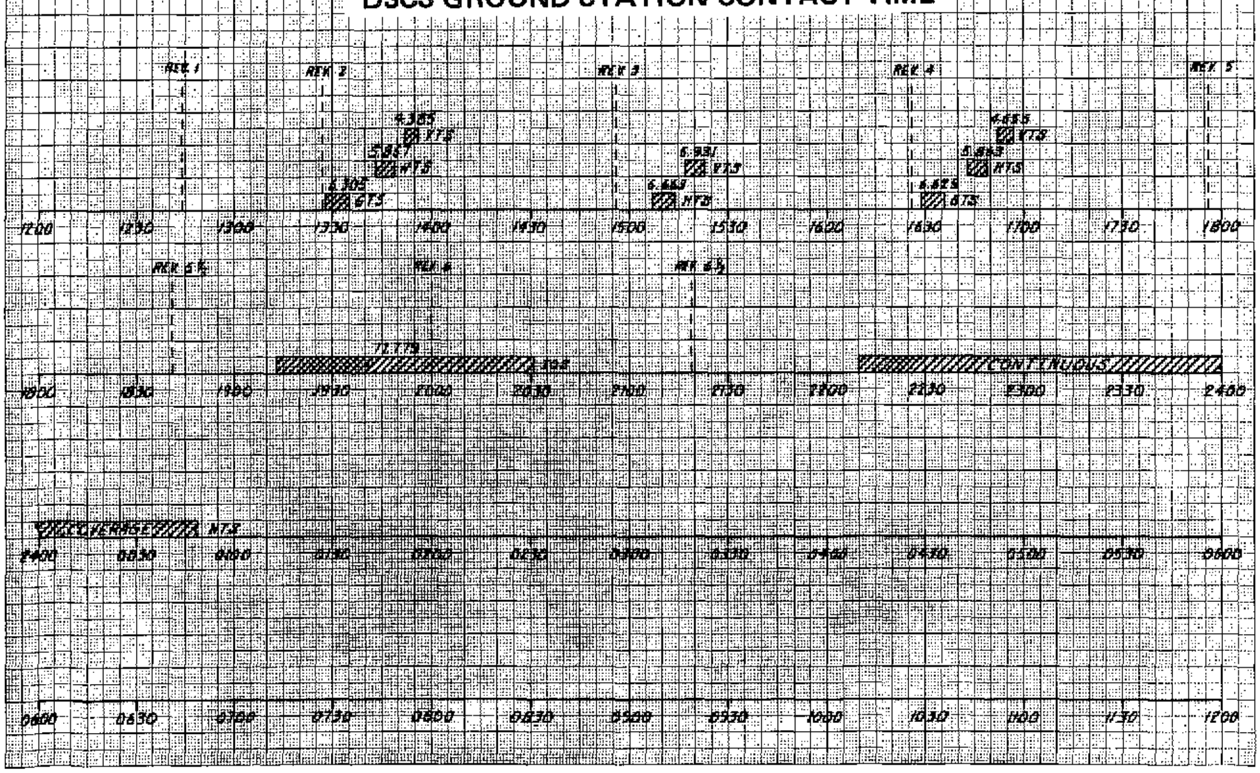


FIGURE B.1-7
DSCS GROUND STATION CONTACT TIME

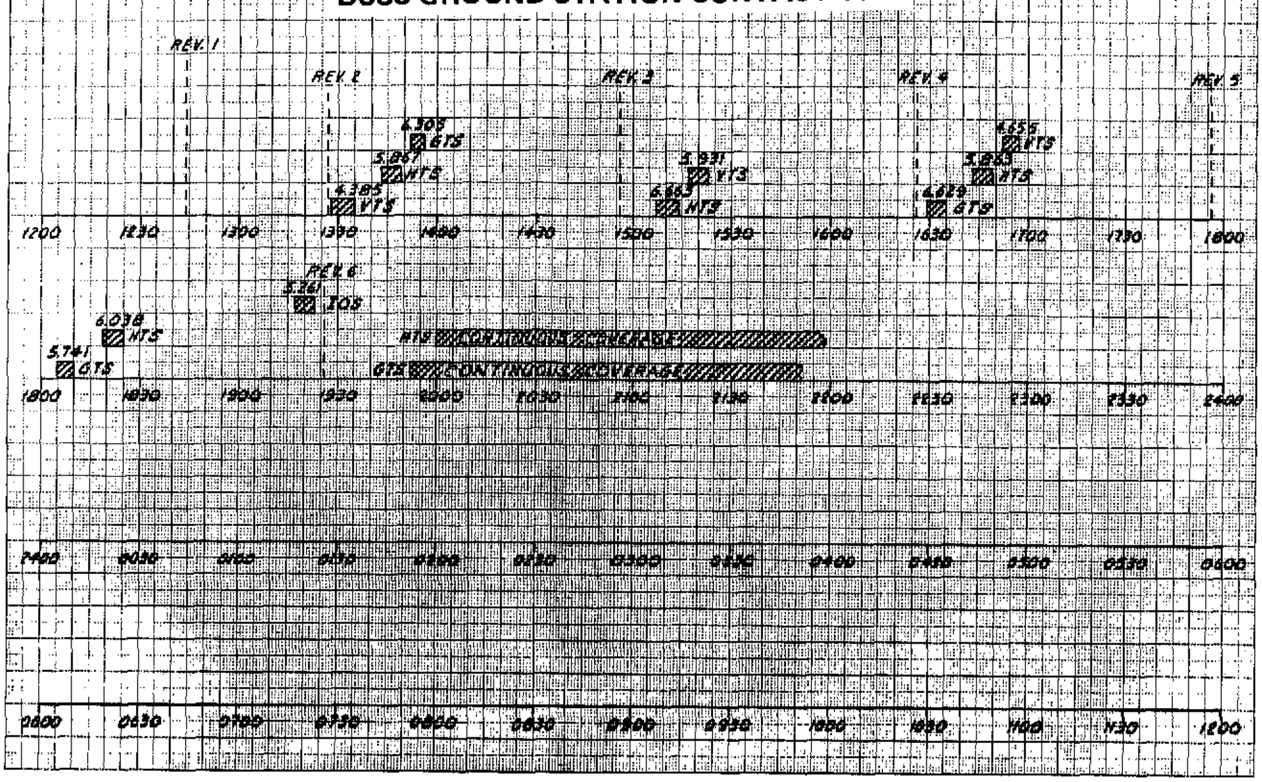
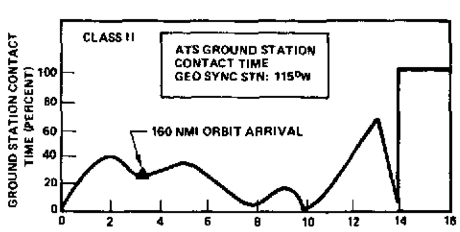


FIGURE B.1-8
GROUND STATION CONTACT TIMES

40449

PARAMETER	CLASS I (EOS)	CLASS III (LST)
ORBITAL PERIOD	99.8 MIN	97.0 MIN
REPETITION CYCLE	40 REVS	31 REVS
MAX TIME WITH NO CONTACT	71.2 MIN	73.6 MIN
AVG STATION CONTACT TIME PER DAY	365 MIN	629 MIN
MINIMUM CONTACT TIME	2.4 MIN	3.3 MIN
CONTACT IN REPETITION CYCLE	25.8 %	44.2 %
AVG CONTACT TIME PER ORBIT	25.6 MIN	42.1 MIN



CONCLUSIONS:

- EOS GROUND CONTACT LIMITATIONS ARE SEVERE
- SHUTTLE SHOULD PERFORM AND ASSIST IN PERFORMANCE OF ORT FOR EOS AND LST
- GROUND STATION CONTACT TIME IS APPX 30% FOR 160 NMI ORBIT PRIOR TO PHASING ORBIT AND GEOSYNC TRANSFER (CLASS II MISSIONS)

Appendix C

PAYLOAD ELECTRICAL INTERFACE REQUIREMENTS

C.1 PAYLOAD/ORBITER ELECTRICAL INTERFACE REQUIREMENTS

The electrical interface functions between the payloads, payload bay services and the mission/payload specialist consoles are essentially defined by the requirements generated in Task 2 (Appendix B), i.e., control/display requirements stemming from prelaunch testing/monitoring, orbital readiness testing (ORT), safety criteria (C&W) and other miscellaneous operational activities such as deployment preparations and deployment.

C.1.1 Class I and III Missions (EOS and LST)

The equipment interconnection (interface) required for EOS and LST is presented in Figure C-1. The electrical functions required in each segment of the interconnection system are delineated in Table C-1 for EOS and C-2 for LST. The differences in functions for the two vehicles are derived primarily from the EOS attached ORT involving testing/calibration of the experiment sensor systems.

FIGURE C-1
EQUIPMENT INTERCONNECTION - EOS AND LST

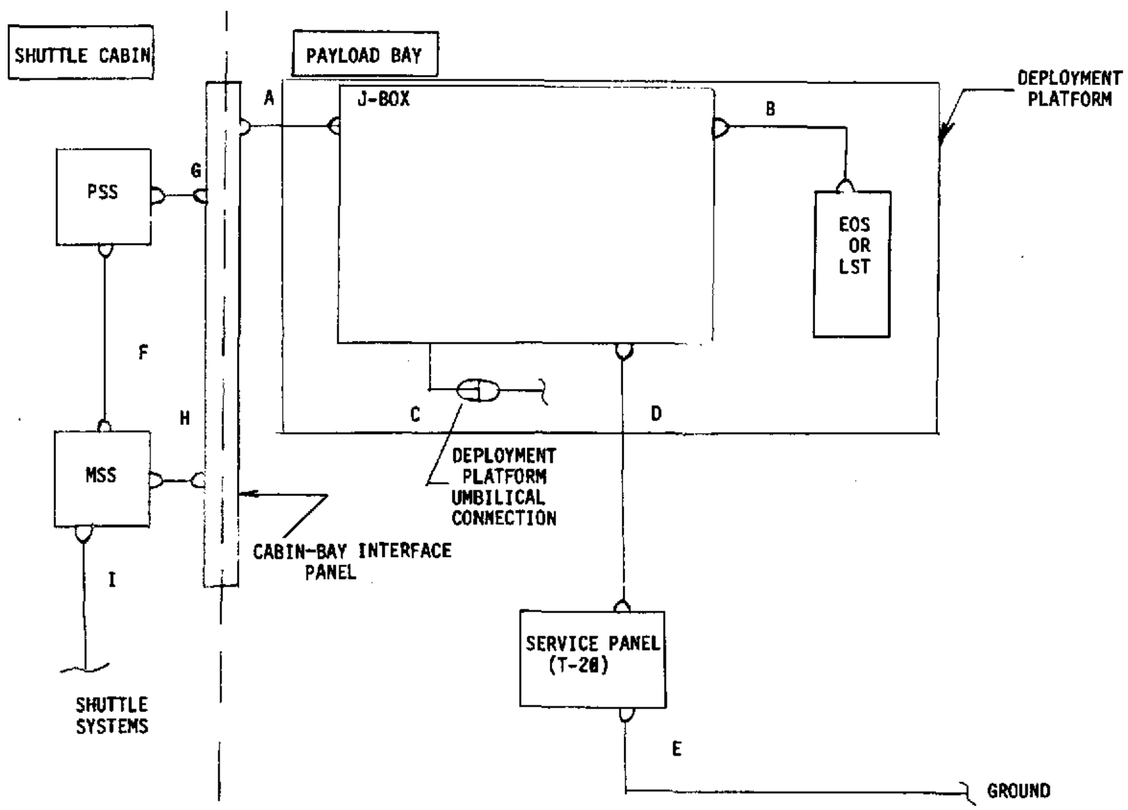


TABLE C-1

EOS ELECTRICAL INTERFACE FUNCTIONS

System	Characteristics	Requirement	Wire/Gage
	Segment A & G		
Power	28 VDC return	450W 450W	2 #12 (41a free air) 2 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	10 functions 2 redundant power	10 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 12.5 KBPS (max)	Housekeeping data, C & W backup	2 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	22 signals (includes redundancy for deployment platform)	44 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: 2 KBPS	Data Clock	1 TSP/20 1 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
Two-way voice	Bandwidth: 3 KHz	Voice	1 TSP/20
Ocean scanning spectrometer	4.6 KHz	Detector amplifier outputs	20 TSP/20
Sea surface radiometer	9.2 KHz	Detector amplifier outputs	5 TSP/20
Cloud physics radiometer	5.83 KHz	Detector amplifier outputs	5 TSP/20
Atmosphere sounder	50 Hz	Detector amplifier outputs	4 TSP/20
Pollution sensor	8 Hz	Detector amplifier outputs	1 TSP/20
Microwave radiometer	400 Hz	Detector amplifier outputs	5 TSP/20
		Totals:	4 #12 114 TSP/20

System	Characteristics	Requirement	Wire/Gage
	Segment B		
Power	28 VDC return	450W 450W	2 #12 (41a free air) 2 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	10 functions 2 redundant power	10 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 12.5 KBPS (max)	Housekeeping data, C & W backup	1 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	16 signals	32 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: 2 KBPS	Data Clock	1 TSP/20 1 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
Ocean scanning spectrometer	4.6 KHz	Detector amplifier outputs	20 TSP/20
Sea surface radiometer	9.2 KHz	Detector amplifier outputs	5 TSP/20
Cloud physics radiometer	5.83 KHz	Detector amplifier outputs	5 TSP/20
Atmosphere sounder	50 Hz	Detector amplifier outputs	4 TSP/20
Pollution sensor	8 Hz	Detector amplifier outputs	1 TSP/20
Microwave radiometer	400 Hz	Detector amplifier outputs	5 TSP/20
		Totals:	4 #12 100 TSP/20

System	Characteristics	Requirement	Wire/Gage
	Segment C		
Deployment platform			
Control	28 VDC, discrete	9 motorized latches 1 ring rotation motor	10 TSP/20
Monitor	28 VDC bilevel (limit switches)	10 monitor function	10 TSP/20
		Total:	20 TSP/20
	Segment D & E		
Ground Power	28 VDC return	1500 W 1500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	7 functions	7 TSP/20
Narrowband digital telemetry	Rate: 12.5 KBPS	Housekeeping & test data	1 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Control & related bilevel monitoring	bilevel-dedicated hardwire system	11 signals	22 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
VIP	VHF S Band	Housekeeping data Housekeeping data	1 Coax 1 Coax
MIRP	S Band	Sensor system data	1 Coax
MOMS	S Band	Sensor systems data	1 Coax
		Totals:	8 #12 43 TSP/20 4 Coax
	Segment F		
Power	28 VDC return	1500 W 1500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
C & W monitor	Bilevel	C & W master alarm	1 TSP/20
Narrowband digital telemetry	Rate: 12.5 KBPS	Data - real time or stored for downlink to ground	2 TSP/20
Mission timing	Undefined	Time signal	4 TSP/20
Computer keyboard	Parallel digital	16 data lines 1 mode	16 TSP/20 1 TSP/20
Two-way voice	Bandwidth: 3 Hz	Voice	1 TSP/20
Video	Bandwidth: 5 MHz	Data - composite signal	1 Coax
		Totals:	8 #12 25 TSP/20 1 Coax
	Segment H		
Video	Bandwidth: 5 MHz	Composite signal	4 Coax
Deployment platform			
Control	28 VDC discrete hardwire	5 control functions	5 TSP/20
Monitor	28 VDC bilevel (limit switches)	6 monitor functions	6 TSP/20
Control	Via computer	Data Clock	1 TSP/20 1 TSP/20
Voice	Bandwidth: 3 KHz	Voice comm (payload bay)	2 TSP/20
		Totals:	15 TSP/20 4 Coax
	Segment I		
Power	28 VDC return	1500 W 1500 W	3 #12 (41a free air) 3 #12 (23a in bundle)
Narrowband digital telemetry	Rate: 12.5 KBPS	Data	2 TSP/20
C & W	Bilevel-undefined (0-28 VDC)	C & W master alarm	1 TSP/20
		Totals:	6 #12 3 TSP/20

TABLE C-2

EOS ELECTRICAL INTERFACE FUNCTIONS

System	Characteristics	Requirement	Wire/Gage
	Segment A & G		
Power	28 VDC return	500 W 500 W	2 #12 (41a free air) 2 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	3 monitor function 2 redundant power	5 TSP/20
Narrowband digital telemetry	Rate: 51.2 KBPS	Housekeeping and test data; C & W backup	2 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	15 signals (max) (includes redundancy for deployment platform)	30 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: 1 KBPS Sub-bit detection 200 BPS	Data Clock	1 TSP/20 1 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
		Totals:	4 #12 52 TSP/20
	Segment B		
Power	28 VDC return	500 W 500 W	4 #12 (41a free air) 2 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	3 monitor function 2 redundant power	5 TSP/20
Narrowband digital telemetry	Rate: 51.2 KBPS	Housekeeping & test data; C & W backup	1 TSP/20
Control & related bilevel monitoring	Bilevel-dedicated hardwire system	8 signals (max) (includes redundancy for deployment platform)	16 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: 1 KBPS Sub-bit detection 200 BPS	Data	1 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
RF	S Band	Telemetry data down link	1 Coax
		Totals:	4 #12 36 TSP/20
	Segment C		
Deployment platform			
Control	28 VDC discrete	9 motorized latches 1 ring rotation motor	10 TSP/20
Monitor	28 VDC bilevel (limit switches)	10 monitor functions	10 TSP/20
		Total:	20 TSP/20
	Segments D & E		
Ground power	28 VDC	1500 W (max)	4 #12 (41a free air) (23a in bundle)
Ground power	Return	1500 W (max)	4 #12
C & W	Bandwidth: 10 Hz	3 functions	3 TSP/20
Narrowband digital telemetry	Rate: 51.2 KBPS	Housekeeping & test data; C & W backup	1 TSP/20

System	Characteristics	Requirements	Wire/Gage
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Control & related bilevel monitoring	Bilevel-dedicated hardwire system	8 signals	16 TSP/20
Batteries	32-35 VDC	Trickle charge 0.6a	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	10 function allowance	10 TSP/20
RF	S Band VHF	Telemetry data down link	1 Coax
		Totals:	8 #12 33 TSP/20 1 Coax
	Segment F		
Power	28 VDC return	1500 W 1500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
C & W monitor	Bilevel	C & W master alarm	1 TSP/20
Narrowband digital telemetry	Rate: 1.6 KBPS	Data - real time or stored for downlink to ground	1 TSP/20
Mission timing	Undefined	Time signal	4 TSP/20
Computer keyboard	Parallel digital	16 data lines 1 mode	16 TSP/20 1 TSP/20
Two-way voice	Bandwidth: 3 Hz	Voice	1 TSP/20
Video	Bandwidth: 5 MHz	Composite signal	1 Coax
Cameras (4)	28 VDC continuous	7 control functions	7 TSP/20
		Totals:	8 #12 32 TSP/20 1 Coax
	Segment H		
Video	Bandwidth: 5 MHz	Composite signal	4 Coax
Deployment platform			
Control	28 VDC discrete hardwire	5 control functions	5 TPS/20
Monitor	28 VDC bilevel (limit switch)	6 monitor functions	6 TSP/20
Control	Via computer	Data Clock	1 TSP/20 1 TSP/20
Voice	Bandwidth: 3 KHz	Voice comm (payload bay)	2 TSP/20
		Totals:	15 TSP/20 4 Coax
	Segment I		
Power	28 VDC	1500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
Narrowband digital telemetry	Rate: 51.2 KBPS		2 TSP/20
C & W	Bilevel-undefined (0-28 VDC)	C & W master alarm	1 TSP/20
		Totals:	8 #12 3 TSP/20

C.1.2 Class II Missions (ATS/SMS/DSCS - Tug)

The equipment interconnection (interface) required for the Class II missions is presented in Figure C-2 based on the functional allocations established for the MSS/PSS in Appendix B. The electrical functions required in each segment of the interconnection system are delineated in Table C-3. The DSCS mission with two satellites was used as the basis for determining the numbers of functions required in order to provide design for the most demanding mission in order to utilize the same design/hardware for the ATS and SMS.

FIGURE C-2

EQUIPMENT INTERCONNECTION - CLASS II MISSIONS

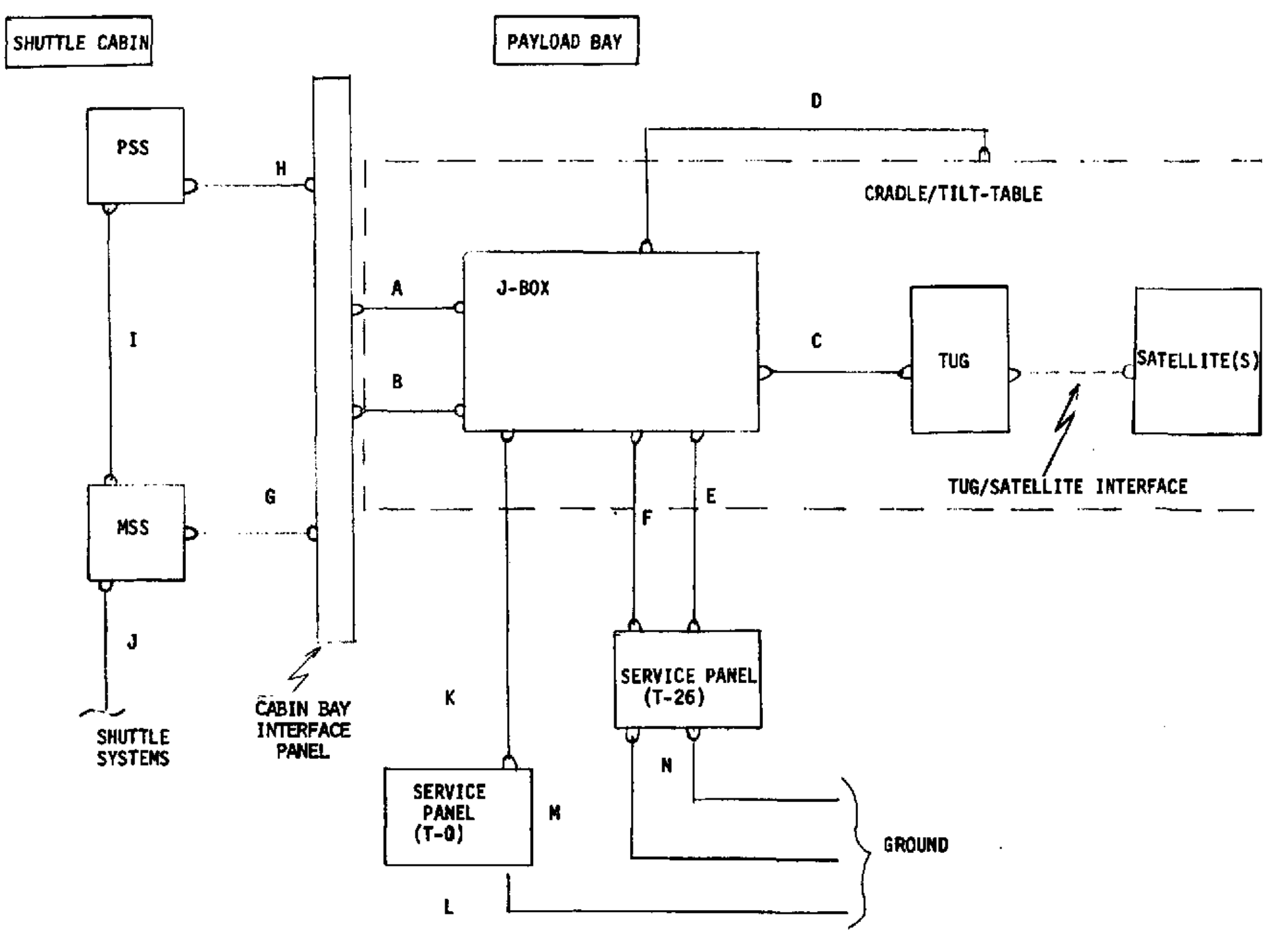


TABLE C-3

CLASS II MISSIONS - ELECTRICAL INTERFACE FUNCTIONS

Systems	Characteristics	Requirement	Wire/Gage
	Segment A & H		
Power	28 VDC return	300 W max	1 #12 (41a free air) 1 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz dedicated hardwire system	12 functions redundant power	12 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 250-640 BPS	Data and C & W backup Clock	1 TSP/20 1 TSP/20
Satellite systems	Bilevel-dedicated hardwire system	16 control signals (max) to satellite	16 TSP/20
	(0 and 28 VDC)	16 talkback signals (max)	16 TSP/20
Computer up-down link	Rate: undefined (< 20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: DSCS 1 KBPS SMS undefined ATS undefined	Data Clock	1 TSP/20 1 TSP/20
Batteries	32-35 VDC	0.6 ampere (max) trickle charge	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	20 monitor functions (allowance)	20 TSP/20
		Totals:	2 #12 73 TSP/20
	Segment B & G		
Power	28 VDC return	2500 W 2500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
C & W monitor	Bandwidth: 10 Hz dedicated hardwire system	26 signal allocation redundant power	26 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 51.2 KBPS	Data and C & W backup	1 TSP/20
Tug systems	Bilevel-dedicated hardwire system	26 control signals	8 TSP/20 18 TSP/20
	0 and 28 VDC	26 talkback signals	26 TSP/20
Computer up-down link	Rate: undefined (25 KBPS)	Data Clock	1 TSP/20
Command	Rate: undefined (2KBPS)	Data Clock	1 TSP/20 1 TSP/20
Battery	32-35 VDC	Trickle charge 0.1a	1 TSP/20
Video	Bandwidth: 5 MHz	Data	4 Coax
Tilt table			
latch control	Dedicated hardwire	20 functions	20 TSP/20
latch control	Serial link	Data	1 TSP/20
latch monitor	(Assume limit switches	Clock 1 function	1 TSP/20 1 TSP/20
raise control	Hardwired	1 function	1 TSP/20
position monitor	Bilevel	2 function	2 TSP/20
		Totals:	8 #12 111 TSP/20 1 Coax

System	Characteristics	Requirement	Wire/Gage
	Segment C		
(Tug)			
Power	28 VDC return	2500 W 2500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	26 functions redundant power	26 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 51.2 KBPS	Housekeeping & test data; C & W backup	2 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	26 functions 16 functions	52 TSP/20 32 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	2 TSP/20 2 TSP/20
Command	Rate: undefined (2 KBPS)	Data Clock	2 TSP/20 2 TSP/20
Battery	32-35 VDC	Trickle charge 0.1a 0.3a	1 TSP/20 1 TSP/20
Tug systems	Analog-bilevel bandwidth undefined	15 functions (allowance) 20 functions (allowance)	30 TSP/20 40 TSP/20
		Totals:	8 #12 117 TSP/20
(Satellite)			
Power	28 VDC return	300 W max	2 #14 (32a free air) 2 #14 (17a in bundle)
C & W	Bandwidth: 10 Hz dedicated hardwire system	12 functions redundant power	12 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 250-640 BPS	Housekeeping & test data; C & W backup Clock	1 TSP/20 1 TSP/20
Satellite systems	Bilevel-dedicated hardwire system (0 and 28 VDC)	16 control signals (max) to satellite 16 talkback signals (max)	16 TSP/20 16 TSP/20
Computer up-down link	Rate: undefined (< 20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: DSCS 1 KBPS SMS undefined ATS undefined	Data Clock	1 TSP/20 1 TSP/20
Batteries	32-35 VDC	0.6 ampere (max) trickle charge	1 TSP/20
Satellite systems	Analog-bilevel bandwidth undefined	20 monitor functions (allowance)	20 TSP/20
		Totals:	4 #14 73 TSP/20
	Segment D		
Tilt table			
latch control	Dedicated hardwire	20 functions	20 TSP/20
latch control	Serial link	Data Clock	1 TSP/20 1 TSP/20
latch monitor	Bilevel- limit switches	1 function	1 TSP/20
raise control	Hardwired	1 function	1 TSP/20
position monitor	Bilevel	2 functions	2 TSP/20
		Total:	26 TSP/20
	Segment E & N		
Power	28 VDC return sense	300 W 300 W Voltage regulator	2 #12 (41a free air) 2 #12 (23a in bundle) 1 TSP/20
C & W	Bandwidth: 10 Hz Dedicated hardwire system	12 functions	12 TSP/20
Narrowband digital telemetry	Rate: 250-640 BPS	Housekeeping & test data; C & W backup	2 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	22 functions (max)	22 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	2 TSP/20
Command	Rate: DSCS 1 KBPS SMS undefined ATS undefined	Data Clock	2 TSP/20
Battery	32-35 VDC	Trickle charge 0.3a	1 TSP/20
		Totals:	4 #12 42 TSP/20

System	Characteristics	Requirement	Wire/Gage
		Segment F & M	
Power	28 VDC return sense	2000 W 2000 W Voltage regulation	6 #12 (41a free air) 6 #12 (23a in bundle) 1 TSP/20
C & W	Bandwidth: 10 Hz dedicated hardwire system	24 functions	24 TSP/20
Computer up-down link	Rate: undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: undefined (2 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Battery	32-25 VDC	Trickle charge 0.1a	1 TSP/20
Video	Bandwidth: 5 MHz	Data	1 Coax
		Total:	12 #12 30 TSP/20 1 Coax
		Segment I	
Power	28 VDC (from MSS) return	2 KW peak 2 KW	6 #12 (41a free air) 6 #12 (23a in bundle)
C & W Monitor	Bilevel-undefined (from PSS)	C & W master alarm	1 TSP/20
Digital data	Rate: 250 BPS low to 51.2 KBPS high (from PSS)	Data-real time or stored for downlink to ground	1 TSP/20
Mission timing	Undefined (from MSS)	Time signal	4 TSP/20
Computer keyboard	Parallel digital	16 data lines 1 mode line	16 TSP/20 1 TSP/20
Two-way voice	Bandwidth: 3 KHz	Voice	1 TSP/20
Video	Bandwidth: 5 MHz	Data	1 Coax
		Totals:	12 #12 24 TSP/20 1 Coax
		Segment J	
Power	28 VDC return	2 KW max	2 #2 (181a free air) 2 #2 (100 a in bundle)
Digital data (Satellites)	Rate: 250 to 640 BPS	Data Relay	2 TSP/20
Digital data (Tug)	Rate: 51.2 KBPS	Data Relay	2 TSP/20
Video	Bandwidth: 5 MHz	Data Relay	1 Coax
C & W	Bilevel-undefined (To commander station)	C & W master alarm (Derived from PSS)	1 TSP/20
Mission timing	Undefined	Time signals	4 TSP/20
Shuttle navigation	Digital-(serial)	Data Clock	1 TSP/20 1 TSP/20
Voice To commander & pilot To data system	Bandwidth: 3 KHz		3 TSP/20
		Totals:	4 #2 14 TSP/20 1 Coax
		Segment K & L	
Narrowband digital telemetry			
Tug	Rate: 51.2 KBPS	Housekeeping data	2 TSP/20
Propellant System (Tug)	Discrete hardwire	20 functions	20 TSP/20
Tug Systems Control	Discrete hardwire		
Control		12 functions	12 TSP/20
Monitor		12 functions	12 TSP/20
		Total:	46 TSP/20

C.1.3 Sortie Laboratory

The equipment interconnection (interface) required for the Sortie Laboratory is presented in Figure C-3. The electrical functions required in each segment of the system are summarized in Table C-4. As noted in Figure C-3 an option is presented wherein the MSS and/or the PSS may be utilized for Sortie Laboratory missions. It is postulated that the configuration selection would be based on the type(s) of experiments in the Sortie Laboratory and an attendant assessment of the value of supplementing the Sortie Lab/Shuttle equipment with equipment (or volume) available in the PSS. In the event that for a particular Sortie Lab mission no requirement is identified for the PSS, it is assumed the complete Sortie Lab interface with Shuttle would be via the MSS with the possibility of PSS removal during Shuttle turn around operations.

FIGURE C-3

EQUIPMENT INTERCONNECTION - SORTIE LABORATORY

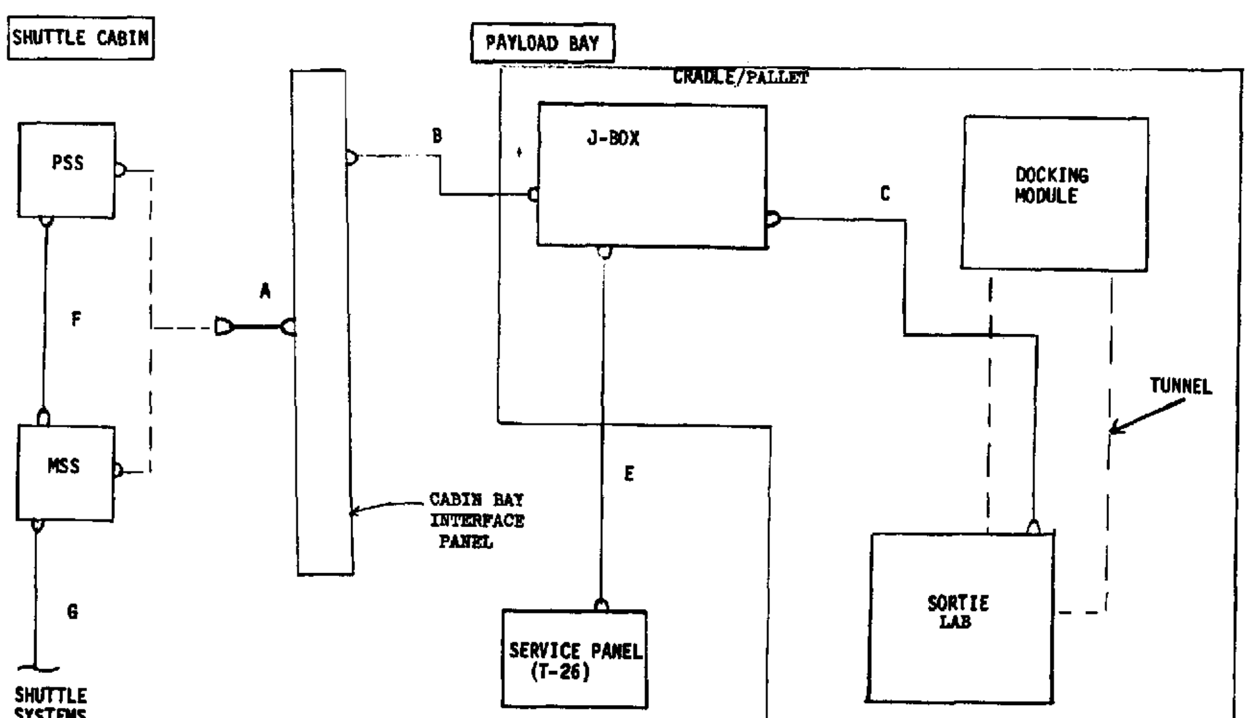


TABLE C-4

SORTIE LAB ELECTRICAL INTERFACE FUNCTIONS

System	Characteristics	Requirement	Wire/Gage
	Segments A, B, C, & D		
Power	28 VDC return	3 KW (Shuttle allowance) 3 KW (Shuttle allowance)	6 #12 (41a free air) 6 #12 (23a in bundle)
C & W	Bandwidth: 10 Hz	20 signal allocation to and from orbiter, redundant power	40 TSP/20 2 TSP/20
Narrowband digital telemetry	Rate: 25 KBPS	Data Clock	1 TSP/20 1 TSP/20
Computer link	Rate: 30 KBPS	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: 2 KBPS	Data Clock	1 TSP/20 1 TSP/20
Stabilization/ Pointing	Undefined (30 KBPS) Attitude Rate	Data Clock	1 TSP/20 1 TSP/20
Wideband data	Rate: 256 KBPS	Data Clock	1 TSP/20 1 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	20 functions	40 TSP/20
Two-way voice	Bandwidth: 3 KHz	Channel select	1 TSP/20
Lab to orbiter	Channels: 2	Station select	1 TSP/20
Lab to orbiter to mission control		Voice	1 TSP/20
Video	Bandwidth: 5 MHz	Data	1 Coax
		Totals:	12 #12 95 TSP/20 1 Coax
	Segment E		
Power	28 VDC return	Undefined (10 KW) Undefined (10 KW)	3 #0 (245a free air) 3 #0 (150a in bundle)
Computer up-down link	Rate: 30 KBPS	Data Clock	1 TSP/20 1 TSP/20
Narrowband data	Rate: 25 KBPS	Data Clock	1 TSP/20 1 TSP/20
Wideband data	Rate: 256 KBPS	Data Clock	1 TSP/20 1 TSP/20
C & W	Bandwidth: 10 Hz	15 functions redundant power	15 TSP/20 2 TSP/20
Control & related bilevel monitoring	Dedicated hardwire system	20 functions	40 TSP/20
Two-way voice	Bandwidth: 3 KHz	Voice comm	2 TSP/20
		Totals:	6 #0 65 TSP/20
	Segment F*		
Power	28 VDC	3 KW (allowance) 550 W (PSS)	6 #12 (41a free air) (23a in bundle)
	Return	3 KW (allowance) 550 W (PSS)	6 #12
C & W monitor	Bilevel	C & W master alarm 20 function exchange	1 TSP/20 20 TSP/20
Narrowband data	Rate: 25 KBPS	Data Clock	1 TSP/20 1 TSP/20
Wideband data	Rate: 256 KBPS Bandwidth 1 MHz	Data Clock	1 TSP/20 1 TSP/20
Computer keyboard	Parallel digital	16 data lines 1 mode	16 TSP/20 1 TSP/20
Two-way voice	Bandwidth: 3 KHz	Voice comm	1 TSP/20
Video	Bandwidth: 5 MHz	Data	1 Coax
		Totals:	12 #12 42 TSP/20 1 Coax

*N/R if PSS not used for Sortie Lab.

System	Characteristics	Requirement	Wire/Gage
	Segment G		
Power	28 VDC return	3 KW (allowance) 550 W (PSS)	6 #12 (41a free air) 6 #12 (23a in bundle)
C & W	Bilevel-undefined (0-28 VDC)	C & W master alarm	1 TSP/20
Narrowband data	Rate: 25 KBPS	Data relay	2 TSP/20
Wideband experiment data	Rate: 256 KBPS	Data relay	2 TSP/20
		Totals:	12 #12 5 TSP/20

C.1.4 Summary

The electrical interface required between the various elements that comprise the payload-payload support system is driven by the control-display functions needed to accomplish in-flight and prelaunch Shuttle-integrated processing (testing, monitoring, preparation) of the payload. The interface wiring requirements generated for each mission class and shown in the preceding tables are classified as worst case estimates with regard to numbers of wires required for the following reasons:

A. Wiring allowances were provided for each mission class to permit redundant hardwire monitoring of parameters at the PSS and MSS that are available for display via processing of the serial digital telemetry stream.

B. Redundant hardwire control is provided as a back-up to the hard-wired serial digital command link for both the payload and tilt table-deployment platform systems.

C. A twisted shielded wire pair (TSP) was allocated to each electrical function. In some cases where it is determined to be acceptable to use a common return line, the numbers of required wires will be reduced.

C.2 DATA TRANSFER TECHNIQUES

Digital data exists in the following common forms:

A. Discretes which are single bits indicative of an event state.

B. Serial digital data either self-clocking or transferred with separate clock lines.

C. Parallel digital data where distances are short accompanied by clock lines and "handshakes" or transfer initiating pulses.

Transfer of data in parallel form is not a serious contender for use in the payload bay for two reasons: 1) the bay is 60 ft long; 2) the signal interfaces between the payload and the Tug are already in a serial format. The transformation of data from one form to the other would simply add unnecessary complexity and increase the cost of equipment.

C.2.1 Serial Data Transfer Technique Selection

The selection of a transfer technique for serial data is usually based upon the following criteria:

A. Numbers of interfaces to be considered
B. Data transfer rate
C. Distance between sources and sinks
D. Allowable error rate
E. Type of multiplexing to employ
F. Transmission medium
G. Synchronization
H. Method of control
I. Degree of redundancy
J. Error detection and correction
K. Interface coupling and isolation

Although all are pertinent to design of the data bus systems within the Tug and the Orbiter only Items B, C, E, F, G, I and K are of particular importance when considering the interfaces between the spacecraft and Tug, Orbiter, payload service panel and integration equipment. One additional consideration which is important is to achieve design consistency with Tug and Orbiter data systems in order to increase equipment commonality and reduce the level of training necessary to understand and repair the systems.

The types of digital data to be transferred are summarized in Table C-5 together with their individual data rates (Item B) which will be used in considering the transfer medium. Satellite narrowband data is baselined for interleaving with Tug data on Tug studies. Digital data transfer to the PSS from the Class II mission satellites will be hardwired from the satellite PCM encoder output, through the Tug using Tug wiring, to the PSS. This approach essentially bypasses the Tug data bus which eliminates any requirement for data searching of Tug-satellite interleaved data by the flight support equipment (PSS) and provides the capability for performance of satellite checkout activities when the Tug is inactive. It is also carried directly to the T-26 service panel to allow pre-launch checkout of the satellite when the Tug is not active. Wideband data will always interface directly with the Orbiter systems although routed through the Tug for Class II spacecraft. Computer uplink and serial commands will interface with the Tug and spacecraft signal conditioners and decoders. However, whether the command emanates from the Orbiter or the Tug the originator should be indistinguishable to the spacecraft.

To ensure that consistent interface designs would be provided for spacecraft independent of their class and interfacing systems, design personnel were contacted at MDC and the Space Division of Rockwell International to ascertain the status of Tug and Orbiter data bus designs. This status is shown in Table C-6. It is seen that designs are virtually identical with the exception of the future possibility of the Orbiter's mission-critical bus going to full duplex operation. The change is contemplated due to forecasts of high bus loading (high data rates in respect to bus rate).

TABLE C-5
DIGITAL DATA TO BE TRANSFERRED

Payload	N.B. Data (KBPS)	W.B. Data (KBPS)	Computer Uplink (KBPS)	Serial Command (KBPS)	Discretes
EOS	12.5	None		2	N.A.
ATS, SMS, DSCS-II	0.25 to 0.64	None	20	1	N.A.
LST	1.6	51.2	30	0.20	N.A.
Space Lab	25	256	30	2	N.A.
Tug	51.2	None	25	2	N.A.

TABLE C-6
DATA BUS CURRENT DESIGN STATUS

Specification	Orbiter (mission critical bus)	Tug
Bus Rate (MBPS)	1	1
Bus Type		
(Current)	Half-duplex	Half-duplex
(Future)	Full-duplex (?)	
Modulation Type	Bi-phase	Bi-phase
Synchronization	User Generated	User Generated
Word Length		
(Data)	16 bits	16 bits
(Overhead)	8 bits	8 bits
(Total)	24 bits	24 bits
Redundancy	Dual Redundancy	Dual Redundancy
Error Detection	Included in Overhead	Included in Overhead

It has been indicated that the Tug bus design will follow the Orbiter's lead to ensure commonality.

Since subsystems within the two STS elements will interface via redundant (Item I) two wire lines (Item F) using biphase modulation (Item E) which implies transformer coupling (Item K) it would appear that these are desirable criteria for payload bay wiring. However, it also seemed reasonable to review some of the tradeoffs pertinent to the bay wiring.

The selection of a PCM modulation technique was first investigated as illustrated by Figure C-4 because so many possibilities exist. The three waveforms illustrated are those which are commonly selected after a review of all characteristics. Due to its self-clocking characteristics (Item G) eliminating clock lines, lack of a DC frequency component allowing transformer coupling and circuit isolation (Item K) and general lack of negative aspects it is seen that biphase or Manchester coding is a reasonable choice.

Table C-7 summarizes the rationale for this selection and also indicates the superiority of Twisted Shielded Pair (TSP) over Coax for data rates requiring bandwidth below 10 MHz on the basis of external noise attenuation as well as cost and weight.

IIS SOAR

TABLE C-7
DATA TRANSFER TECHNIQUE SELECTION

CABLE TYPE

ALTERNATIVE	BANDWIDTH	WEIGHT	COST	NOISE ATTENUATION
TSP	TO 10 MHz	1 TO 2 LB/100 FT	$18/500 FT	56 DB AT 1 MHz, 53 DB AT 10 MHz
COAX	TO 500 MHz	15 TO 20 LB/100 FT	$100/500 FT	38 DB AT 1 MHz, 51 DB AT 10 MHz

SELECTION: TSP FOR DIGITAL DATA

MODULATION TYPE

NO. OF ALTERNATIVES	COMMONLY USED	AC COUPLED	SELF CLOCKING
23	HRZ - LEVEL	NO	NO
	BIO - LEVEL	YES	YES
	BI - POLAR*	YES	YES

SELECTION: BIO - LEVEL

*LEAST COMMON

FIGURE C-4

PCM WAVE FORMS

WAVE FORMS	ASPECTS	
	Positive	Negative
1 0 1 1 0 0 0 1 1 0 1 	Available Circuit Output	Requires Clock Line
NRZ - Level		
One represented by plus level	Simple Detection	DC Component
Zero represented by minus level	High Signal to Noise Ratio	Susceptible to Impulse Noise
		
Biϕ - Level	Clock Information Available	Clock must be Reconstructed
One Represented by Plus Minus	No DC Frequency Component	Signal Inversion Potential
Zero Represented by Minus Plus		
		
Bi-Polar NRZ	No DC Frequency Component	Lower Signal to Noise
One represented by equal magnitude opposite polarity pulses	Error Detecting Capability	Requires Forced Transitions
Zero represented by zero level		Sophisticated Bit Synchronized

C.2.2 Multiplexing Vs Hardwire

The question of whether to hardwire or multiplex data channels was first addressed in a general manner by estimating the equipment required for each case and the cost, weight and power demands. These parameters were traded and the expected weight savings of multiplexing resulted along with the expected higher costs. Consideration of other factors led to the selection of multiplexing as the recommended approach.

C.2.2.1 Assumptions and Procedure

The basic assumptions which were made are shown in Table C-8. Multiplexing required a master unit for program control irrespective of the number of channels multiplexed. A converter and remote multiplexer were then added to the system for each 32 channels of analog data to be acquired. Finally two twisted-shielded-pairs (TSP) were provided to carry a clock, synchronization and control bits to the multiplexers and data back to the controller. For the case of hardwire, a 30-foot average length of cable was assumed.

TABLE C-8

MULTIPLEXING VS HARDWIRE

	Unit Wt. (lb.)	Unit Cost ($ X 10^3)	Unit Pwr. (W)	No. A. (1000 Mea.)	No. B (100 Mea.)	No. C (10 Mea.)	Wt.			Cost			Pwr.		
							A	B	C	A	B	C	A	B	C
Master Unit	14	59.1	12	1	1	1	14	14	14	60	60	60	12	12	12
Converter Unit	2	4.4	2	32	3	1	64	6	2	140	13	4	64	6	2
Multiplex Unit	1.2	5.9	0.06	32	3	1	38	4	1	192	18	6	2	0.2	0.06
2 TSP at 100'	2	4.0	--	2	2	2	2	2	2	4	4	4	--	--	--
Total							118	26	19	396	95	74	78	18	14
TSP at 30' Avg.	.66	1.33	--	1000	100	10	660	66	666	1.33	.13	.013	--	--	--

C.2.2.2 General Results

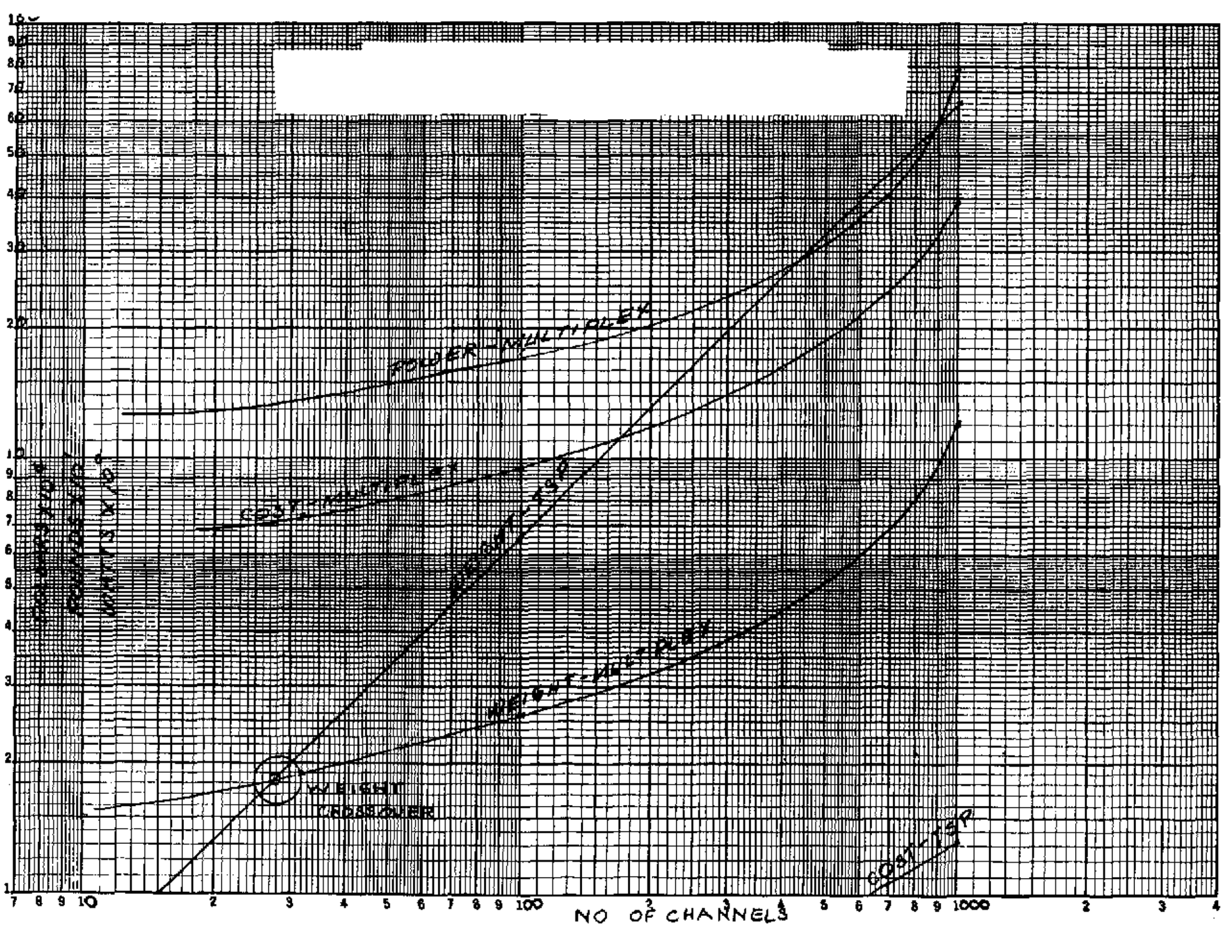
The results of the trade are shown in Figure C-5. It is seen that the cost of the multiplexed system is always much higher than for hardwire and there is a power penalty not paid by the latter system. The advantages of the multiplexed system appear in the weight tradeoff where the crossover point occurs at about 28 channels. A similar curve would result if volume were the parameter being traded.

C.2.2.3 Applicability of Results

Since the mission and payload stations contain computers, these devices will undoubtedly be used as the controlling elements. Their higher cost in relation to the master unit used in the trade is offset by their being shared for other functions such as display generation so that differences in approach tend to balance out. The multiplexed system will obviously require short cable lengths to connect from multiplexers to transducers or signal conditioners which have not been included. This is offset by the additional capacity of such a system when a number of discrete or event functions must be monitored. On the whole, the trends portrayed would seem to be valid.

FIGURE C-5

MULTIPLEX VS HARDWIRE TRADE



C.2.2.4 Other Considerations

Other factors which must be taken into account are (1) the panel area required to treat individual controls and displays which is synonymous with the use of hardwire, and (2) the time required for installation of equipment during Shuttle turnaround. Panel space is at a premium requiring a limitation on the quantity of switches and discrete readouts. Remote multiplexers and command units could be left in the bay from flight to flight since they are remotely programmable while payload peculiar cables would require changeout for every flight.

Finally, the majority of uplink and downlink measurements and command functions are already in multiplexed format and are simply not available in hardwire format.

C.2.2.5 Conclusion

In conclusion, the use of multiplexing appears to be the proper approach except for the disparity in cost. The advantages of time sharing appear to override this penalty.

C.3 CABLE DEFINITION

The required electrical signals and wire sizes for the study mission classes were established as presented in Figures C-1 through C-4 in Section C.1.

Specific considerations related to the determination of cabling systems for the mission classes are as follows:

A. Type of cabling; flat, belted, round

B. Types of connectors; standard, special purpose

C. Type of wiring insulation; teflon, kapton

Use of flat cabling is discarded basically because of the higher degree of confidence level associated with the connectors required for usage of round or belted cabling, viz., the state of the art.

Where geometric considerations are not germane, standard construction round cables are recommended. In applications where cables are routed through a narrow restricted passage, the recommended approach is usage of belted cables which are a flat braided configuration of the standard round version. This type of construction was utilized on the Lunar Excursion Module.

Recommendations with regard to type of connectors to be utilized are for usage of standard connectors which have already been flight qualified to avoid the cost and uncertainties related to development of special purpose connectors. Standard connectors in this case are defined as the NAS 1599 type (NASA 40Mxxx series) such as ST234, ST232 and ST278 as specified by MDAC drawing STC0010. Connectors involved in remote demate/mate operations (umbilicals) are specified as a rack and panel type such as the Deutsch U79.

The characteristics comparison of teflon and kapton wire insulations are shown in Table C-9.

TABLE C-9

TEFLON AND KAPTON INSULATION

Teflon (TFE)		Kapton	
burns with less vigor		type 3 flammable characteristic	
cold flow if pinched		no cold flow	
-252°C	low temperature	-195°C	low temperature
+260°C	high temperature	-200°C	high temperature
		has notch sensitivity	
		rugged - high scrape/abrasion resistance	
		carbon-oxygen reaction in pure O_2	

One of the significant advantages of kapton insulated wiring is the 30-40 percent reduction in weight and volume when compared with teflon insulation. Consideration of installations, environment, predicted traffic and handling lead to the general conclusion for usage of teflon insulated wiring in the Shuttle cabin and kapton in the payload bay.

Cabling schematics developed for the mission classes are shown in Figures C-6 through C-8. Details of the cabling with regard to functional allocation, connector pins/gages and size estimates are presented in Tables C-10 through C-12.

FIGURE C-6
EOS/LST EQUIPMENT CABLING

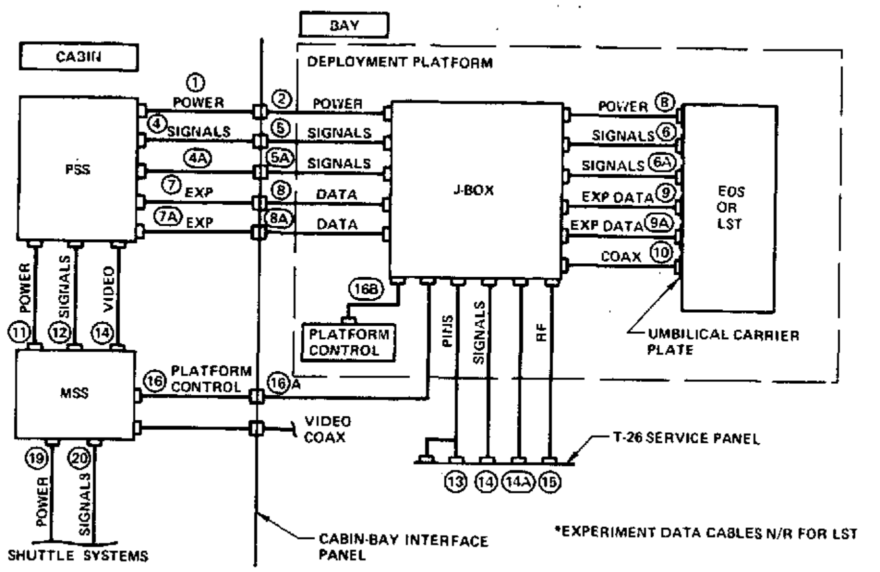


TABLE C-10
EOS/LST CABLING DEFINITION

CABLE I.D.	FUNCTION	PINS-GAGE	CONN. DIAMETER	
1, 2, 3	POWER	4-12	1-1/2 IN.	
4, 5, 6	SIGNALS	61-20	1-1/2 IN.	
4A, 5A, 6A	SIGNALS	61-20	1-1/2 IN.	
*7, 8, 9	EXPERIMENT DATA	61-20	1-1/2 IN.	
*7A, 8A, 9A	EXPERIMENT DATA	26-20	1 IN.	
10, 15	RF (GROUND	MULTIPLE COAX	1-1/2 IN.	
11	POWER	8-12*	1-1/8 IN.	
12	SIGNALS	55-20	1-3/8 IN.	
13	POWER (GROUND)	8-12	2 IN (2)	
14	SIGNALS (GROUND)	61-20	1-1/2 IN.	
14A	SIANGLS (GROUND)	32-20	1-1/8 IN.	
15	RF (GROUND)	MULTIPLE COAX	1-1/2 IN.	
16, 16A	PLATFORM CONTROL	32-20	1-1/8 IN.	
16B	PLATFORM CONTROL	55-20	1-3/8 IN.	
17, 18	VIDEO	MULTIPLE COAX	1-1/2 IN.	
19	POWER	6-12	1-1/2 IN.	
20	SIGNALS	6-20	5/8 IN.	*N/R FOR LST

FIGURE C-7

CLASS II MISSION EQUIPMENT CABLING

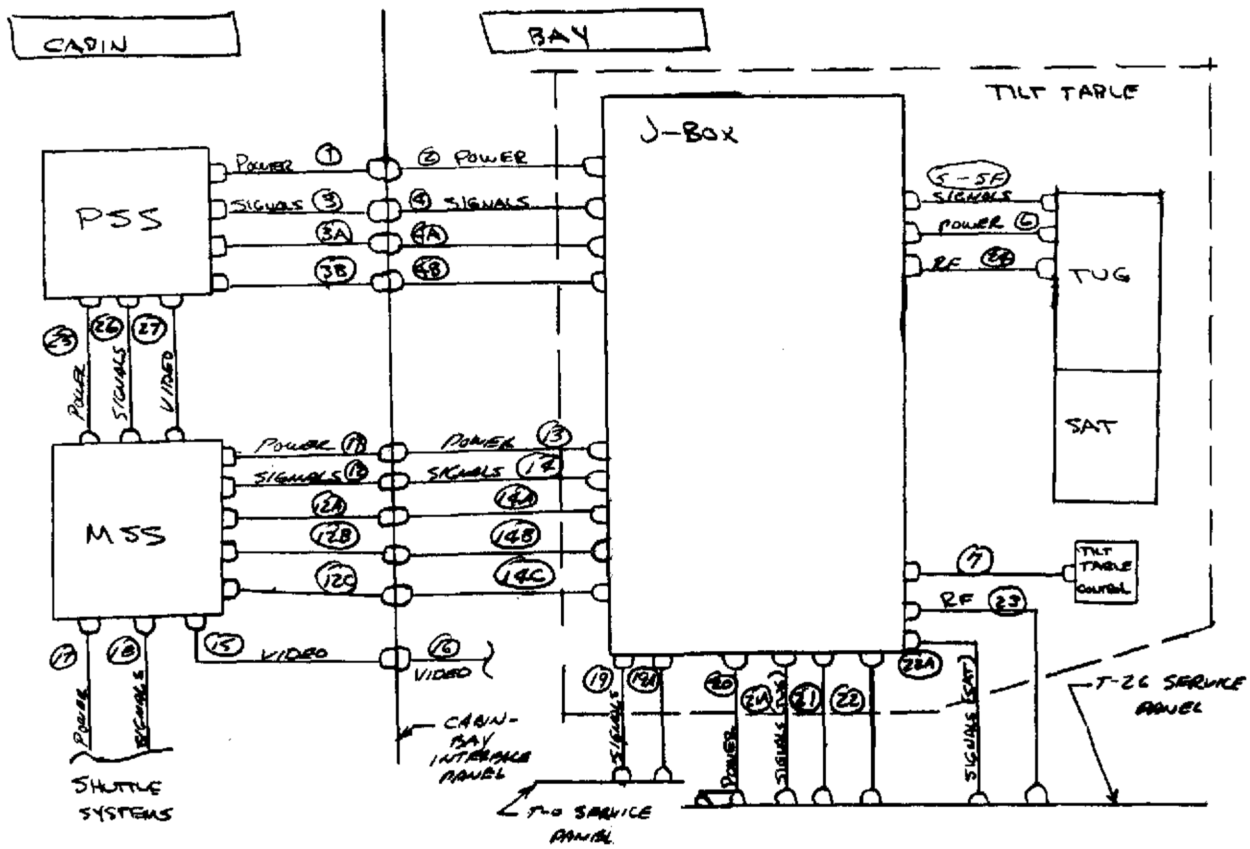


TABLE C-11

CLASS II MISSION CABLING DEFINITIONS

CABLE I.D.	FUNCTION	PINS-GAGE	CONN. DIAMETER
1, 2, 25	Power	4-12	7/8 in.
3, 4	Signals	61-20	1-1/2 in.
3A, 3B	Signals	61-20	1-1/2 in.
4A, 4B, 26	Signals	26-20	1 in.
5, 5A, 5B, 5C, 5D, 5E, 5F	Signals	61-20	1-1/2 in.
6	Power	8-12	1-3/8 in.
7	Tilt Table Control	55-20	1-3/8 in.
8	Power	12-12	1-3/8 in.
9	Signals	55-20	1-3/8 in.
10	Video	Multiple Coax	1-1/2 in.
11, 13	Power	8-12	1-3/8 in.
12, 14	Signals	61-20	1-1/2 in.
12A, 12B, 12C	Signals	61-20	1-1/2 in.
14A, 14B, 14C	Signals	61-20	1-1/2 in.
15, 16, 27	Video	Multiple Coax	1-1/2 in.
17	Power	8-12	1-3/8 in.
18	Signals	32-20	1-1/8 in.
19	Signals	61-20	1-1/2 in.
19A	Signals	55-20	1-3/8 in.
20	Power	12-12	2 in (2)
21, 21A	Signals	61-20	1-1/2 in.
22	Signals	61-20	1-1/2 in.
22A	Signals	26-20	1 in.
23, 24	RF Coax	Multiple Coax	1-1/2 in.

FIGURE C-8
SORTIE LABORATORY EQUIPMENT CABLING

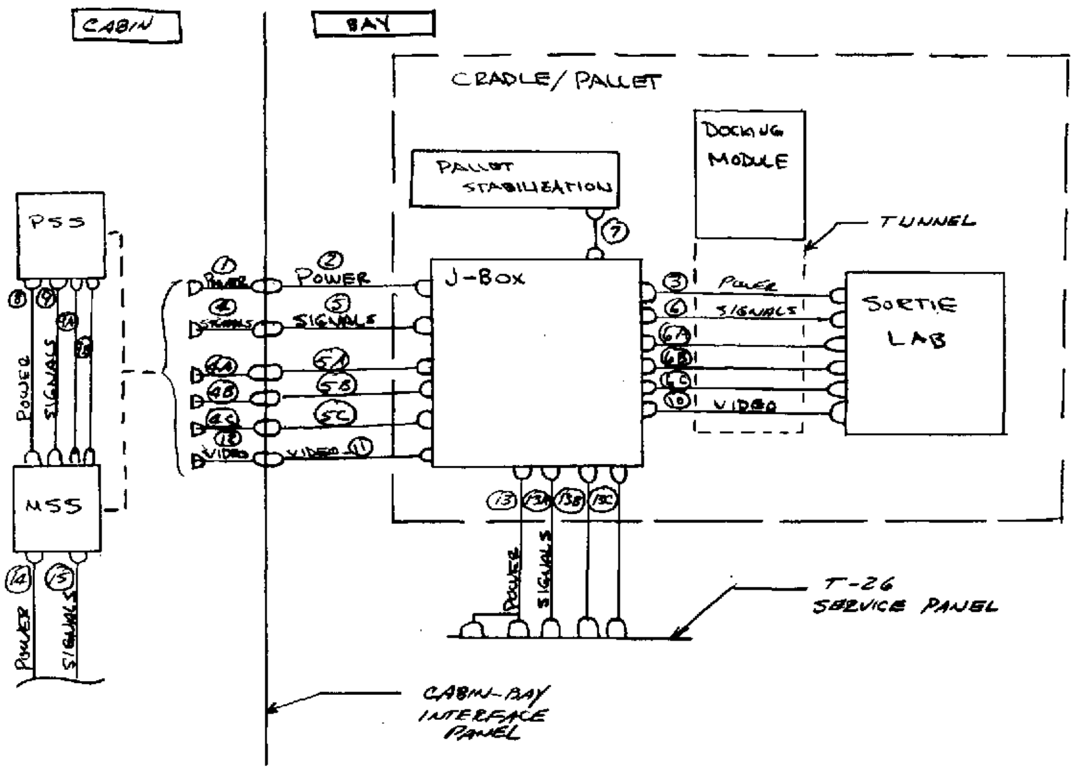


TABLE C-12
SORTIE LABORATORY CABLING DEFINITION

CABLE I.D.	FUNCTION	PINS-GAGE	CONN. DIAMETER
1,2	Power	12-12	1-3/8 in.
3	Power	4-00	3 in.
4, 5, 6	Signals	61-20	1-1/2 in.
4A, 4B, 4C	Signals	61-20	1-1/2 in.
5A, 5B, 5V	Signals	61-20	1-1/2 in.
6A, 6B, 6C	Signals	61-20	1-1/2 in.
7	Pallet Stabilization (Serial Digital)	6-20	5/8 in.
*8	Power	12-12	2 in. (2)
*9, 9A, 9B	Signals	61-20	1-1/2 in.
10, 11, 12	Video	Multiple Coax	1-1/2 in.
13	Power	4-00	3 in.
13A, 13B	Signals	61-20	1-1/2 in.
13C	Signals	10-20	3/4 in.
14	Power	12-12	1-1/2 in.
15	Signals	6-20	5/8 in.

Each system shown in Figures C-6 through C-8 includes a J-box (distribution box) that is mounted on the deployment platform and/or tilt table (as appropriate) which provides signal/power distribution and houses various items of support equipment such as isolation/buffering systems, power regulators and command decoders.

The isolation/buffering systems are required to provide isolation of various grounds/returns throughout the Shuttle/payload/FSE systems and to facilitate effective control and monitoring of payloads by interconnected GSE. Isolation systems typically use diodes, resistors, buffer amplifiers and transformer coupling to achieve the desired isolation of interconnected systems.

Power regulators are required to condition the Shuttle supplied power to regulation values within satellite system requirements.

Figure C-9 provides a representative J-box layout for the EOS and LST. The isolation system is required to handle 115-120 functions between the bay and cabin, and 45-50 functions between the bay and payload related GSE. The noted number of bay-cabin functions are driven by acquisition of EOS experimental data during Shuttle attached ORT at LEO and is therefore reduced by 40 functions for the LST mission.

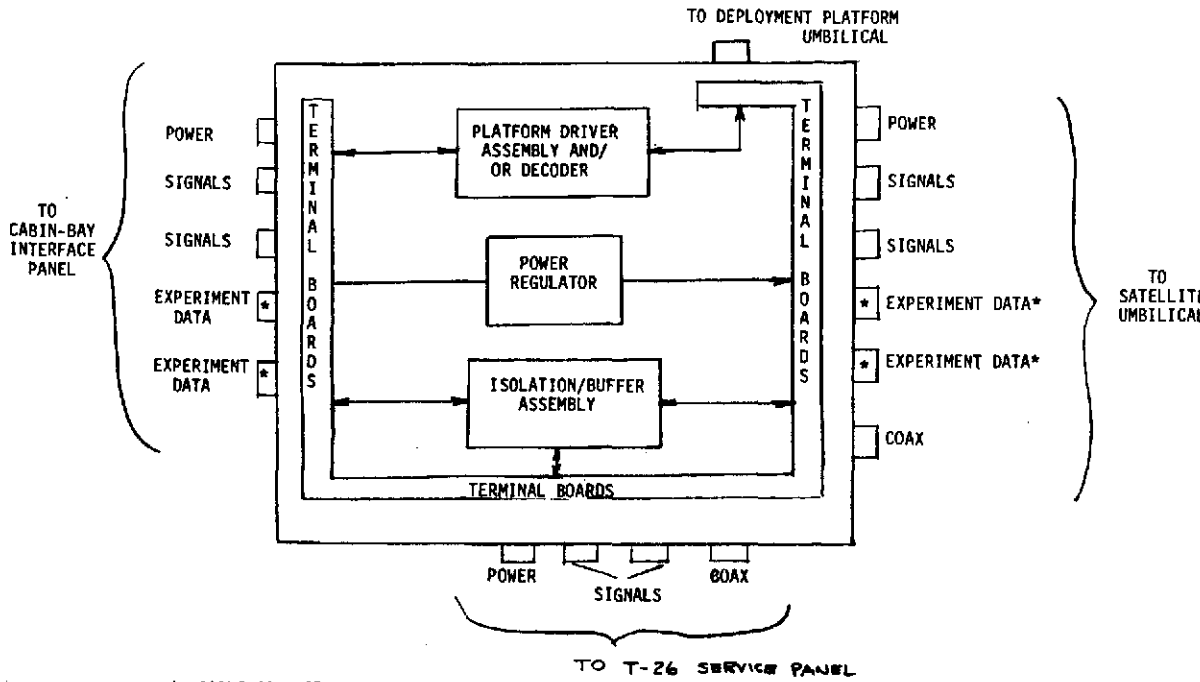
The deployment platform driver and decoder assembly provides a redundant system for platform control via hardware control from the PSS and MSS to switching amp drivers within the assembly and through utilization of a serial digital command line to the command decoder.

Estimate of the J-box characteristics follows:

Dimensions	12 x 14 x 18 in
Weight	60 - 80 lbs
Power	40 - 50 watts

FIGURE C-9

ECS/LST J-BOX



* CABLE CONNECTIONS NOT REQUIRED FOR LST

Figure C-10 presents a representative J-box for the Class II missions (ATS/SMS/DSCS - Tug). The system is conceptually identical to the EOS and LST (Figure C-10). The driver assembly and decoder in this case provides redundant hardwire/digital control of the tilt table. Power regulation equipment is provided for regulation of both tug and satellite power. The isolator buffer assembly for Class II missions is required to handle 118 tug functions (bay-cabin) 74 satellite functions (bay-cabin) 43 T-26 satellite functions, 59 T-26 tug functions and 46 T-0 tug functions.

An estimate of J-box characteristics follow:

Dimensions	12 x 16 x 18 in.
Weight	90 - 100 lbs.
Power	50 - 60 watts

FIGURE C-10

CLASS II MISSIONS - J-BOX

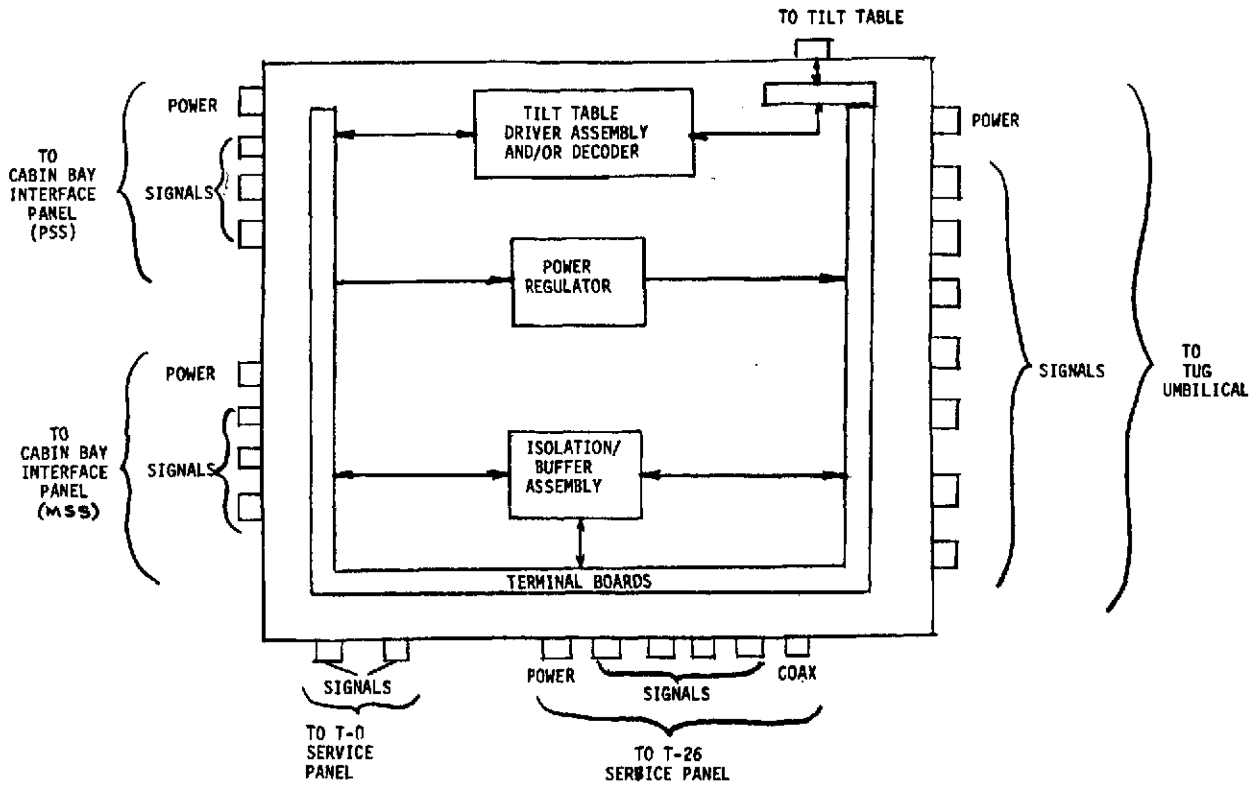


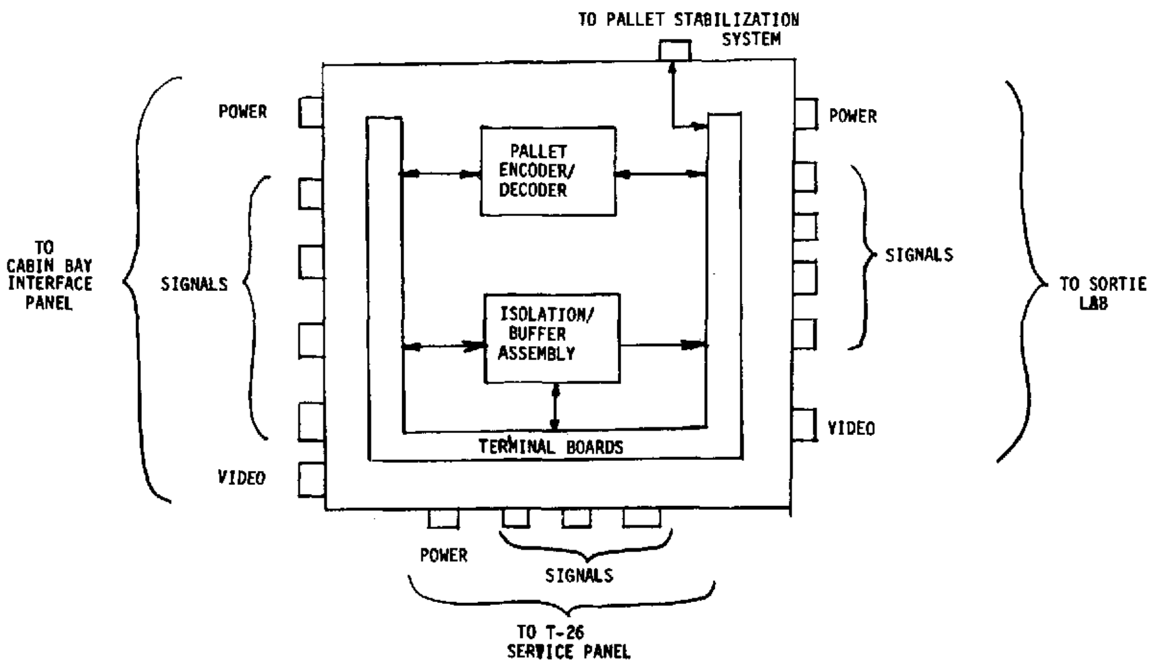
Figure C-11 presents a J-box layout for the Sortie Lab. Power conditioning equipment for this mission is omitted based on the assumption that the lab has the internal capability for power conditioning. Pallet type missions may require the use of power regulation equipment depending on specific configurations and requirements. A stabilization (attitude control) encoder-decoder is included for this mission (pallet) to provide Shuttle computer control of the stabilization platform. This approach was selected as compared to a hardwired approach per the rational developed in Section C.2

An estimate of J-box characteristics follows:

Dimensions	12 x 14 x 18 in.
Weight	30 - 40 lbs.
Power	30 - 40 watts

FIGURE C-11

SORTIE LAB J-BOX



C.4 PAYLOAD/GSE INTERFACE REQUIREMENTS

C.4.1 Electrical Interfaces

The following describes the required payload electrical interfaces with the GSE by mission class.

C.4.1.1 Class I and III (EOS and LST)

From Figure C-1, the GSE electrical interfaces for the EOS and LST are through the Shuttle T-26 service panel, through interface segments D and E which correspond to cables 13, 14, 14A and 15 in Figure C-6.

The functions provided for each satellite are presented in Table C-13. The approach for the EOS and LST provides no functions through the T-0 service panel based on the premise that caution and warning and health data are available to the launch control center via the Shuttle-satellite interleaved RF data and that satellite system control is achieved from the PSS commencing no later than T-26 minutes.

C.4.1.2 Class II Missions (ATS/SMS/DSCS-Tug)

From Figure C-2, the electrical interface functions to the T-0 and T-26 service panels are through segments K, F and E respectively. These segments correspond to cables 19 and 19A to the T-0 panel and cables 20, 21, 21A, 22 and 22A to the T-26 panel (Figure C-7).

At the T-26 panel cables 21 and 21A are allocated to Tug functions; cables 22 and 22A are allocated to satellite functions. Ground power is supplied through cable 20; RF signals to ground are routed through multiple coaxial cable No. 23.

At the T-0 service panel, cables 19 and 19A are allocated to carry Tug propellant systems control and display functions to maintain continuous propellant systems control and off loading capability, and to provide control of the remaining Tug systems since operation of the MSS is impractical until reaching low Earth orbit. No satellite functions are provided through the T-0 service panel based on the rational developed for the EOS and LST.

The T-0 functions for Tug and the T-26 functions for the Tug and the satellites are presented in Tables C-15, C-16 and C-17 respectively.

TABLE C-13

EOS ELECTRICAL FUNCTIONS T-26 PANEL

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Ground Power	28 VDC Return	1500 W 1500 W	4 #12 (41a free air) 4 #12 (23a in bundle)
Caution & Warning	Bandwidth: 10 Hz	7 Functions	7 TSP/20
Narrowband Digital Telemetry	Rate: 12.5 KBPS	Housekeeping and Test Data	1 TSP/20
Computer Up-Down Link	Rate: Undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Control and Related Bilevel Monitoring	Bilevel-Dedicated Hardwired System	11 Signals	22 TSP/20
Batteries	32-35 VDC	Trickle Charge 0.6a	1 TSP/20
Satellite Systems	Analog-Bilevel Bandwidth Undefined	10 Functions (Allowance)	10 TSP/20
VIP	VHF S-Band	Housekeeping Data Housekeeping Data	1 Coax 1 Coax
MIRP	S-Band	Sensor Systems Data	1 Coax
MOMS	S-Band	Sensor Systems Data	1 Coax
		Totals	8 #12 43 TSP/20 4 Coax

TABLE C-14
LST ELECTRICAL FUNCTIONS T-26 PANEL

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Ground Power	28 VDC	1500 W (max)	4 #12 (41a free air) (23a in bundle)
Ground Power	Return	1500 W (max)	4 #12
Caution & Warning	Bandwidth: 10 Hz	3 Functions	3 TSP/20
Narrowband Digital Telemetry	Rate: 51.2 KBPS	Housekeeping & Test Data, C&W Backup	1 TSP/20
Computer Up-Down Link	Rate: Undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Control and Related Bilevel Monitoring	Bilevel-Dedicated Hardwired System	8 Signals	16 TSP/20
Batteries	32-35 VDC	Trickle Charge 0.6a	1 TSP/20
Satellite System	Analog-Bilevel Bandwidth Undefined	10 Functions (allowance)	10 TSP/20
	S-Band	Telemetry Data Down Link	1 Coax
		Total	8 #12 33 TSP/20 1 Coax

TABLE C-15
TUG ELECTRICAL INTERFACE FUNCTIONS T-0 PANEL

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Narrowband Digital Telemetry	Rate: 51.2 KBPS	Housekeeping Data	2 TSP/20
Propellant System (Tug)	Discrete Hardwire	20 Functions	20 TSP/20
Tug Systems Control	Discrete Hardwire	12 Functions	12 TSP/20
Monitor	Discrete Hardwire	12 Functions	12 TSP/20
		Total	36 TSP/20

TABLE C-16
TUG ELECTRICAL INTERFACE FUNCTIONS T-26 PANEL

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Power	28 VDC Return Sense	1800 W 1800 W Voltage Regulation	6 #12 (41a free air) 6 #12 (23a in bundle) 1 TSP/20
Caution & Warning	Bandwidth: 10 Hz Dedicated Hardwire System	24 Functions	24 TSP/20
Computer Up-Down Link	Rate: Undefined (20 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Command	Rate: Undefined (2 KBPS)	Data Clock	1 TSP/20 1 TSP/20
Battery	32-35 VDC	Trickle Charge 0.1 Ampere	1 TSP/20
Video	Bandwidth: 5 MHz	Data	1 Coax
		Total	12 #12 30 TSP/20 1 Coax

TABLE C-17
CLASS II SATELLITE ELECTRICAL INTERFACE FUNCTIONS T-26 PANEL

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Power	28 VDC Return Sense	300 W 300 W Voltage Regulation	2 #12 (41a free air) 2 #12 (23a in bundle) 1 TSP/20
Caution & Warning	Bandwidth: 10 Hz Dedicated Hardwire System	12 Functions	12 TSP/20
Narrowband Digital Telemetry	Rate: 250-640 BPS	Housekeeping and Test Data, C&W Backup	2 TSP/20
Control and Related Bilevel Monitoring	Dedicated Hardwire Systems	22 Functions (max)	22 TSP/20
Computer Up-Down Link	Rate: Undefined (20 KBPS)	Data Clock	2 TSP/20
Command	Rate: DSCS 1 KBPS SMS Undefined ATS Undefined	Data Clock	2 TSP/20
Battery	32-35 VDC	Trickle Charge 0.3a	1 TSP/20
		Total	4 #12 32 TSP/20

C.4.1.3 Sortie Laboratory Missions

From Figure C-3, the GSE electrical interface for the Sortie Lab is through interface segment E which corresponds to cables 13, 13A, 13B and 13C in Figure C-8. The electrical functions provided through the T-26 panel are shown in Table C-18. It should be noted that approximately 60 percent of the T-26 functions are allocated to an allowance for control and related bilevel monitoring which creates the need for 40 twisted shielded wire pairs. This allowance was made due to the lack of definition of systems contained within the Sortie Lab and is purely an assessment of Sortie Lab needs.

TABLE C-18
SORTIE LABORATORY T-26 FUNCTIONS

SYSTEM	CHARACTERISTICS	REQUIREMENT	WIRES/GAGE
Power	28 VDC Return	Undefined (10 KW) Undefined (10 KW)	2 #00 (2830 free air) 2 #00 (1756 in bundle)
Computer Up-Down Link	Rate: 30 KBPS	Data Clock	1 TSP/20 1 TSP/20
Narrowband Data	Rate: 25 KBPS	Data Clock	1 TSP/20 1 TSP/20
Wideband Data	Rate: 256 KBPS	Data Clock	1 TSP/20 1 TSP/20
Caution & Warning	Bandwidth 10 Hz	15 Functions Redundant Power	15 TSP/20 2 TSP/20
Control & Related	Dedicated Hardwire System	20 Functions (allowance)	40 TSP/20
Two-Way Voice	Bandwidth: 3 KHz	Voice Comm.	2 TSP/20
		Totals	4 #00 65 TSP/20

C.4.2 Fluid Interfaces

All four classes of SOAR-IIS payloads use fluids, and as such will require ground fluid interfaces. In addition, one (Sortie Lab) may have flight interfaces with Orbiter subsystems. Tables C-19 and C-20 summarize the gas and fluid interfaces for each payload class. The spacecraft interfaces are straightforward, with both GN_2 and N_2H_4 preloaded (at the PSA) before mating with the Orbiter. However, propellant drain capability is required on the pad for emergency dump. Drain procedures require access to the cargo bay for manual attachment of the drain line, which safely removes the propellant to an approved container or area.

The Tug propulsion system interfaces are similar to existing vehicles, and will require the following 8 to 10 umbilical connections in the T-0 panel:

- 2 propellant fill
- 2 tank vent
- 2 accumulator fill
- 2 helium fill
- 2 dump (LO_2 may be inflight dump only; LH_2 may not have a dump line.)

Tug ground purge uses the Orbiter bay purge system. The Tug and Orbiter will share common ground equipment.

Final decision on the Tug dump requirements for abort have not been specified, but inflight dump capability for the LO_2 tank is likely. A 2-3 in. line through the Tug/Orbiter interface panel will be sufficient since there is no abort mode prior to solid motor rocket shutdown. This line dumps LO_2 out the bottom of the Orbiter, and will not go through the T-0 launch umbilical panel. The current baseline includes abort landing with the LH_2 tanks full, so no LH_2 dump line is required. If one is eventually required, it will be similar to the LO_2 dump line.

The LST is a payload extremely sensitive to particulate contamination. If the 100,000 class cleanliness of the cargo bay is not sufficient, and/or local covering of sensitive areas inadequate, the entire LST will be enshrouded with a class 10,000 air purge. This purge would require two 4 in. lines (inlet and return) for this specially cleaned air through the T-26 umbilical panel.

TABLE C-19
PAYLOAD GAS INTERFACES

40384

MISSION CLASS

	I EOS	II ATS/SMS DSCS-II	II TUG	III CST	IV SORTIE LAB	SPECIAL
N_2	PRELOADED-NO PAD REQMN'T	PRELOADED-NO PAD REQMN'T	-	PRELOADED - NO PAD REQMN'T	USES SHUTTLE N_2 -NO PAD REQMN'T	
H_E	-	-	1-1/2" COLD HE 1-1/2" AMB HE	-	-	
GO_2	-	-	1-1/2" VENT 1-2" FILL	-	USES SHUTTLE GO_2-NO PAD REQMN'T	
GH_2	-	-	1-1/2" VENT 1-2" FILL	-	-	
AIR	10,000 CLASS CLEANLINESS	-	-	10,000 CLASS CLEANLINESS IF LST SHROUDED	PURGE MAY BE RQD (POS P)	

TABLE C-20
PAYLOAD LIQUID INTERFACES

40384-1

MISSION CLASS

	I EOS	II ATS/SMS DSCS-II	II TUG	III CST	IV SORTIE LAB	SPECIAL
N_2H_4	PRELOADED-DRAIN RQD (NOT THRU PANEL)	PRELOADED-DRAIN RQD (NOT THRU PANEL)	-	-	-	
LH_2	-		1-2" FILL/DRAIN 1 - TBD DUMP (MAY NOT BE RQD)	-	TBD	
LO_2	-		1-2" FILL/DRAIN 1 - TBD" DUMP (MAY BE IN INFLIGHT ONLY)	-	TBD	
ECS	-		-	-	USES SHUTTLE ECS - NO PAD REQMN'T	MJS REQUIRES RTG THERMAL CONTROL

The Sortie Lab fluid interfaces cannot be finalized until the autonomous vs Shuttle provided ECS trade is completed. The current baseline supplies fluids to the Sortie Lab from the Shuttle subsystems. However, MSFC trades indicate an autonomous ECS is preferable, since the Shuttle provided thermal control system may not be adequate for Sortie Lab requirements. For the baseline configuration, the following Shuttle/Sortie Lab interfaces are received.

Freon inlet and return	(1" O.D.)
Water inlet and return	(1" O.D.)
LO_2 Fuel Cell Feed	(1/2" O.D.)
LH_2 Fuel Cell Feed	(1/2" O.D.)
ECS Air	(4" O.D.)

It is assumed that fuel cell water will be stored in the Sortie Lab. The only possible ground interface could be a GN_2 purge (supply and return) through the T-26 panel. This requirement has not been firmly established, but if it is required, two 4 in. O.D. lines will be required.

If, however, the Sortie Lab requires an autonomous ECS system, there will be no Freon, water, GN_2 or cryogenic fluid interfaces with the Shuttle. GN2, freon and water will probably be preloaded prior to mating. Cryogenics (LH_2 and LO_2) can be loaded through the T-26 panel (1 in. O.D. Line). Vent provisions for the LO_2 and LH_2 tanks will also be required and the simplest implementation is to use 2 in. lines and use the GH_2 and GO_2 vent umbilicals used for the Tug. Air circulation and conditioning will be entirely within the Sortie Lab, with no interface with the Orbiter except that which occurs through an open airlock. Atmosphere makeup will come from GN_2 bottles and LO_2 tanks within the Sortie Lab.

All payload using fluids of any kind are required to pass acceptance tests to verify system integrity. Such tests usually consist of proof, leakage and functional operation. Shuttle launched payloads are no different; however, all such tests are planned to occur prior to mating with the Orbiter. Therefore, no on-pad GSE or connections are required for fluid system testing.

The summary of payload required fluid/gas interfaces is presented in Figure C-12.

FIGURE C-12
PAYLOAD UMBILICAL REQUIREMENT

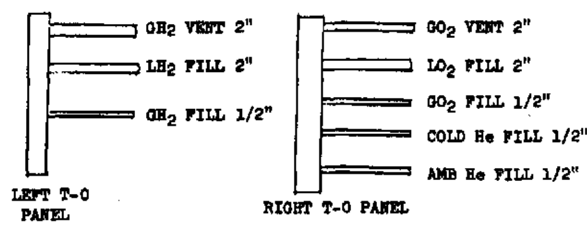
I

NONE REQUIRED - PROPULSION SYSTEM DUMP WILL REQUIRE MANUAL HOOKUP WITHIN CARGO BAY

II

SPACECRAFT - SAME AS I

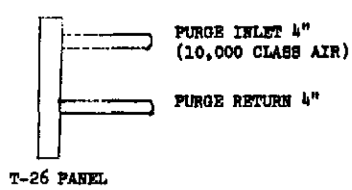
TUG -



III

NO PURGE - SAME AS I

WITH PURGE -



IV

SHUTTLE SUPPLIED - ONLY POSSIBLE REQUIREMENT IS PURGE AIR (10,000 CLASS), WHICH WOULD BE THE SAME AS III

AUTONOMOUS -

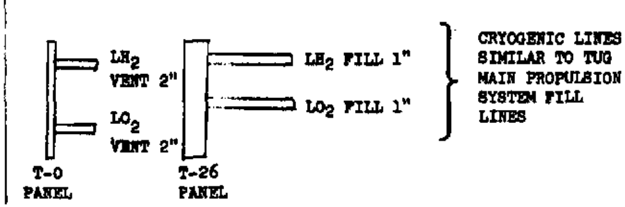
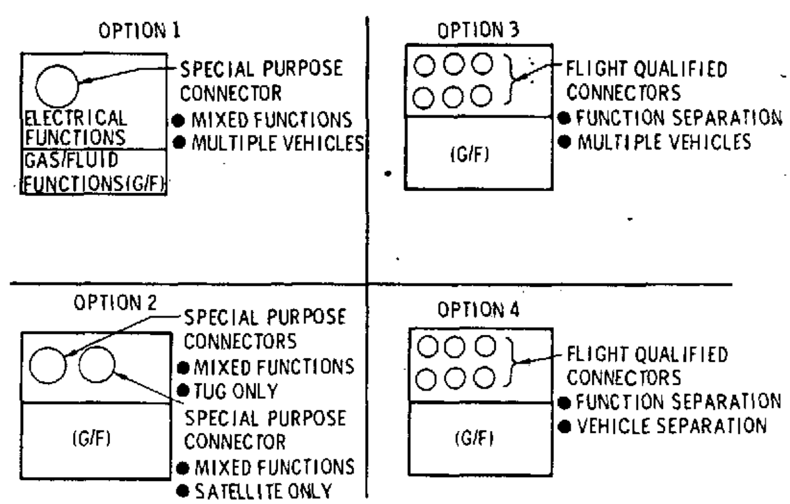


FIGURE C-13
SERVICE PANEL OPTIONS - ELECTRICAL



C.5 INTERFACE CONCEPTS

Selection of a GSE-Shuttle service panel interface concept is essentially governed by the following criteria.

A. Basis of connector separation

B. Available hardware

C. Operations

Connector functional allocations (Item A) may be based on maintaining separation of the various types of systems such as power, RF, control and talkbacks, and data. Using this approach, separate connectors and associated separate cabling are provided for each system and establishes the requirement to maintain the separation through system distribution points such as J-boxes. Connector assignments may also consider separation by vehichle wherein for example the interface to tug and satellite systems is provided through separate service panel connectors.

The primary consideration related to available hardware (Item B) is selection of existing flight qualification components versus the development of special purpose hardware. Use of existing flight qualified hardware provides a slight degree of restriction in system definition but eliminates the need for development of special purpose hardware with its attendant costs and introduction of the element of uncertainty.

Operational aspects are directed to consideration of requirements to provide independent checkout capability for multiple vehicle missions which again encompasses the area of connector functional assignments.

It is clear the three previous items comprising the previous criteria are closely aligned and interacting. The prime point is that their consideration results directly in specification of service panel characteristics.

Figure C-13 is presented to demonstrate conceptual service panel configuration options for the Class II missions with tug since this mission provides the widest latitude of configuration wherein option 1 provides all electrical functions for payloads through a single special purpose connector; option 2 provides a single special purpose connector for each vehicle, i.e., one for tug and one for satellites; option 3 provides flight qualified connectors with function separation but no vehicle separation; option 4 provides flight qualified connectors with both function and vehicle separation.

Option 4 is selected/recommended on the basis of the following merits:

A. Usage of existing flight qualified hardware eliminates the development costs related to special purpose equipment and the attendant operational risks.

B. Separation of electrical signals by function is desirable in order to minimize cross talk and its ultimate effects on separate systems and data.

C. Separation of electrical signals by vehicle is desirable in order to provide the versatility to accomplish prelaunch certification of one payload element when the other element is perhaps inactive.

C.6 ACCESS REQUIREMENTS

The locations requiring spacecraft and upper stage electrical access via the payload service panel, shown in Figure C-14 are seen to encompass a majority of the launch area facilities; the operations performed by the facilities are indicated in Table C-21. The functions required on the panel following loading of the spacecraft/Tug into the payload bay in the Integration and Mating Facility (CAB), during transport to the pad on the mobile launch platform and after Orbiter connection to the Launch Umbilical Tower are as follows:

A. Power, battery charge and monitoring lines required for Low-Earth-Orbit (LEO) spacecraft and, perhaps, for all spacecraft if the upper stage will be unpowered (and, therefore, incapable of supporting the spacecraft) at any time during prelaunch operations.

B. Serial PCM telemetry and command lines for status monitoring and final system checkout.

C. Caution and warning signals. Spacecraft now contain live ordnance and are fueled.

D. Discrete controls and talkback for function such as Tug fill and drain and system control.

E. A computer link for software update.

F. A voice link for Sortie Lab during any final on-pad equipment changeouts.

G. A video link for checkout of the Tug TV acquisition system.

As previously indicated, functions are split between the T-26 minute and T-0 panels. Tug hardwire and telemetry signals are available on the latter in case the Orbiter should pre-empt (the total data link) prior to liftoff.

After arrival at the pad, checkout and test of the payloads will be performed using equipment within the Payload Support Facility (NASA payloads), Payload Processing Facility (DOD payloads) and the Tug Maintenance and Refurbishment Facility. Integrated stage checkout also requires that controls and telemetry functions interface with the launch control firing room. This interface will be implemented via the Launch Processing System which accepts the Orbiter data stream with interleaved Tug and spacecraft data and distributes it to the various facilities.

FIGURE C-14

LOCATIONS WITH PAYLOAD SERVICE PANEL/TEST CONNECTOR ACCESS REQUIREMENTS

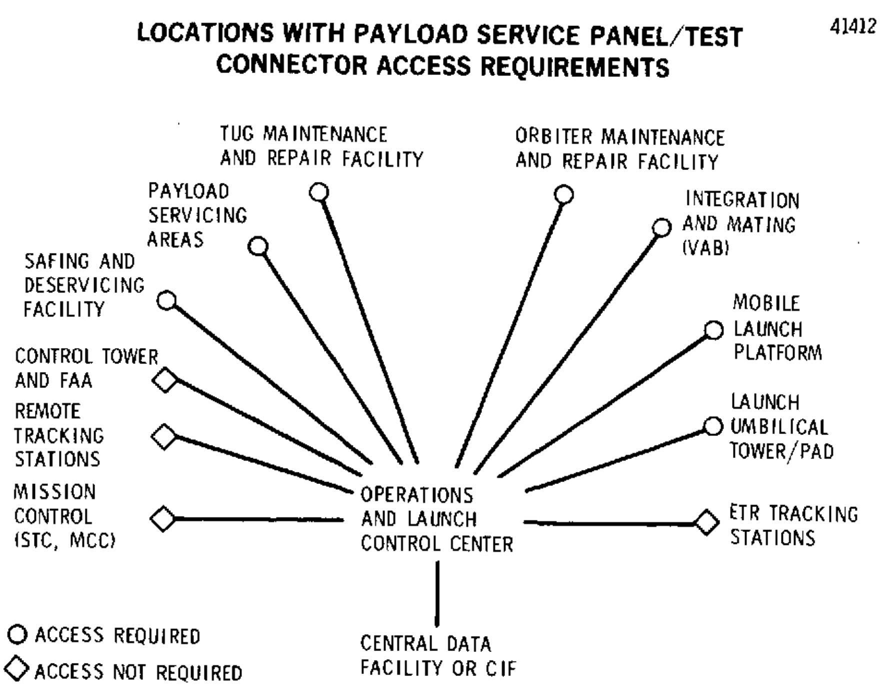


TABLE C-21

FACILITIES

SAFING AND DESERVICING FACILITY

- GROUND POWER
- ENVIRONMENTAL CONTROL
- DRAIN FUEL CELLS, TANKS
- PURGE TANKS AND LINES
- REMOVE HAZARDOUS PAYLOADS

TUG MAINTENANCE AND REFURBISHMENT

- RECEIVING AND READINESS TESTS
- SIMULATION AND CHECKOUT

PAYLOAD PROCESSING FACILITY

- RECEIVING AND CHECKOUT
- PRE-INSTALLATION MATING TESTS
- SIMULATION AND CHECKOUT

PAYLOAD SERVICING FACILITY

- RECEIVING AND CHECKOUT
- PRE-INSTALLATION MATING TESTS

ORBITER MAINTENANCE AND REFURBISHMENT CHECKOUT FACILITY

- PAYLOAD REMOVAL
- PAYLOAD INSTALLATION

INTEGRATION AND MATING (VAB)

- SRB MATING
- ET MATING
- SHUTTLE TEST AND CHECKOUT
- VEHICLE MOBILE LAUNCH PLATFORM MATING
- INTERFACE VERIFICATION

LAUNCH PAD/LUT

- ABBREVIATED AVIONICS TEST AND INTEGRATED CHECKOUT
- TUG FUELING

LAUNCH CONTROL FACILITY

- CONTROL ROOM - SUPPORT M&R
- CONTROL ROOM - SUPPORT PAD

Figure C-15 illustrates the distribution process. An antenna is provided on the Launch Umbilical Tower for the reception of the Orbiter's interleaved data. The signal is routed to an amplifier room and then transferred via hardline to the data processing system within the Central Instrumentation Facility. The data streams are demultiplexed at this point and input to the computer complex for processing prior to dissemination to remote terminals in the various facilities. A hardwire Orbiter umbilical is also routed to the LUT electrical equipment room to allow checkout to proceed during periods of RF silence.

FIGURE C-15
LAUNCH SITE COMMUNICATIONS

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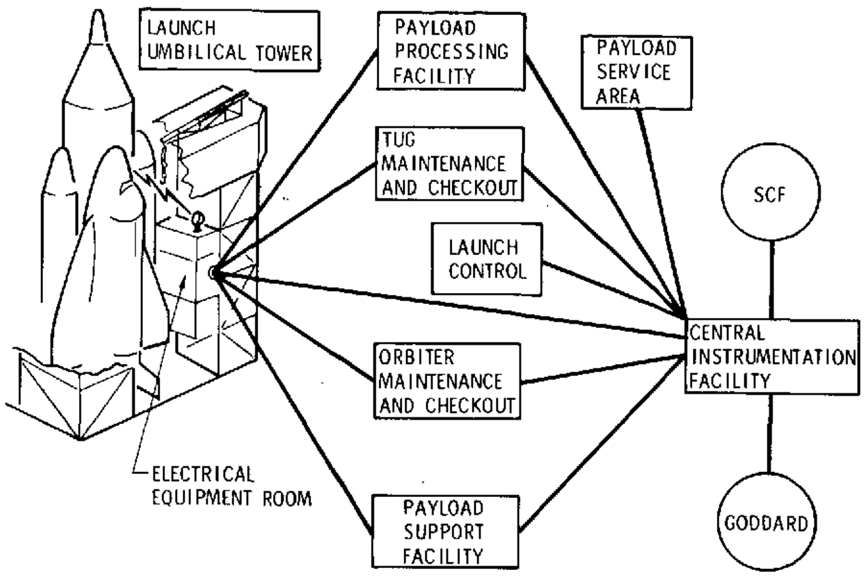

C.6.1 Pad Electrical Aerospace Ground Equipment (EAGE)

The EAGE required at the LUT which interfaces with the payload service panel is seen to be the following:

A. RF Amplifiers

B. Video Amplifiers

C. Line Amplifiers for Serial PCM and Serial Commands

D. Voice Communications Relay Equipment

E. Battery Chargers

F. Payload Power Supplies

G. Command Decoders and Relay Drivers

H. Remote Multiplexers

I. Patch Panel and Distribution Equipment

C.6.2 Mobile Launcher Equipment

The only interfaces with the Orbiter and payload service panels appear to be the following:

A. Battery Charge and Monitor

B. Caution/Warning Monitor

C.6.3 Orbiter Maintenance and Repair Facility

No requirements for service panel access have been found in the Orbiter Maintenance and Repair Facility with the exception of battery chargers and caution/warning monitoring. As indicated in Table C-22, all tests are concerned solely with Orbiter, external tank and solid rocket checkout with two exceptions. One, a combined booster/spacecraft system test conducted with the payload in the bay (performed via MSS and PSS consoles) is primarily for verification of connector mating. The second is a communications check verifying the Orbiter, Tug or spacecraft RF link and takes place prior to their installation within the bay.

C.6.4 Spacecraft Service/Payload Processing Facilities

Although the spacecraft has not been installed in the Orbiter at this point, it is, perhaps of interest to define how the lines, required at the S/C interface for the service panel, are integrated with spacecraft test connectors in order to provide the spacecraft/GSE interface. It also allows an initial assessment and identification of the GSE.

TABLE C-22

ORBITER MAINTENANCE/REPAIR/CHECKOUT FACILITY

TEST/OPERATION	CONNECTOR	EQUIPMENT
PRELIMINARY ELECTRICAL AND R.F. TESTS	ORBITER	NOT APPLICABLE
LOAD FLIGHT SOFTWARE	ORBITER	NOT APPLICABLE
SCF COMPATIBILITY TEST	R. F. BONNET	R.F. AMPLIFIER ANTENNA
ORBITER/PAYLOAD COMPATIBILITY TESTS	R.F. BONNET	R.F. CABLES
INTEGRATED SYSTEM TESTS (ORBITER/EXTERNAL TANK/BOOSTER MATE)	UMBILICAL	ORBITER GSE
MECHANICAL CHECKS	NONE	NONE
COMBINED BOOSTER/SPACECRAFT SYSTEM TEST	UMBILICAL	M.S.S., P.S.S. CONSOLES

Figure C-16 illustrates the test sequence normally followed in the Satellite Assembly Building and Propellant Laboratory Facility which are to be replaced by the Payload Processing Facility. After receiving inspection, the spacecraft undergo a reaction control system leak test, which only required valve controls, followed by a Satellite Control Facility compatibility check of transponders. This is followed by a check of the solar panels to detect any faulty cell strings. The spacecraft then loads propellant in a safe area after which the thrusters are fired. The last major operation is the checkout of ordnance circuits and the installation of pyrotechnics.

Table C-23 delineates the tests or operations which are performed and the type of test connection to be made. It also indicates the GSE required to support the tests. The designation test connector, under the "Connection" column, indicates a connector usef for test only which is either capped off prior to payload bay installation or provides circuit continuity when mated with an in-flight jumper (IFJ). For example, the solar array illumination test requires that the individual cell strings be available to GSE. Upon test completion, the cell strings are joined by means of IFJ(s) to control circuits within the spacecraft's Power Control Unit. All connections labeled interface connector are brought out to the service panel via the Tug and J-Box within the bay.

FIGURE C-16

TEST SEQUENCE - PAYLOAD PROCESSING FACILITY

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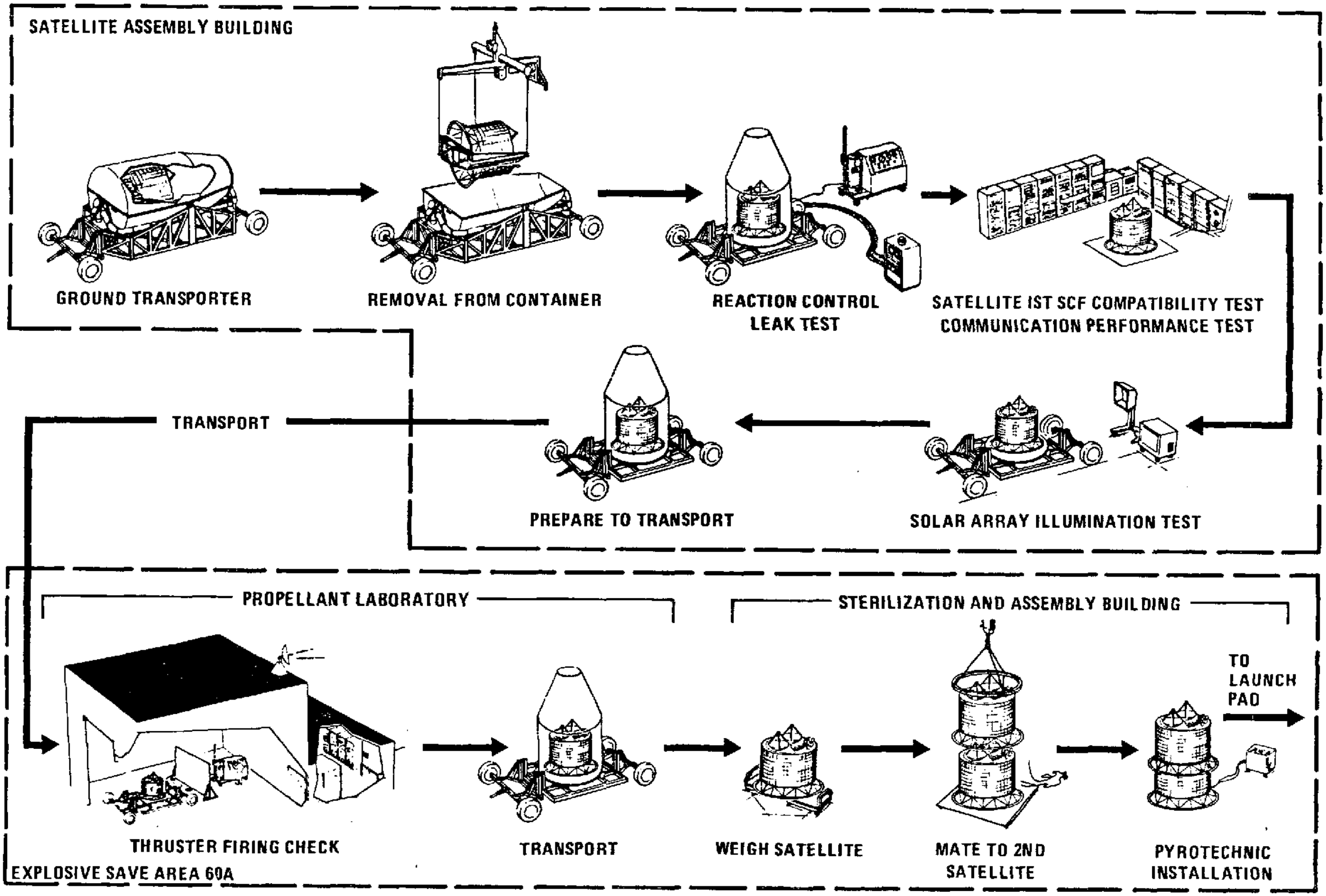

TABLE C-23

SPACECRAFT PROCESSING FACILITY TESTS/EQUIPMENT

TEST/OPERATION	CONNECTION	EQUIPMENT
REACTION CONTROL SYSTEM LEAK TEST	TEST CONNECTOR	1 RCS TEST SET
BATTERY INSTALLATION, CHARGE, MONITOR	INTERFACE CONNECTOR	2 BATTERY CHARGER AND PANEL
INTERNAL/EXTERNAL POWER TEST	INTERFACE CONNECTOR AND TEST CONNECTOR	3 POWER SUPPLY AND CONTROL UNIT
INTEGRATED SYSTEMS TEST	INTERFACE CONNECTOR AND TEST CONNECTOR	4 DATA ACQUISITION, DISPLAY/ CONTROL PANEL COMPUTER
SCF COMPATIBILITY TEST	INTERFACE CONNECTOR	5 COMMAND PROCESSOR, ENCRYPTION/ DECRYPTION EQUIPMENT
COMMUNICATIONS PERFORMANCE TEST	NONE	6 GROUND STATION
SOLAR ARRAY ILLUMINATION TEST	TEST CONNECTOR	7 CHECKOUT DRAWER, DISCRETE CONTROLS AND DISPLAYS
COUNTDOWN TIME TEST	INTERFACE CONNECTOR	4
PROPELLANT LOADING AND FIRING TEST	TEST CONNECTOR	1 2ND SET
PREINSTALLATION MATING SIMULATION	INTERFACE CONNECTOR	8 TUG/ORBITER SIMULATORS
SAFE AND ARM DEVICE TEST	INTERFACE CONNECTOR	9 ORDNANCE TEST DRAWER
ORDNANCE INSTALLATION	FLIGHT SYSTEMS	10 NONE
LRU TESTS	NONE	11 LRU TEST CONSOLES

C.6.5 Tug Maintenance and Refurbishment Test Facility

The process of reviewing the tests to be performed, the availability of existing connectors required for the service panel at the launch pad, the identification of new test connectors and the EAGE required to perform the tests was also performed for the Tug M&R facility as shown in Table C-24. Test equipment for conducting propulsion system tests is illustrated in Figure C-17. Items of equipment include a test operator's station which defines the progress of the test and individual control consoles for establishing test conditions. The tests themselves would be under computer control. Figure C-18 illustrates the types of equipment which would be required for the Avionics Verification Testing and also depicts various types of Line Replaceable Unit (LRU) or component test sets which would be required.

C.6.6 DOD/NASA Launch Area Operations

In reviewing the checkout and build-up of the spacecraft and stages, the differences in the handling of DOD and NASA payloads became apparent. The flow diagram, Figure C-19, illustrates the present plans for integrating vehicles and stages. It is seen that spacecraft Tug/payload operations are reversed for the two agencies as a result of the sensitive nature of DOD spacecraft sensors and the requirement to provide Comsec equipment and transponders compatible with the SCF. It is suggested that the present approach of transporting the Tug to the PPF requires additional Tug GSE and that a more efficient approach is to provide secure areas at the Tug facility for equipment changeout.

TABLE C-24

MAINTENANCE AND REFURBISHMENT TUG FACILITY TEST EQUIPMENT

TEST	CONNECTION	EQUIPMENT
LOAD C/O SOFTWARE	TEST CONNECTOR	DMS TEST SET, POWER SYSTEM TEST SET
VEHICLE CALIBRATION	UMBILICAL	TELEMETRY GROUND STATION, COMMAND CONSOLE, BATTERY CHARGER
RUN ONBOARD CHECKOUT	TEST CONNECTOR	DMS TEST SET, POWER SYSTEM TEST SET, PNEUMATIC CONSOLE
INTERFACE C/O	INTERFACE CONNECTOR	SPACECRAFT/ORBITER SIMULATORS AND CHECKOUT EQUIPMENT
OPTICS C/O	TEST CONNECTOR	STAR TRACKER SIMULATOR, HORIZON SENSOR TEST SET, TV TEST KIT
MAIN PROP PRESSURE LEAK ON FILL, DRAIN, VENT FEED, CONDITIONING	TEST CONNECTOR	CHECKOUT EQUIPMENT
MAIN PROP FUNCTIONAL TEST ON FILL, DRAIN, VENT, FEED, CONDITIONING	TEST CONNECTOR	CHECKOUT EQUIPMENT
PRESSURE LEAK ON PRESSURE AND PNEUMATIC SYSTEMS	TEST CONNECTOR	CHECKOUT EQUIPMENT
FUNCTIONAL TEST ON PRESSURE AND PNEUMATIC SYSTEMS	TEST CONNECTOR	CHECKOUT EQUIPMENT
GIMBAL TEST	TEST CONNECTOR	CHECKOUT EQUIPMENT
ACPS PRESS LEAK TEST ON PROPELLANT TANKS AND PRESS. AND PRESSURANT	TEST CONNECTOR	ACPS PRESSURE KIT, ACPS BREAKOUT BOS, CHECKOUT EQUIPMENT
ACPS FUNCTIONAL TEST ON PROPELLANT TANKS AND PRESSURANT	TEST CONNECTOR	
TRANSFER SCF TUG TO SECURE AREA INSTALL COMSEC EQUIPMENT ADD SCF TRANSPONDER		
COMMUNICATIONS C/O	R.F. BONNET UMBILICAL	TELEMETRY GROUND STATION, COMMAND CONSOLE, BATTERY CHARGER & MONITOR
S/C CONTROL SOFTWARE LOAD	UMBILICAL	
MECHANICAL MATING & CHECKS	UMBILICAL	
VALIDATE ELECTRICAL INTERFACES	UMBILICAL	
VALIDATE SPACECRAFT CONTROL	UMBILICAL	TELEMETRY GROUND STATION, COMMAND CONSOLE, POWER BATTER CHARGER AND MONITOR

FIGURE C-17

TUG M&R FACILITY CONTROL GSE

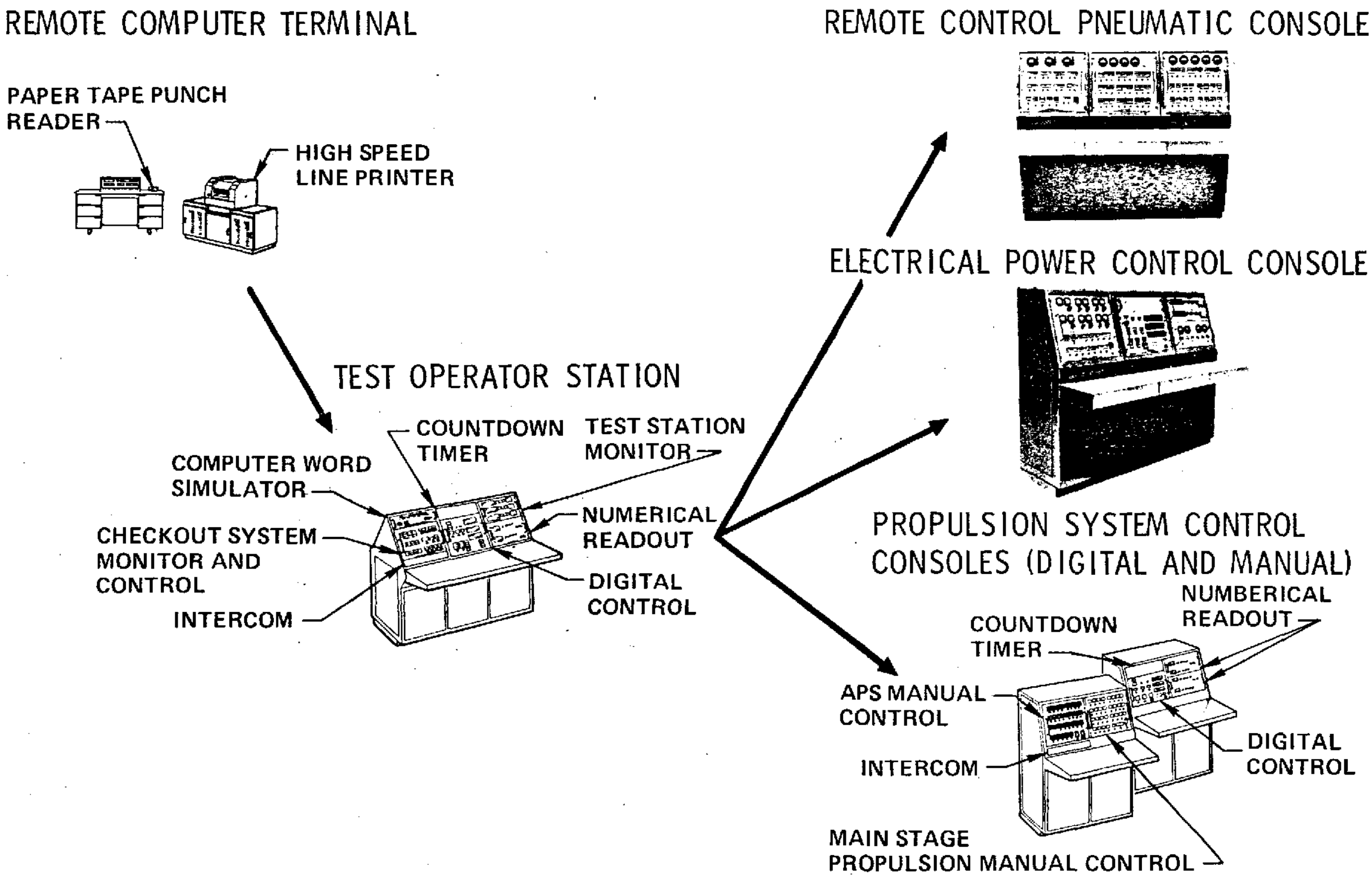

FIGURE C-18

TUG AVIONICS VERIFICATION EQUIPMENT

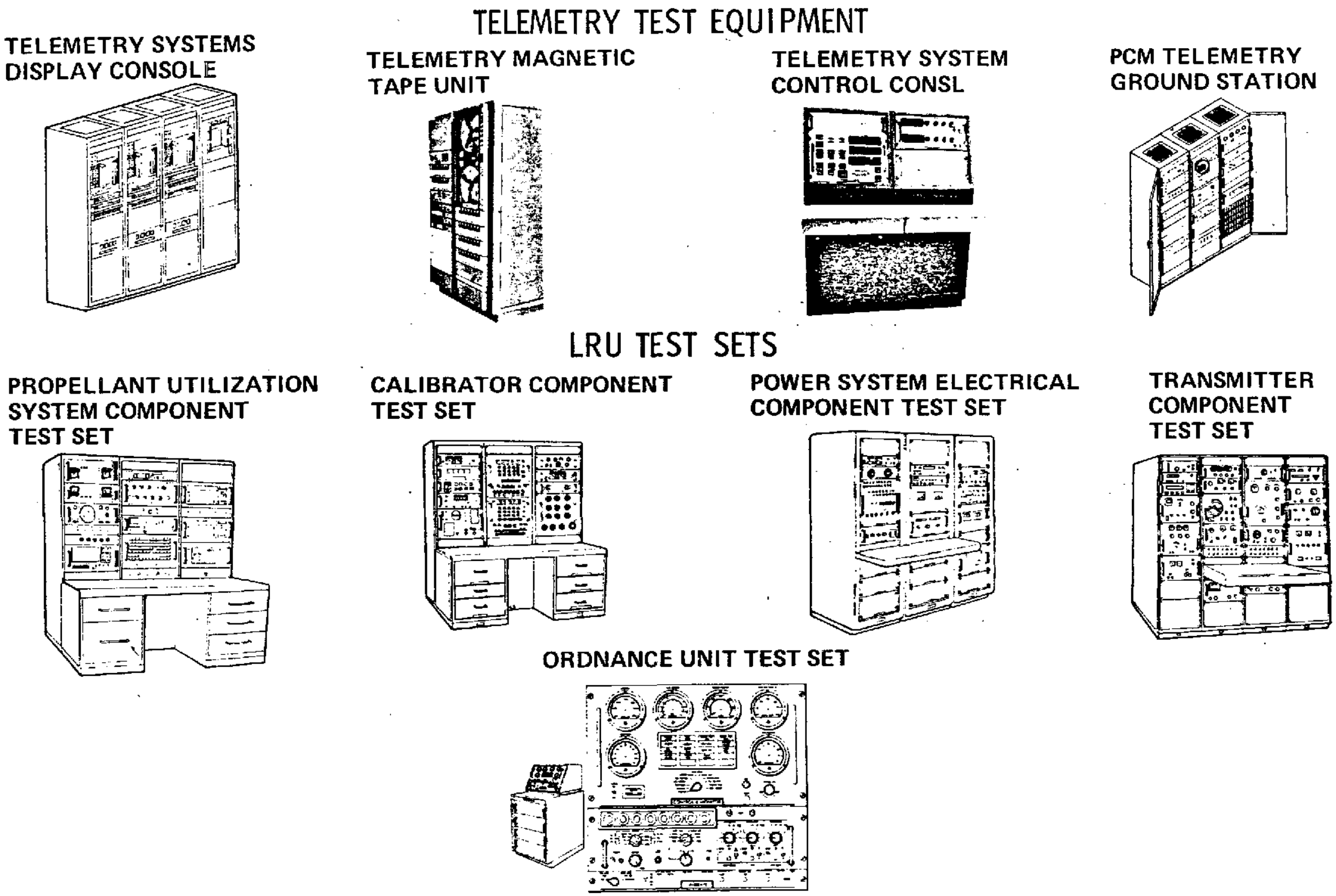

FIGURE C-19
DOD/NASA OPERATION FLOWS

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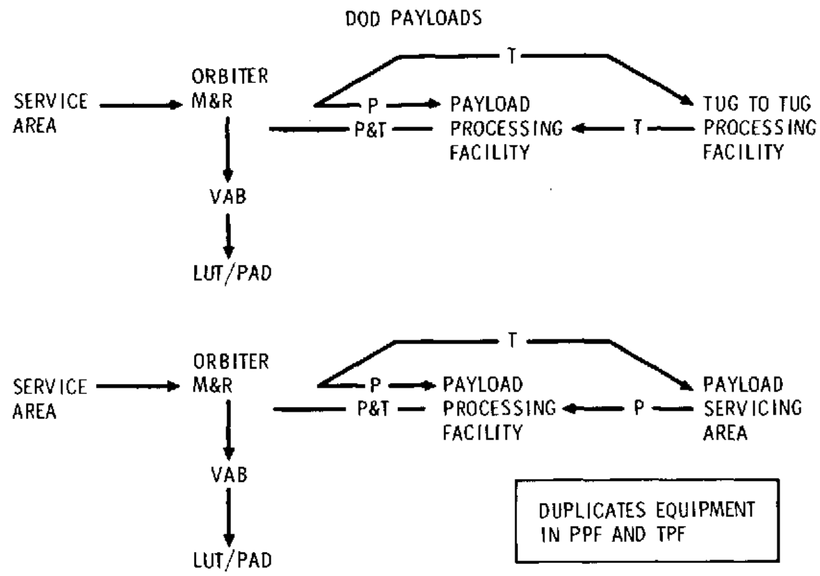

C.7 CABLE INSTALLATIONS

Figures C-20 through C-22 provide descriptions of representative cable installations in the Shuttle payload bay wherein installations for the following interfaces are shown:

A. Cabin-bay interface panel to payload J-box (cradle or tilt table mounted).

B. Payload J-box to Shuttle service panels (T-0 and T-26).

C. Payload J-box to payload umbilical

Schematics of these systems are shown for each mission class in Figures C-7 - C-9.

It should be noted that the depicted installations are arbitrary inasmuch as teh Shuttle system payload lateral c.g. envelope (which is presently undefined) may preclude cable installation along one side of the Orbiter wall as shown. Alternatives available are splitting of cable runs to provide balanced runs on each side of the Orbiter and/or the addition of ballast to provide an acceptable lateral c.g. location. Division of cable runs requires the installation of additional mounting hardware which results in additional perturbation to the payload bay interior skin with attendant effects on the Shuttle insulation system.

Representative weights of the cabling system are presented in Table C-25 which provide an estimate for the EOS required system.

TABLE C-25

EOS CABLING SYSTEMS WEIGHT ESTIMATE

	Weight (lbs)
Cabin-bay interface panel to cradle J-box (38 feet)	
Power Cables	10
Signal Cables	60
Experiment data cables	60
J-box to T-26 service panel (28 feet)	
Power cables	16
Signal cables	60
Coaxial cable	2
Connectors	20
J-box	80
Total	308 lbs

Weight for the LST system is estimated at 125 percent of the EOS system; Class II missions at 200 percent of EOS; Sortie Lab at 50 percent of EOS.

Conceptual service panel configurations required for each mission class are also shown in the noted figures as derived from the Shuttle baseline allocation of one-half of the area in the 34 x 34 in. T-26 panel.

Additional available options for the installation include location of the payload distribution box at the Shuttle forward cabin wall as opposed to location on the mounting/deployment mechanisms. The former approach provides a reduction of interface cabling length/weight which may be significant with regard to Class II mission delivery altitudes since the greatest cabling weight exists for these missions but presents a disadvantage in the area of testing wherein it is desirable to include the distribution box as part of the payload mounting structure in order to accomplish certification of the box prior to payload integration with Shuttle.

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Appendix D

PAYLOAD DESIGN/OPERATING IMPACT ANALYSIS - DOCKING MODULE

D.1 GROUND OPERATIONS

D.1.1 Docking Module/Orbiter Integration

Introduction of a docking module in the Orbiter payload bay has an impact on both the Shuttle and Payload ground operations.

The Shuttle baseline prelaunch ground processing schedule (Figure D-1), currently requires 232 hours to complete. Integration of a docking module with the Orbiter must occur prior to integration of the payload due to the "soft" interface between the docking module and the payload.

Orbiter maintenance is scheduled for completion at launch minus 163 hours and payload installation occurs 14 hours later at launch minus 150 hours. Docking module installation should occur during this 14 hour period of Orbiter turnaround operations. Two factors however suggest that module installation operations may conflict with Orbiter operations.

The first factor is that 12 of the 14 hours are involved with the performance of systems verification tests and subsequent removal of electrical and mechanical test GSE. The Shuttle baseline does not indicate whether these tests occur in the payload bay or not. If the bay is occupied with GSE and personnel for the performance of these tests, docking module installation operations must be delayed until test completion and the Orbiter turnaround schedule must be increased by the amount of time required to install the module.

Docking module/Orbiter integration operations were estimated as follows:

Function	Time
Transfer docking module to integration area	0.50
Install portable contamination shelter	0.50
Condition shelter environment	1.00
Remove module protective cover	0.75
Attach hoisting GSE	0.25
Hoist docking module	0.50

Function	Time
Lower module into payload bay	0.50
Attach module to payload bay fwd. bulkhead	3.75
Remove hoisting GSE	0.25
Connect Orbiter/module electrical interfaces	2.00
Pressurize module & leak check interfaces	4.00
Perform module systems verification test	4.00
TOTAL	18.00 hours

If docking module integration operations (Figure D-2) must be performed serially with Shuttle ground processing operations, Shuttle turnaround time is increased from the baseline of 232 hours to 250 hours.

In order to assess the impact which this 18 hour increase to Shuttle turnaround time has on the overall Shuttle Program, the Shuttle Traffic Model (NAS TM X-64731) was reviewed (Figure D-3) to determine the potential number of flights which would utilize a docking module. Of the 366 flights on which NASA payloads are scheduled to be launched, 109 flights potentially require a docking module. This represents about 30 percent of the NASA payload traffic model. It should be noted that the traffic model utilized for the analysis contains no Sortie Module flights. Additionally, although DoD payloads are included in the model, there is insufficient data available in the model regarding their individual characteristics to include them in the assessment.

Since about one of every three Shuttle flights potentially requires a docking module, and since module/Orbiter integration will occur in the Shuttle Maintenance & Checkout Facility, the MCF will be required to provide both facility space and equipment as well as integration GSE. Per the Shuttle baseline, payloads are integrated in the MCF. Docking module/Orbiter integration equipment can be reduced if module handling points are designed to be compatible with payload integration GSE.

It is concluded that:

A. docking module/Orbiter integration impacts Orbiter turnaround time by an additional 18 hours.

FIGURE D-1

SPACE SHUTTLE BASELINE PRELAUNCH PROCESSING

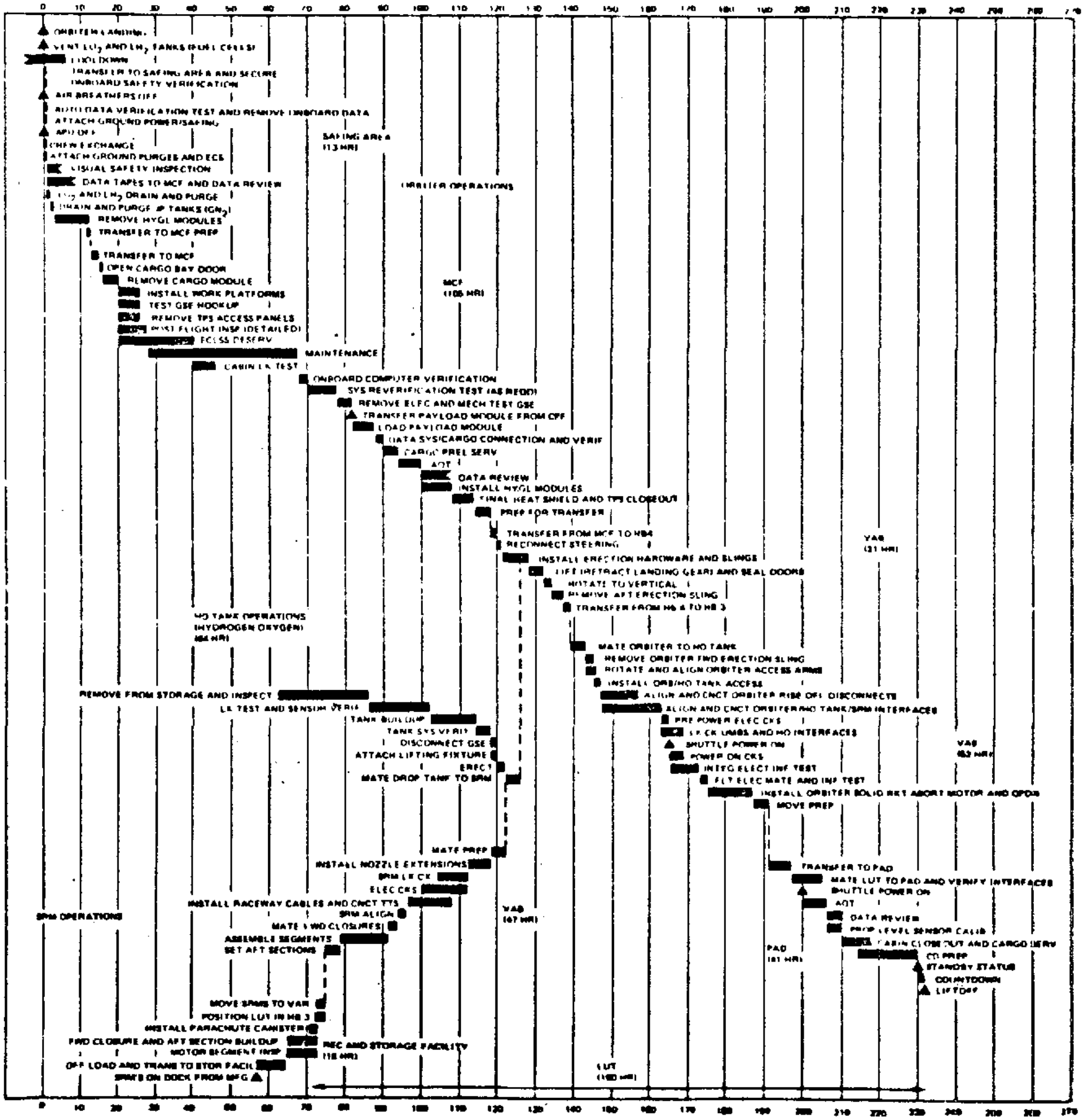

FIGURE D-2

DOCKING MODULE/ORBITER INTEGRATION OPERATIONS

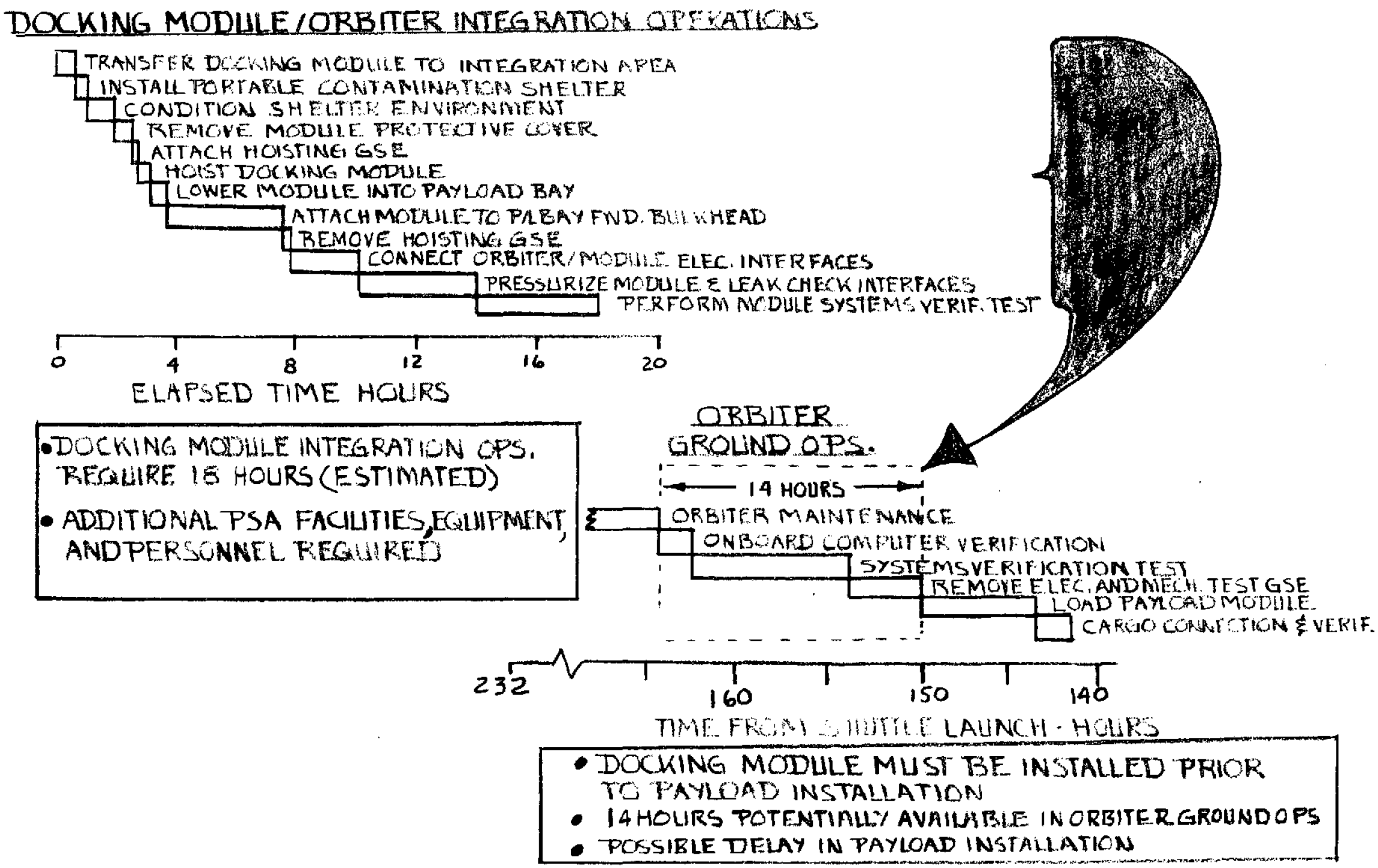

FIGURE D-3

NASA TM X-647.31
SHUTTLE TRAFFIC MODEL*
POTENTIAL DOCKING MODULE REQUIREMENTS

* NO SORTIE MISSIONS
* NO DOD PAYLOADS
* TRAFFIC MODEL CONTAINING SORTIE MODULE MISSIONS EXPECTED TO REQUIRE DOCKING MODULES FOR ABOUT 50 % OF SHUTTLE FLIGHTS

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE LAUNCHES (TOTAL)	8	22	27	22	28	24	44	30	40	38	44	39	366
REVISIT MISSIONS (DOCKING / MAINTENANCE)	—	2	2	4	4	6	5	8	8	7	8	8	62
CREW CARGO MODULE LAUNCHES (DOCKING/CREW XFER.)	—	—	—	—	—	—	1	6	6	6	6	8	33
SPACE STATION MODULE (DOCKING/CREW XFER.)	—	—	—	—	—	—	6	—	—	1	4	3	14
SUBTOTAL	—	2	2	4	4	6	12	14	14	14	18	19	109

30% OF THE SHUTTLE TRAFFIC MODEL POTENTIALLY REQUIRES A DOCKING MODULE (NO DOD PAYLOADS)

B. about one third of the Shuttle traffic model (NAS TM X64731) requires the use of a docking module. It is expected that traffic models which include Sortie Lab missions will require docking modules for at least 50 percent of the Shuttle flights.

C. the Maintenance and Checkout Facility must provide facility space and associated equipment for docking module integration operations.

D. the docking module handling points should be compatible with payload/Orbiter integration equipment.

D.1.2 On-Pad Payload Access

A review of the NASA TM X-64731 Shuttle Traffic Model revealed that 226 (60%) of the Shuttle missions carry payloads of current design which may require on-pad access for in-flight-jumper connection, protective cover removal, etc. When a docking module is installed in the Orbiter, manned access to the payload through the crew compartment/payload bay hatch is not possible except under extremely questionable operational conditions. This is in conflict with the capability stated in the Space Shuttle System Payload Accommodations Document JSC 07700.

> "--- The capability for payload checkout and component replacement in the vertical position will be possible through the Orbiter crew compartment/payload bay hatch. Access to, removal of, and loading of payload items on the pad must be accomplished no later than TBD hours prior to launch."

The SOAR II study briefly assessed the payload bay manned access requirements for the Bio-Research Module spacecraft whose launch configuration included a docking module and concluded that access was only possible through the payload bay doors.

In addition to access requirements potentially imposed by payloads of current design, it is anticipated that problems with three out of every one hundred cryogenic TUGs will be discovered at the launch pad and will require in-bay access in order to rectify them.

Figure D-4 illustrates the module in the payload bay with the docking tunnel in the retracted position. In this configuration, the crew compartment/payload bay hatch can only be opened 38 degrees at which point it is physically prevented from further opening due to interference with the docking tunnel. In addition, about 80 percent of the docking module exit hatch is covered by the retracted docking tunnel (Figure D-5). These two factors preclude access to the payload bay from the Orbiter crew compartment.

An extremely questionable method of accessing the payload bay from the crew compartment would be to open the payload bay doors and extend the docking tunnel to its operational position. This mode of operation is either not feasible or undesirable for the following reasons:

A. Extending the docking tunnel to its operational position in a 1-G environment for vertical access at the launch pad requires that the module structure and Orbiter/module and module/payload structural interfaces be capable of sustaining 1-G static loading during extension operations and while in an operational configuration. Provisions for this capability potentially increase module and Orbiter structural

FIGURE D-4

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PRR BASELINE (WITH DOCKING MODULE)

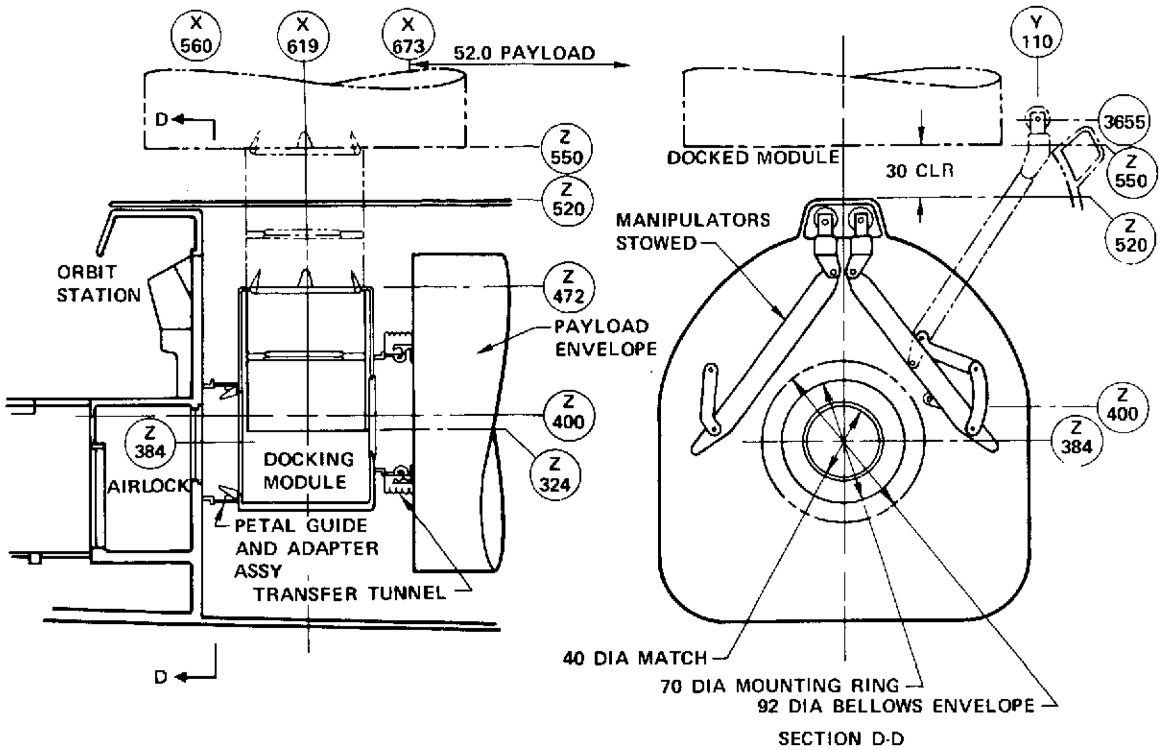

FIGURE D-5

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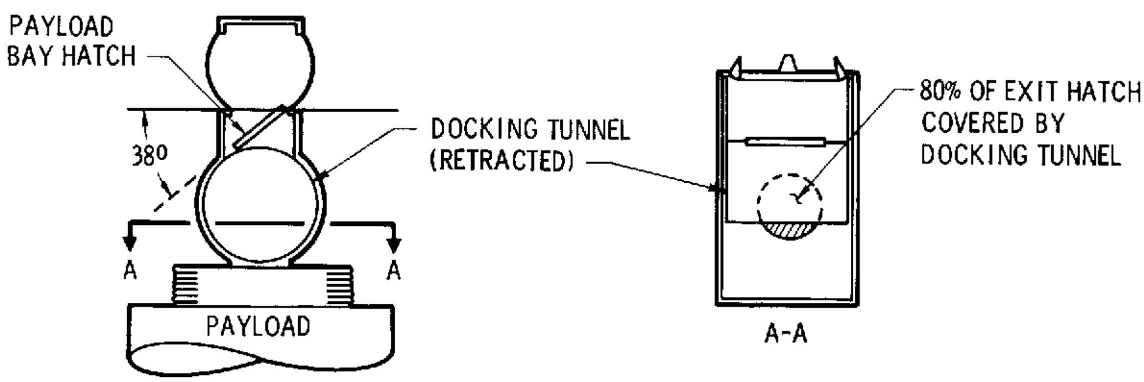
PRELAUNCH ON-PAD PAYLOAD ACCESS CONSTRAINT



- DOCKING MODULE PRECLUDES ACCESS TO 66% OF SHUTTLE PAYLOADS THROUGH AIRLOCK AT LAUNCH PAD
- UP TO 226 (25%) OF SHUTTLE MISSIONS CARRY PAYLOADS OF CURRENT DESIGN WHICH MAY REQUIRE ON-PAD ACCESS FOR IFJ CONNECTION, PROTECTIVE COVER REMOVAL, ETC
- UP TO 367 (41%) OF SHUTTLE MISSIONS CARRY SORTIE LABS WHICH MAY REQUIRE INSTALLATION OF TIME CRITICAL EQUIPMENT AT THE LAUNCH PAD

weight at the expense of the payload.

B. Special and docking module peculiar GSE which is compatible with the docking module and its payload access tunnel is required.

C. Introduction of this GSE for manned access would significantly constrain the size and volume of payload equipment which could be moved to and from the payload through the docking module. This constraint impacts payload prelaunch access and checkout requirements planning and philosophy and must be accounted for.

   The payload bay hatch is presently sized to allow a 27 x 27 x TBD inch object (per JSC 07700) to be moved to or from a payload through the docking module. Instruction of any required on-pad access GSE within the docking module volume would reduce this capability.

D. Entrance into the payload from above while it is in a vertical position and in a 1-G environment has significant implications on payload cleanliness maintenance capability as well as introducing the potential for physical damage to payload mounted equipment due to accidental dropping of checkout equipment (and equipment being changed out) by the checkout/maintenance crew.

E. Adopting this mode of payload access increases payload access time requirements at the launch pad and potentially impacts the Orbiter ground processing turnaround schedule. Schedule on-pad operations are presently allotted 38 working hours.

From the above considerations it is concluded that if on-pad manned access to the payload is required, utilization of the docking module is not recommended. Access to the payload at the launch pad can only be accomplished through the Orbiter payload bay doors. Additionally, access to the internal volume of a payload is best facilitated by the incorporation of an access hatch (reusable or non-reusable) in the side wall or bottom of the payload structural shell.

D.2 FLIGHT OPERATIONS

1.2.1 EVA Operations

In order to determine the interactions of EVA operations with the docking module, it was necessary to determine the equipment and equipment peculiar operations associated with EVA preparations and vehicle egress. The basis for making this determination was data extracted from "Apollo Space Suit and Extra Vehicular Mobility Unit", LM&SC 5-02-66-1, dated 3-1-66.

The EMU is a self contained anthropomorphic protective enclosure consisting of the following major subassemblies:

SUBASSEMBLY	WEIGHT (lbs)	VOLUME (cu.ft.)
Constant Wear Garment (CWG)	0.83	0.07
Liquid Cooled Garment (LCG)	4.3	0.7
Pressure Garment Assembly (PGA)	32.0	4.88
Helmet Assembly	5.5	1.2
Gloves	1.65	0.42
Portable Life Support System (PLSS)	46.0	2.8
TOTAL	90.28	10.07

The anticipated operational EMU compliments usage are presented below.

Operational Phase	Major EMU Subassembly				Operating Condition
	CWG	LCG	PGA	PLSS	
Normal Earth Orbital Operations	x	-	-	-	Shirtsleeve
Earth Orbital EVA	-	x	x	x	Pressurized, Liquid Cooled
Emergency Earth Orbital Operations	x	-	x	-	Pressurized, PLSS if ECS fails

EVA equipment donning timelines were developed to establish the relative times which would have to be allotted to equipment peculiar operations. These timelines are presented in Figures D-6 and D-7.

For nominal "equipment-only" donning operations, about 38 minutes are required. For emergency "equipment only" donning about 7 minutes are required. It

FIGURE D-6

EMU DONNING FOR EARTH ORBITAL EVA

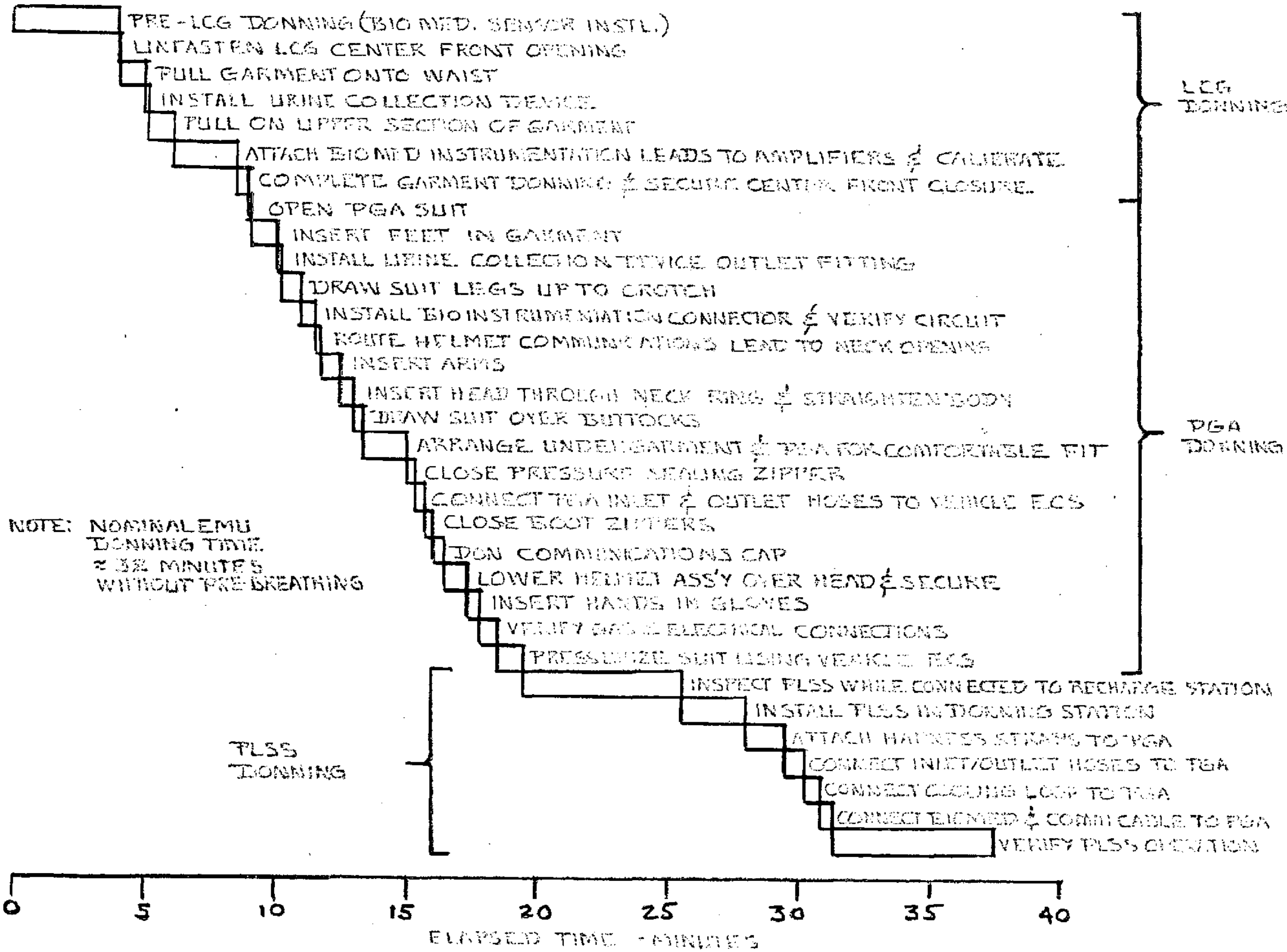
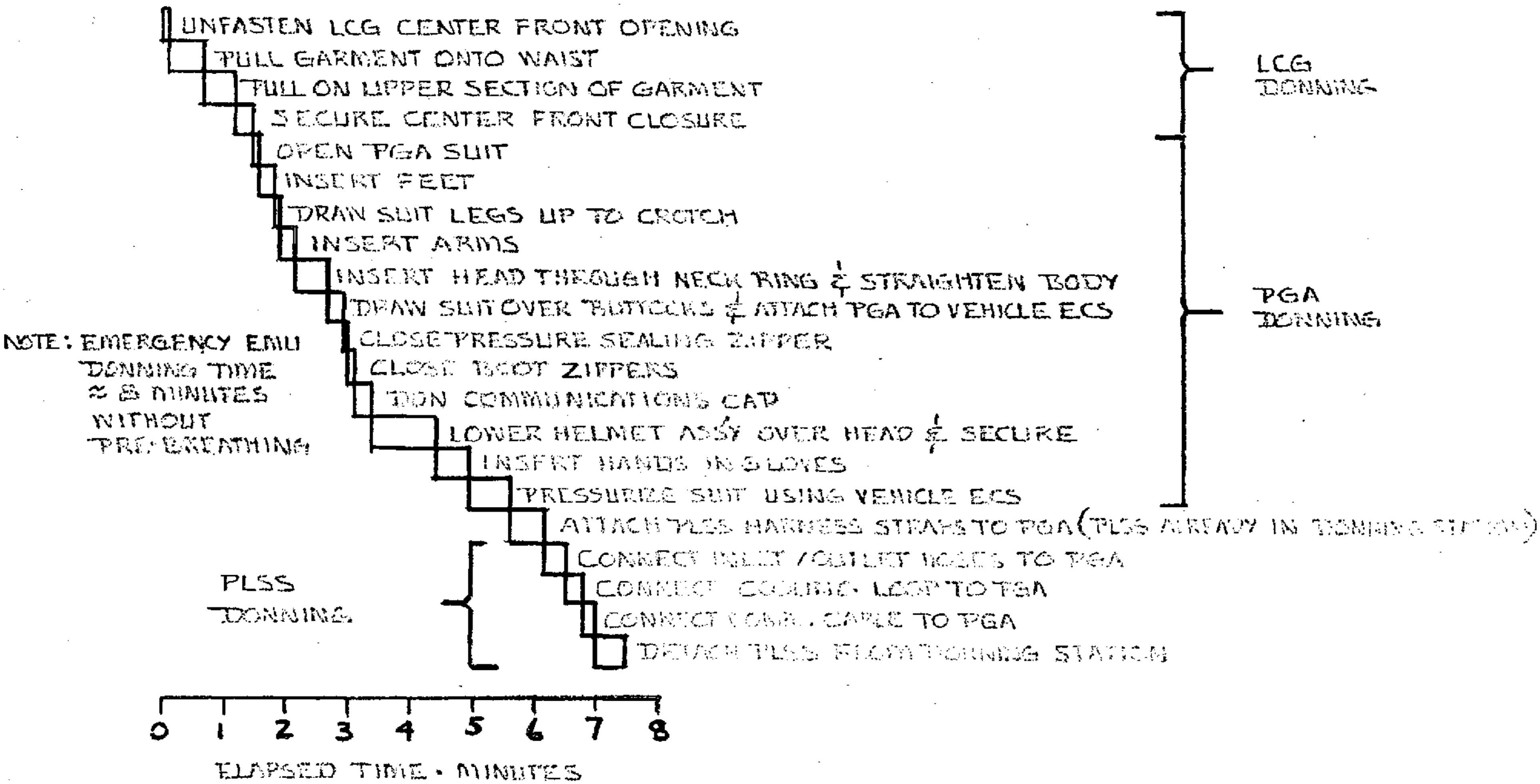


FIGURE D-7

EMERGENCY EMU DONNING FOR EARTH ORBITAL EVA



should be noted that these times do not take into account any necessary pre-breathing requirements which are necessary to eliminate the risk of decompression sickness. For a 14.7 psia Orbiter cabin pressure, the required suit pressure necessary to avoid pre-breathing is in the range of 7-8 psia. If, however, state-of-the-art pressure suits having an operational pressure of 3.5-5 psia are utilized, at least 1.5 hours would have to be allotted to pre-breathing.

For purposes of EVA analysis, pre-breathing will be assumed as a pre-requisite.

In developing the crew EVA preparations and vehicle egress timelines, two additional assumptions were made.

The first assumption deals with the capability of two fully suited crewmen to occupy the Orbiter airlock. The results of the SOAR II study indicated that simultaneous occupancy might be marginal. During pre-PGA donning operations, the crewmen (prime and backup) will either suit up simultaneously or sequentially in the airlock. Simultaneous pre-suit-up operations require about 20 minutes. If pre-suit-up operations are performed sequentially by each crewman, the total pre-suit-up time required is about 40 minutes. Additionally, if final suit-up operations are performed sequentially, about 4 minutes are required.

The second assumption was that the back-up crewman remains in the airlock during EVA operations (Figure D-8), ready to provide rescue support if required. In this condition, vehicle egress can be accomplished by the back-up crewman within six minutes in the event that the EVA crewman encounters an emergency. If the back-up crewman were only partially suited and pre-breathing in the lower deck during EVA operations, about 36 minutes would be required to egress the vehicle and assist the disabled EVA astronaut. Due to the substantial amount of time involved, this mode of operation was rejected.

The EVA preparations and vehicle egress timelines developed in Figures D-9 and D-10 were based on simultaneous suit-up and a fully suited back-up crewman in the airlock. The total time involved in preparing for EVA operations is about two hours.

In addition to the necessary 90 pounds of EMU subassemblies required for each EVA crewman, depending on the types of EVA operations required, the following general equipment may also be required:

A. Low pressure umbilical
   Length: 119 inches
   Weight: 20 - 25 lb.

B. High pressure umbilical
   Length: 60 ft.
   Weight: 120 lb. (estimated)

C. Hand-held Maneuvering Unit
   Weight: 7.5 lb.

D. Astronaut Maneuvering Unit
   Volume: 3 ft^3
   Weight: 245-lb unit including life support, 23 to 234 lb. fuel and tankage

E. Restraints, Tethers and Work Platforms
   1. Foot Restraints
      Dimensions: 21 x 13 x 4 in. per pair
      Weight: 25 lb.
   2. Worksite Variable Waist Restraints
      Weight: 2 lb. (estimated)

F. Equipment Transporters and Restraints
   1. Clothesline
   2. Track
   3. Velcro-Type Patches
   4. Equipment Safety Tether
   5. Equipment Restraints
   6. Flexible Dual Waist Restraint
   7. 10 ft. safety tether
   8. 60 to 200 ft. safety tether

G. Mobility Aids
   1. Portable Handrails
   2. Portable Handholds

FIGURE D-8

BACK-UP CREWMAN IN AIRLOCK DURING EVA

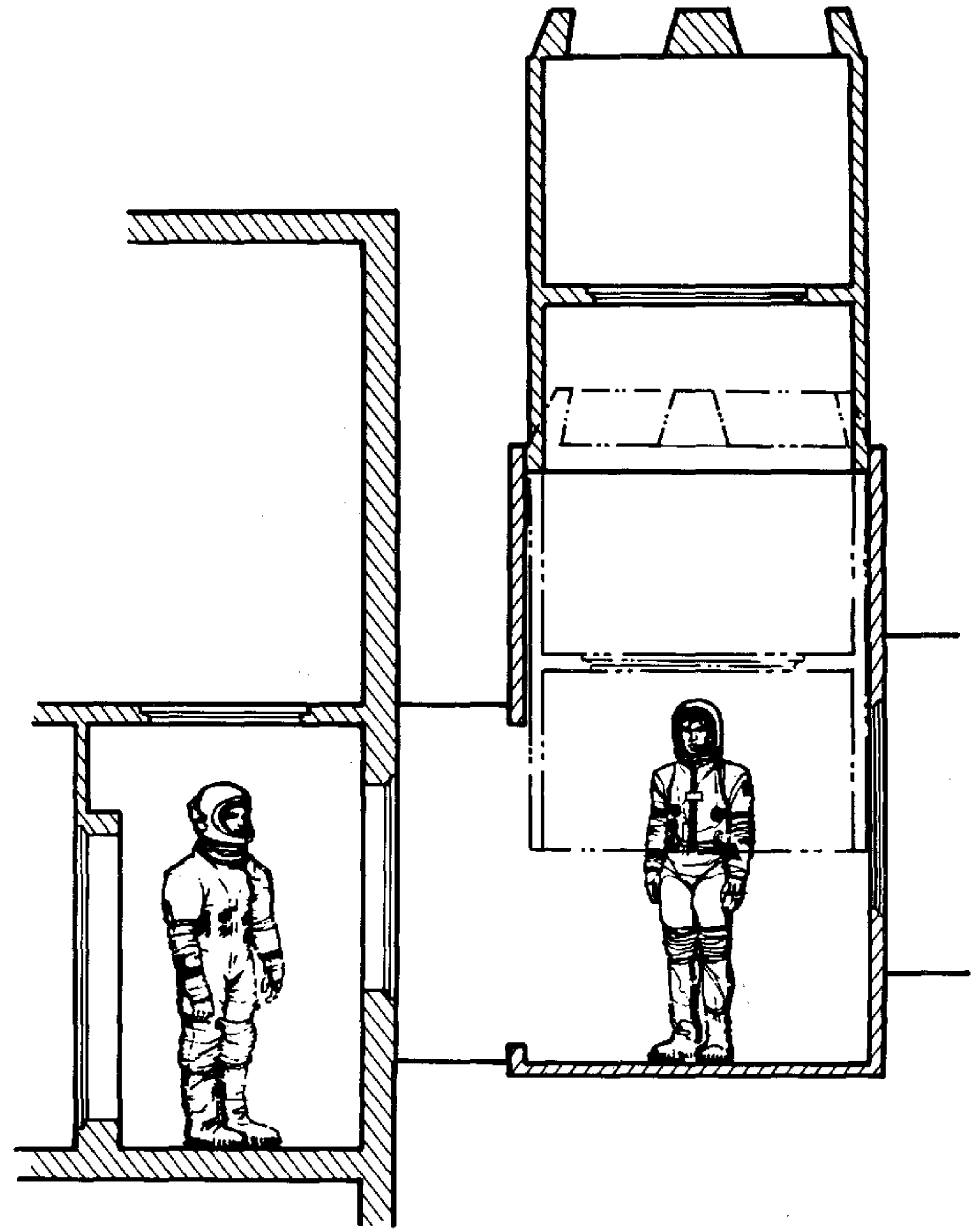
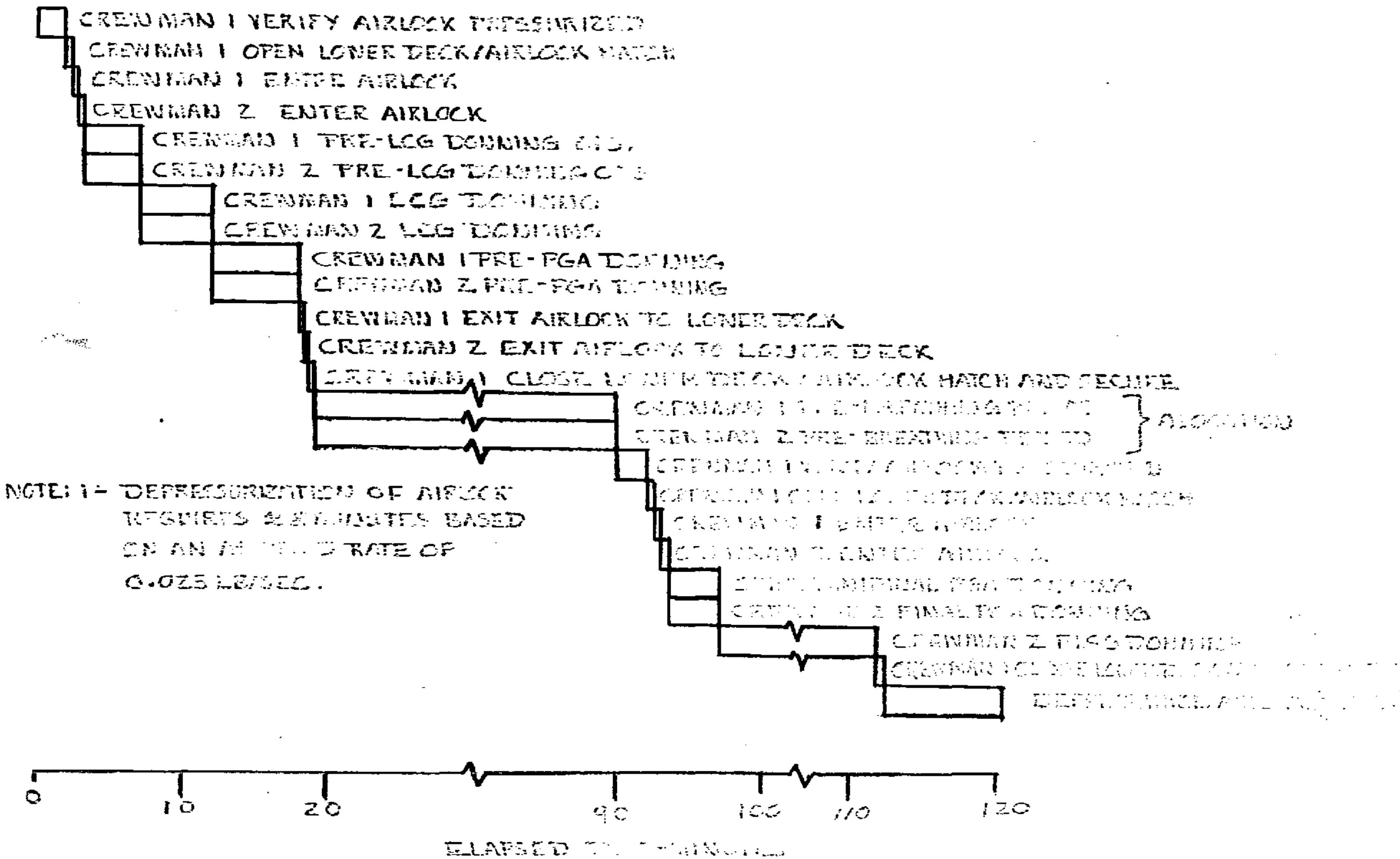


FIGURE D-9

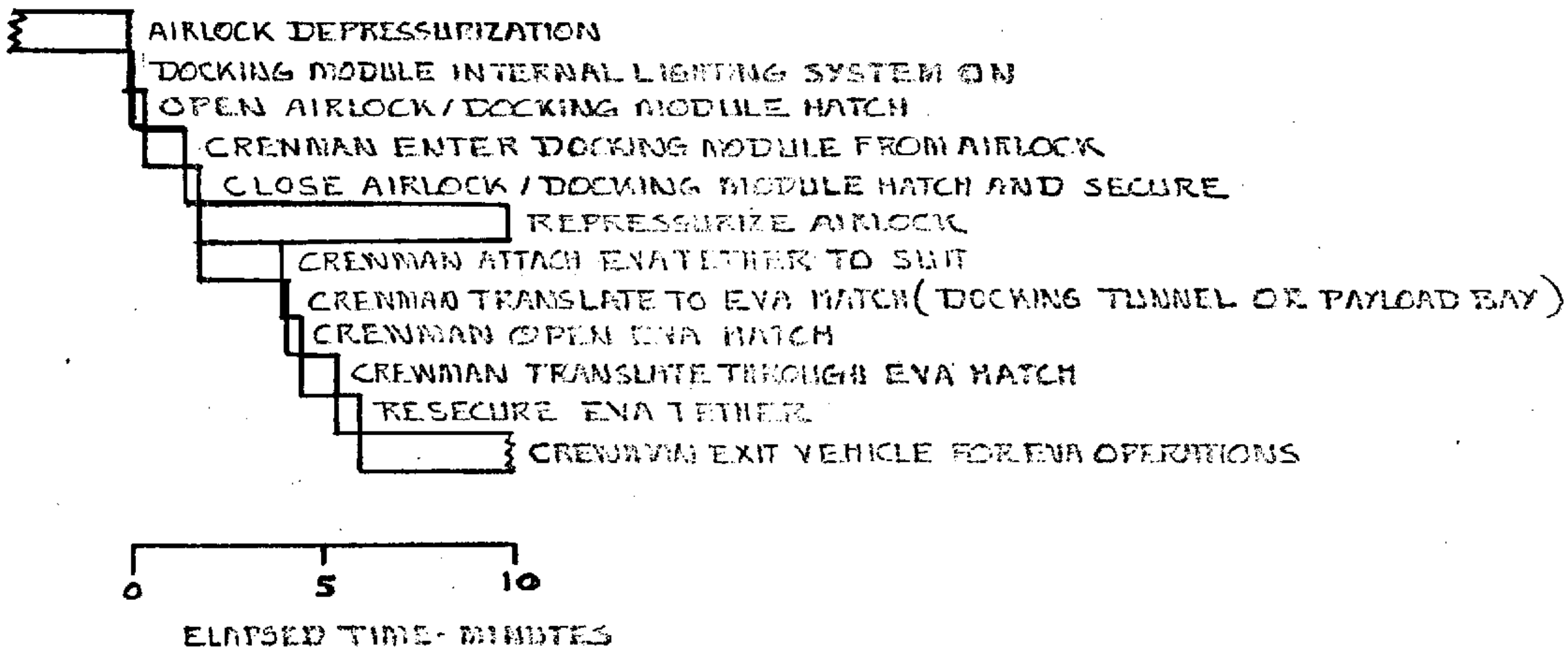
EVA PREPARATIONS



NOTE: 1 - DEPRESSURIZATION OF AIRLOCK REQUIRES [illegible] MINUTES BASED ON AN [illegible] RATE OF 0.025 LB/SEC.

FIGURE D-10

VEHICLE EGRESS OPERATIONS



D.2.2 Concurrent EVA/IVA and Shirtsleeve Operational Interferences

There are four operational conditions involving the docking module during which concurrent EVA/IVA and shirtsleeve operations can interfere with one another. These conditions are summarized in Figure D-11.

Each of these conditions is examined in the following paragraphs. It should be noted that crew activity times which deal with extra vehicular mobility unit equipment donning and doffing were derived from "Apollo Space Suit and Extra Vehicular Mobility Unit", LM&SC 5-02-66-1, dated 3-1-66.

D.2.2.1 Case 1: Orbital Element Servicing Mission

This configuration involves a pressurizable module or orbital element which is attached to the extended docking tunnel of the docking module and both the docking module and pressurizable module are pressurized and shirtsleeve operations are occurring.

Under these conditions

A. EVA operations cannot be initiated unless shirtsleeve activities are terminated (Figure D-12) and the pressurized volume is evacuated of unsuited personnel. Personnel evacuation requires about 30 minutes and shirtsleeve operations are interrupted for the amount of time required for

1. Evacuation of shirtsleeve personnel (26 min.)
2. Final suit donning by EVA crew (20 min.)
3. Airlock decompression (8 min.)
4. Vehicle egress by EVA crew (6 min.)
5. EVA operations (4 hours)
6. Vehicle ingress (6 min.)
7. Airlock repressurization (8 min.)
8. Suit doffing (20 min.)
9. Ingress of service crew (26 min.)

Shirtsleeve servicing operations are interrupted for a total of six hours. Based on this 6-hour interruption time, it is recommended that, during orbital element maintenance and servicing operations which employ a docking

FIGURE D-11

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CONCURRENT SHIRTSLEEVE AND EVA/IVA OPERATIONS CASES STUDIED

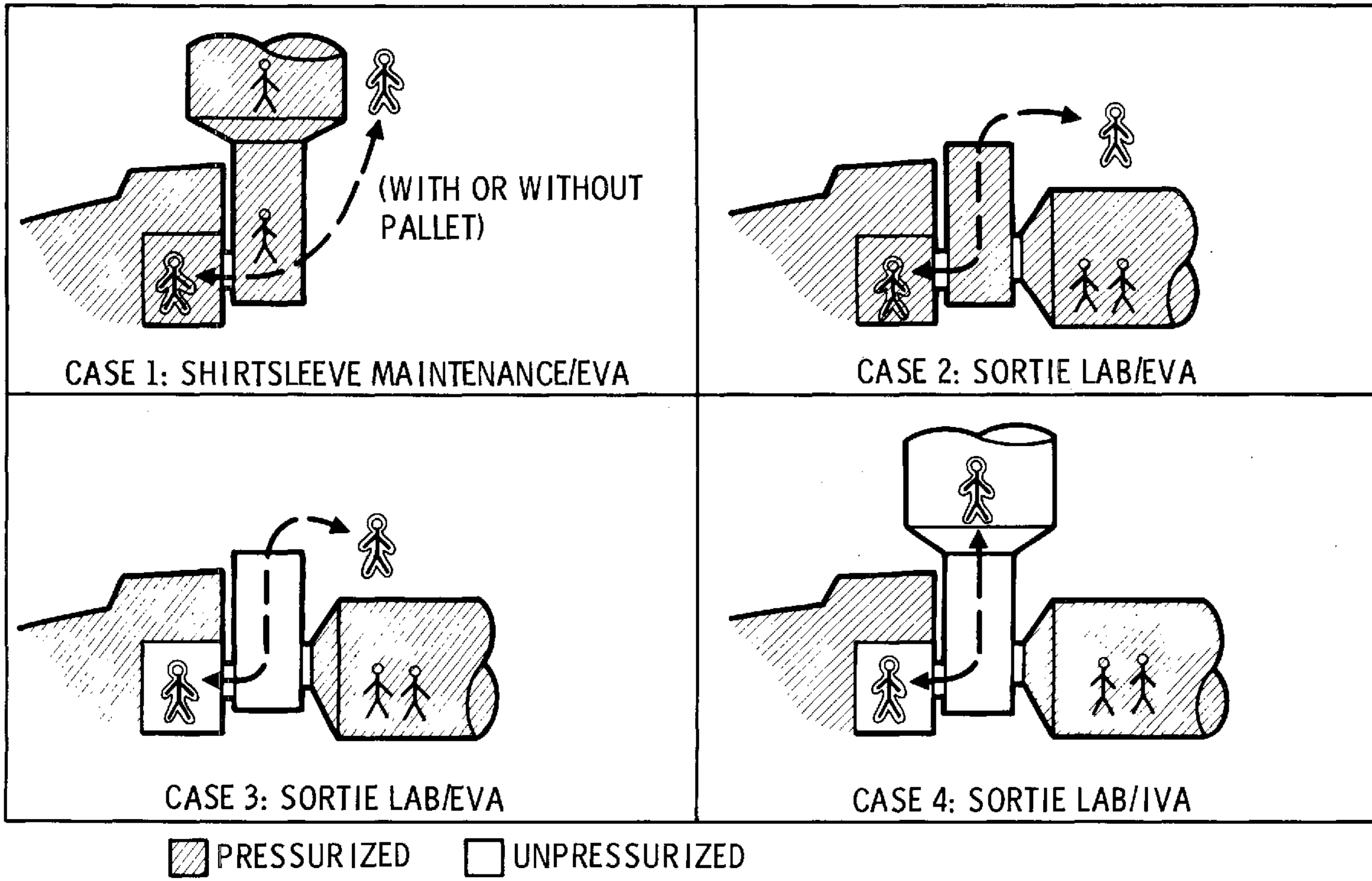
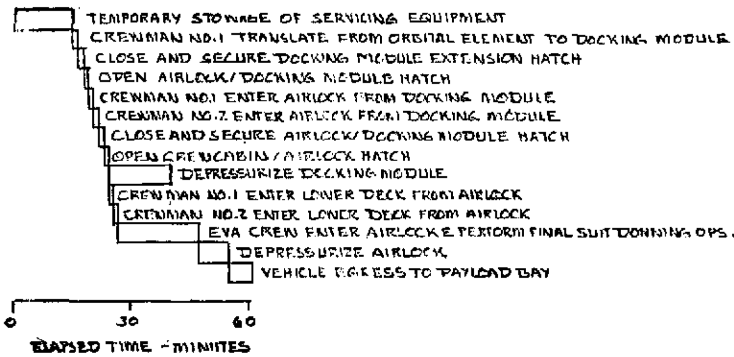


FIGURE D-12

SHIRTSLEEVE CREW ORBITAL ELEMENT/ORBITER TRANSFER OPERATIONS VIA DOCKING MODULE



module, EVA operations should not be performed concurrently.

B. Concurrent EVA/Shirtsleeve operations are strongly not recommended since in the event that the EVA crewman becomes disabled or requires assistance from the back-up EVA crewman an excessively critical amount of time is required to reach the disabled crewman. Assuming that the disabled crewman is in the immediate vicinity of the docking module/payload bay hatch, the back-up crewman would require at least 49 minutes to reach him. Activity times developed for these operations are as follows:

1. Evaluation of shirtsleeve personnel (26 minutes)
2. Airlock and docking module decompression (17 minutes)
3. Vehicle egress by back-up crewman (6 minutes)

In the event that the disabled crewman is not in the immediate vicinity of the docking module/payload bay hatch, and is (as is most probable) located near the external structure of the docked orbital element, it is likely that it will require significantly longer than one hour for the back-up crewman to reach him.

If a disabling contingency occurs at some time in the fourth hour of the EVA, the excessive amount of time required to offset rescue could result in crew casualty.

Based on the above considerations, it is concluded that concurrent EVA/shirtsleeve operations during orbital maintenance and servicing missions is not recommended.

D.2.2.2 Case 2: Sortie Lab Type Mission (Docking Module Pressurized)

This configuration involves a pressurizable module in the Orbiter payload bay which is attached to the docking module. Both the pressurizable module and the docking module are pressurized during shirtsleeve operations in the pressurizable module.

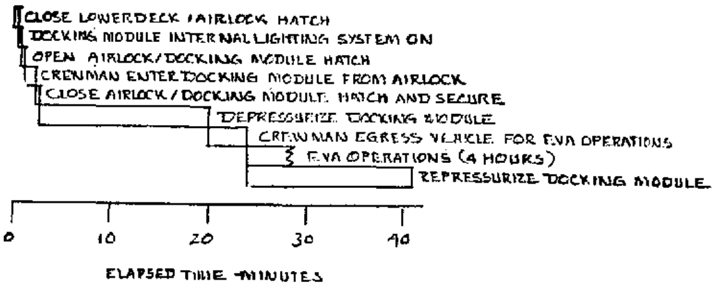
This case is essentially the same as Case 1 with regard to EVA operations. EVA cannot be initiated unless shirtsleeve operations in the pressurizable module are terminated or unless the shirtsleeve crew is isolated from the Orbiter crew cabin. If operations in the pressurizable module are terminated to allow EVA, a six-hour interruption is required. Similar to the recommendation of Case 1, concurrent EVA/shirtsleeve operations are not recommended.

If crew operations in the pressurizable module are allowed to continue during EVA operations, two serious impacts to the operations crew arise.

The first impact is on the crew in the pressurizable module. During the initiation (Figure D-13) and termination of EVA operations, the docking module is depressurized for a period of about 38 minutes for each operation and during this time should an emergency in the pressurizable module occur, which requires rapid egress to the safety of the docking module or the Orbiter crew compartment, crew safety is endangered. For this condition, the pressurizable module must provide pressure suits for each of its crewmen. Since emergency egress is precluded, crew safety is endangered for at least five minutes until each crewman can perform an emergency suit-up. If the emergency also involves the environmental control systems of the pressurizable module, this time is increased to nearly eight minutes because of PLSS donning requirements.

FIGURE D-13

EVA PREPS & VEHICLE EGRESS OPS. WITH DOCKING MODULE PRESSURIZED



Should the EVA astronaut become disabled and require assistance or rescue by the back-up crewman, the docking module will remain depressurized during these operations and the crew of pressurized module will remain isolated for at least 76 minutes plus whatever time is required to perform rescue operations.

The second impact is on the EVA crewman. If after vehicle egress the docking tunnel hatch is closed for docking module repressurization and cannot be opened (due to malfunction) for vehicle ingress, the EVA crewman is marooned outside the vehicle and an alternate method of affecting EVA is required to accomplish his rescue.

Conclusion: Concurrent EVA/shirtsleeve operations during sortie module operations is not recommended.

D.2.2.3 Case 3: Sortie Lab Type Mission (Docking Module Depressurized)

This configuration involves a pressurizable module in the Orbiter payload bay which is attached to the docking module. The pressurizable module is pressurized and the docking module is depressurized.

This case is similar to Case 2 with regard to EVA operations. EVA cannot be initiated unless shirtsleeve operations in the pressurizable module are terminated and the crew returns to the safety of the crew cabin, or unless the shirtsleeve crew is isolated from the crew cabin and remains in the sortie module.

In this case, during EVA operations, the docking module is depressurized for six hours during which the crew in the pressurized module is completely isolated. Similar to Case 2, in the event of an emergency, the safety of the shirtsleeve crew is endangered.

Conclusion: Concurrent EVA/shirtsleeve operations during sortie module operations is not recommended.

D.2.2.4 Case 4: Sortie Lab/Orbital Element Servicing Mission

This configuration involves a pressurizable module in the Orbiter payload bay which is attached to the docking module and an orbital element which is attached to the extended docking tunnel of the docking module. The pressurizable module is pressurized and the docking module and orbital element are unpressurized during IVA servicing.

This case is similar to Case 2. During IVA operations when the docking module is depressurized, the shirtsleeve crew is isolated from the crew cabin of the Orbiter in the event of an emergency. Should an emergency arise in the sortie mdoule, about 21 minutes would be required to secure and repressurize the docking module in order to rescue the shirtsleeve personnel. For this condition, the pressurizable module must provide pressure suits for each of its crewmen. Since emergency egress is precluded for this 21 minute period, crew safety is endangered for up to eight minutes until each crewman can perform an emergency suit-up. In addition, if the docking module cannot be secured, and contingency suits are not provided, the shirtsleeve crew is marooned in the pressurized module.

Conclusion: Concurrent IVA/shirtsleeve operations during sortie module operations are not recommended (Table D-1).

40416

TABLE D-1
CONCURRENT SHIRTSLEEVE AND EVA/IVA OPERATIONS CASES STUDIED

	PROBLEMS	RECOMMENDATION
CASE I	• CONCURRENT EVA OPERATIONS ISOLATE EVA CREW FOR UP TO 6 HOURS • EVA CREW SAFETY ENDANGERED • EMERGENCY RETURN TO ORBITER BY EVA CREW PROHIBITED • DISABLED EVA ASTRONAUT CANNOT BE REACHED FOR AT LEAST 44 MINUTES • MALFUNCTION OF DOCKING MODULE HATCH MAROONS EVA CREWMAN	NO CONCURRENT EVA/IVA AND SHIRTSLEEVE PAYLOAD OPERATIONS
CASE 2	• CONCURRENT EVA OPERATIONS ISOLATE SHIRTSLEEVE CREW FOR 36 MIN DURING EVA EGRESS AND INGRESS AND FOR AT LEAST 76 MIN DURING DISABLED EVA ASTRONAUT RESCUE OPERATIONS • SHIRTSLEEVE CREW SAFETY ENDANGERED • EMERGENCY RETURN TO ORBITER PRECLUDED • MALFUNCTION OF DOCKING MODULE TUNNEL MAROONS EVA CREWMAN	
CASE 3	• CONCURRENT EVA OPERATIONS ISOLATE SHIRTSLEEVE CREW FOR UP TO 6 HOURS • SHIRTSLEEVE CREW SAFETY ENDANGERED • EMERGENCY RETURN TO ORBITER PRECLUDED	
CASE 4	• CONCURRENT IVA OPERATIONS ISOLATE SHIRTSLEEVE CREW • SHIRTSLEEVE CREW SAFETY ENDANGERED • EMERGENCY RETURN TO ORBITER PRECLUDED	

D.2.3 Disabled Orbiter Rescue Operations

Disabled Orbiter rescue operations represent the most critical and complex aspect of docking module operations. A schematic rescue operations scenario derived from Rockwell International drawings is presented in Figure D-14.

For analysis purposes, it was assumed that the disabled Orbiter was launched without a docking module and utilized the full 60 foot payload accommodation capability of the payload bay. It was further assumed that the payload launched was either of the deployable or non-deployable class.

In the case of a deployable payload, such as that of a TUG-S/C, an additional constraint was imposed by assuming that the spacecraft required a support beam/cradle which remained in the payload bay after payload deployment.

For either class of payload, either the payload itself or any remaining payload associated ancillary equipment which would physically or operationally interfere with Orbiter/docking module on-orbit assembly must be relocated or removed from the payload bay.

Examples of the two configurations in question are illustrated in Figure D-15.

In order to determine whether the payload bay must be reconfigured (or equipment removed from the payload bay), the on-orbit docking module-to-Orbiter assembly envelope must be known. Available Rockwell International drawings were reviewed and it was estimated that on-orbit docking module assembly requires about a 15 foot operational envelope. This estimate is corroborated based on the following assumptions:

A. The in-place docking module operational envelope is essentially a right-cylinder having an 8 ft. diameter and an 11 ft. length (when retracted).
B. The worst case docking module operational dimension during on-orbit assembly is approximately 13.5 ft. (cylinder base-to-top diagonal).
C. Allowing 10 percent operational margin, the worst case operational dimension during on-orbit assembly is approximately 15 ft.

FIGURE D-14

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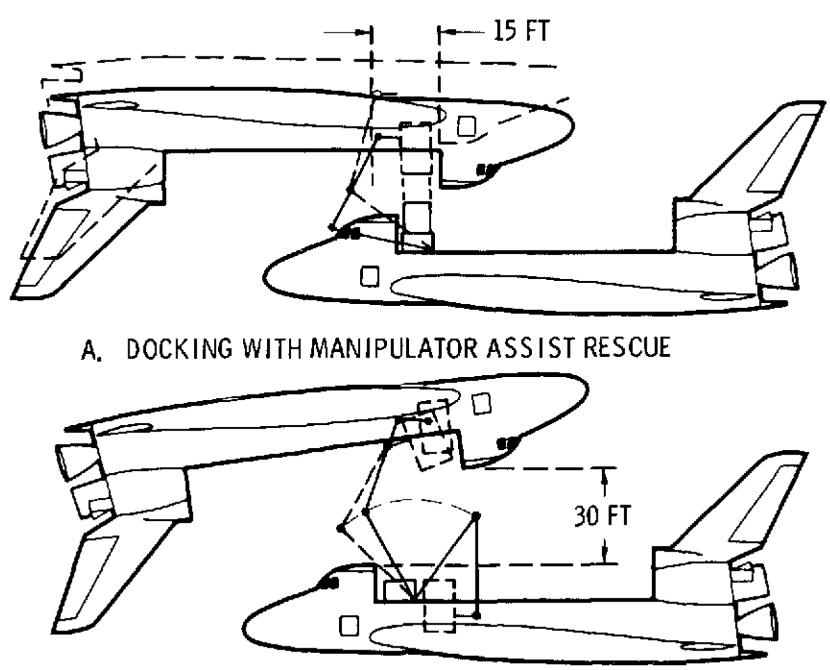
DISABLED ORBITER RESCUE OPERATIONS SCENARIO



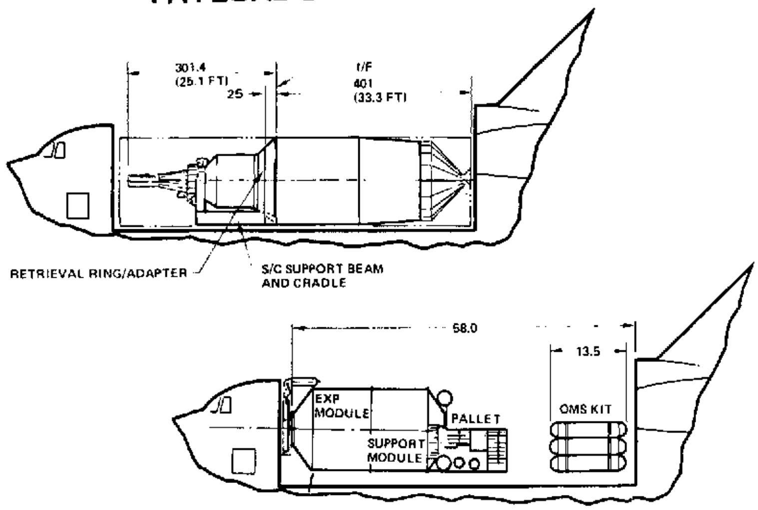
A. DOCKING WITH MANIPULATOR ASSIST RESCUE

B. DOCKING MODULE TRANSFER RESCUE

C. EVA RESCUE (NO DOCKING MODULE)

FIGURE D-15

PAYLOAD BAY CONFIGURATIONS



Payloads or payload ancillary equipment remaining in the payload bay must, therefore, not interfere with this handling envelope and should not be closer than 15 feet from the payload bay forward bulkhead. (Note that the handling envelope corresponds to the payload bay diameter.)

This dimensional constraint results in the following considerations:

A. For a sortie lab mission requiring an OMS kit of 13.5 ft. in length and an Orbiter/lab access tunnel of about 2 ft., in order not to have to jettison the payload, the maximum allowable payload length is [60' - 2' - 13.5' - 15'], or about 29-1/2 feet. This assumes that the payload can be relocated from the forward to the rear from the payload bay.

B. For deployable payload missions not requiring a 13.5 ft. OMS kit, any payload greater than 45 ft. in length must be removed from the payload bay.

C. Any payload ancillary equipment within 15 ft. of the payload bay forward bulkhead must be relocated prior to on-orbit docking module assembly operations.

Re-configuration of the payload bay involves the two basic options of relocation of equipment or deployment of equipment out of the bay.

In order to relocate payload associated ancillary equipment which remains in the bay after payload deployment, there are three potential operational modes available.

A. Remotely controlled automatic equipment relocation.

B. Relocation of equipment utilizing the Remote Manipulator.

C. EVA operations.

Automatic equipment relocation requires appropriate relocation devices and Orbiter interface controls. No attempt is made here to assess the impact which this capability would have on the Shuttle or the payload except that for weight-critical deployable payloads, introduction of such payload chargeable equipment may be prohibitive from a weight standpoint.

Relocation of equipment (such as a support beam/cradle) utilizing the manipulator system appears feasible if the appropriate manipulator/equipment and equipment/payload bay interfaces are provided. It is assumed that provision of such interfaces would be negligible from a weight standpoint. Relocation operations would ty pically involve:

A. Grasping the equipment with the manipulator.

B. Disengaging equipment tie-down hardpoints.

C. Translation of the equipment to its new location in the bay where it will not interfere with docking module/Orbiter assembly operations.

D. Installation of the equipment on its new mounting provisions.

E. Engaging the equipment on its new mounting provisions.

EVA reconfiguration operations exhibit several significant disadvantages as follows:

A. If unscheduled EVA is required the Orbiter must fly EVA suits for the two man EVA operations plus any additional equipment necessary to affect payload bay equipment relocation. The combined weight of this equipment could be as much as 600 pounds. This weight would be chargeable to the payload and for weight-critical missions, this extra weight could make mission accomplishment prohibitive.

B. Equipment, such as a spacecraft support beam/cradle will probably weigh on the order of 200 lb. and be dimensionally about 13 ft. long and 10 ft. wide. Mass handling of equipment of the 100 to 300 lbm category requires the EVA astronaut to utilize rigid waist restraints in addition to foot restraints in order to have the capability to exert forces which may be out of his plane of restraint. Such restraint requirements make relocation of equipment different if not impossible.

C. A malfunctioning (leaking) crew cabin/payload bay hatch would require the entire Orbiter crew to suit-up prior to any unscheduled EVA operations. For this condition, an additional 90 lb. of equipment would be required for each crewman in addition to the two EVA astronauts.

D. Appropriate volumetric storage accommodations in the Orbiter crew compartment would have to be provided for stowage of unscheduled EVA equipment. For a four man crew this would amount to 40 cubic feet. Available Orbiter documentation does not reflect provisons for such stowage accommodations.

For payloads which are normally not deployed (typically the size and mass of a Sortie Lab), EVA reconfiguration of the payload may not be feasible.

When a large payload envelope is involved (greater than 45 ft.) reconfiguration of the payload bay is not acceptable and the payload must be removed from the payload bay.

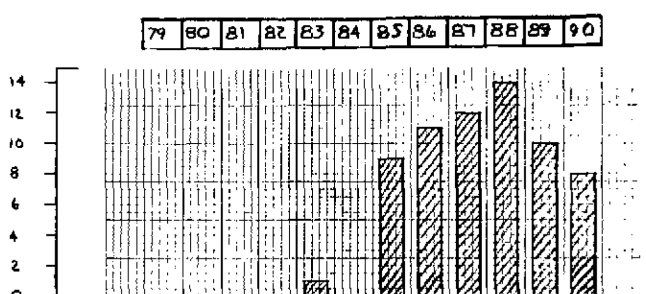
In order to determine the impact which on-orbit docking module assembly has on the Shuttle program, the NASA TM X-64731 Shuttle Traffic Model was reviewed.

For purposes of the analysis it was assumed that the Shuttle had completed its orbital mission but that a main propulsion and back-up deorbit system failure had occurred. The traffic model revealed (Figure D-16A & B) that 65 (27%) of the payloads to be returned to earth exceeded the 45 ft. length limitation. Since on-orbit docking module assembly operations are not possible while these payloads remain in the payload bay, an evaluation of whether they could be erected out of the bay (in a manner similar to that of the TUG) such that they would not interfere with docking module rescue operations. One of the key considerations involved in making the evaluation was that the rescue orbiter must approach to within 30 ft. of the disabled Orbiter in order for the manipulator system to perform the necessary docking module assembly operations. In all cases, for payloads whose length exceeds 45 ft., erection of these payloads prohibits the rescue Orbiter from closing to within the 30 ft. distance requirement (Figure D-17).

Deployable payloads which are longer than 45 ft. must therefore be jettisoned. Payloads which are not normally deployed and which are less than 21-1/2 feet in length do not have to be jettisoned if the necessary payload bay

FIGURE D-16A

RETURN PAYLOADS WHICH INTERFERE WITH DOCKING MODULE SHIRTSLEEVE RESCUE

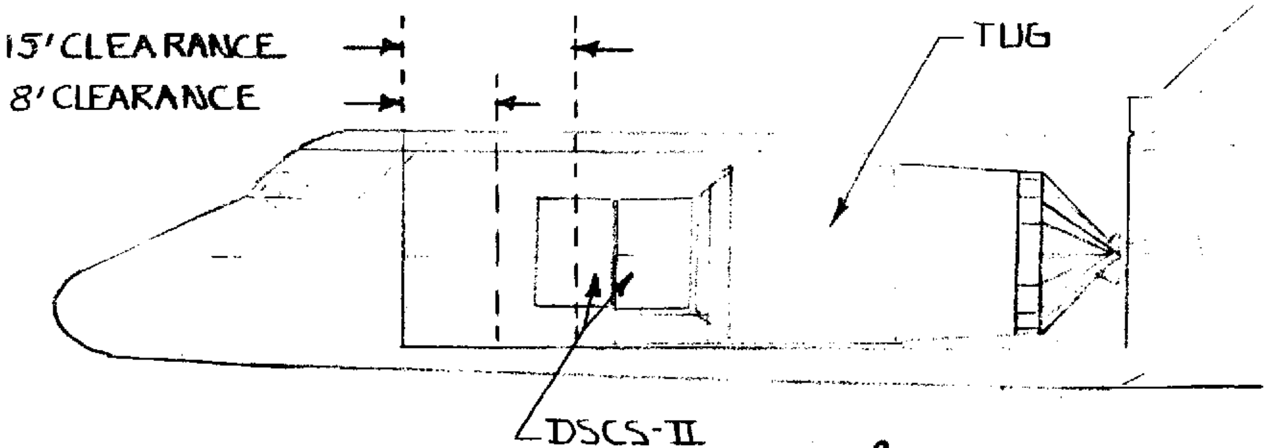


	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
PAYLOADS WHICH INTERFERE WITH DOCKING MODULE	—	—	—	—	1	—	9	11	12	14	10	8	65
PLANNED RETURN PAYLOADS	—	3	7	5	9	8	36	28	36	35	37	32	236

FOR SHIRTSLEEVE DOCKING MODULE RESCUE 27% OF PLANNED RETURN PAYLOADS INTERFERE WITH RESCUE OPERATIONS

FIGURE D-16B

RETURN PAYLOADS WHICH INTERFERE WITH RESCUE DOCKING MODULE



- DOCKING MODULE REQUIRES UP TO 15 FT OF PAYLOAD BAY LENGTH FOR ON-ORBIT RESCUE INSTALLATION OPERATIONS
- UP TO 27% OF RETURN PAYLOADS INTERFERE WITH ON ORBIT DOCKING MODULE INSTALLATION

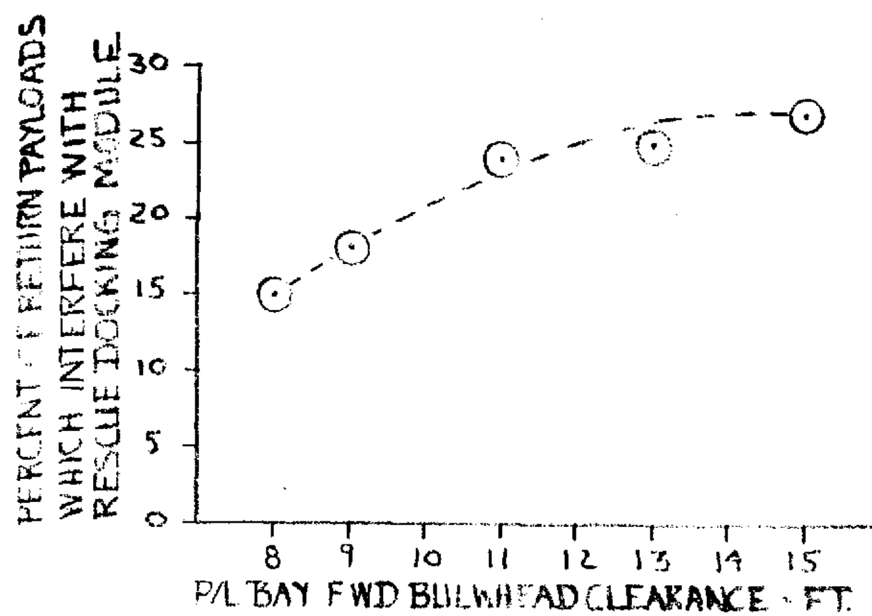


FIGURE D-17

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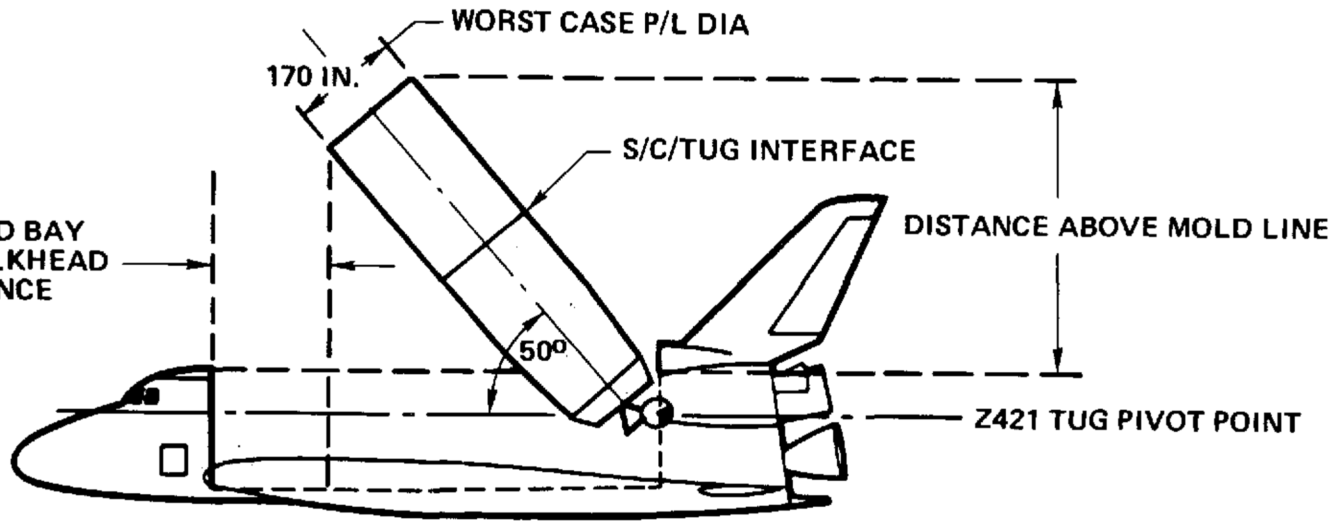
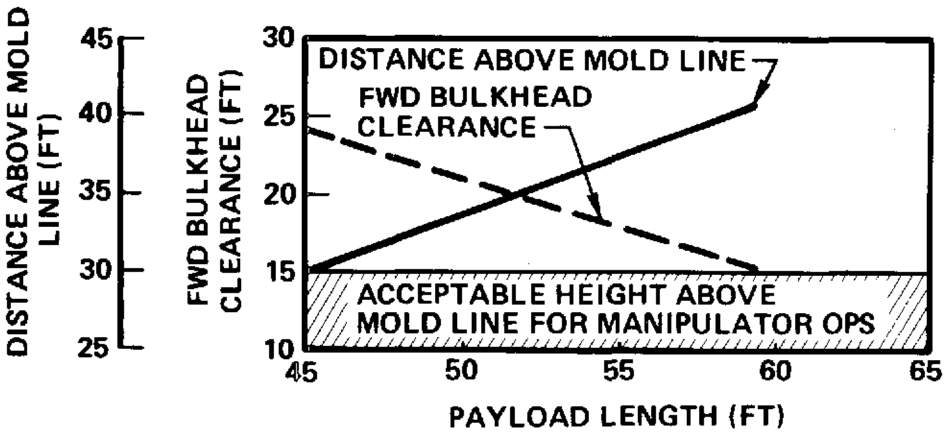
DOCKING MODULE INTERFERENCE





- PAYLOADS LONGER THAN 45 FT INTERFERE WITH ON-ORBIT DOCKING MODULE INSTALLATION
- ERECTION OF PAYLOADS LONGER THAN 45 FT CLEARS THE PAYLOAD BAY BUT PRECLUDES APPROACH BY RESCUE ORBITER
- PAYLOADS LONGER THAN 45 FT MUST BE JETTISONED TO EFFECT SHIRTSLEEVE RESCUE

reconfiguration equipment is provided. Reconfiguration would, for example, require that the payload be rail mounted and remotely repositioned from the Mission Specialist Station prior to rescue docking module assembly operation.

To satisfy the payload jettison requirement, certain payload and Orbiter accommodations must be provided. The payload mounting hard-point tie-downs should be capable of automatic disengagement and the payload should be provided with a propulsive device capable of providing sufficient separation distance between it and the disabled Orbiter to ensure no recontact subsequent to jettison or during rescue Orbiter operations while in the vicinity of the disabled Orbiter.

The jettison operations are accomplished by the manipulator system. The Orbiter attached payload access tunnel remains with the payload and is disengaged from the Orbiter, the manipulator grasps the payload and payload tie-down devices are disengaged. The manipulator deploys the payload out of the bay, properly orients and releases it. The propulsive device on the payload is then initiated by command from the Orbiter.

Up to 65 Shuttle missions are scheduled to return payloads whose length precludes on-orbit docking module assembly and shirtsleeve rescue operations. Alternate methods for docking and rescue were considered in order to maximize the capability of shirtsleeve rescue. The most acceptable alternate docking/rescue concept involves the use of an in-bay docking module/airlock which has similar operational and dimensional characteristics to that of the PRR Baseline docking module. The configuration selected (Figure D-18) was derived from information contained in Rockwell International drawings. The significant features associated with this alternate concept are listed below.

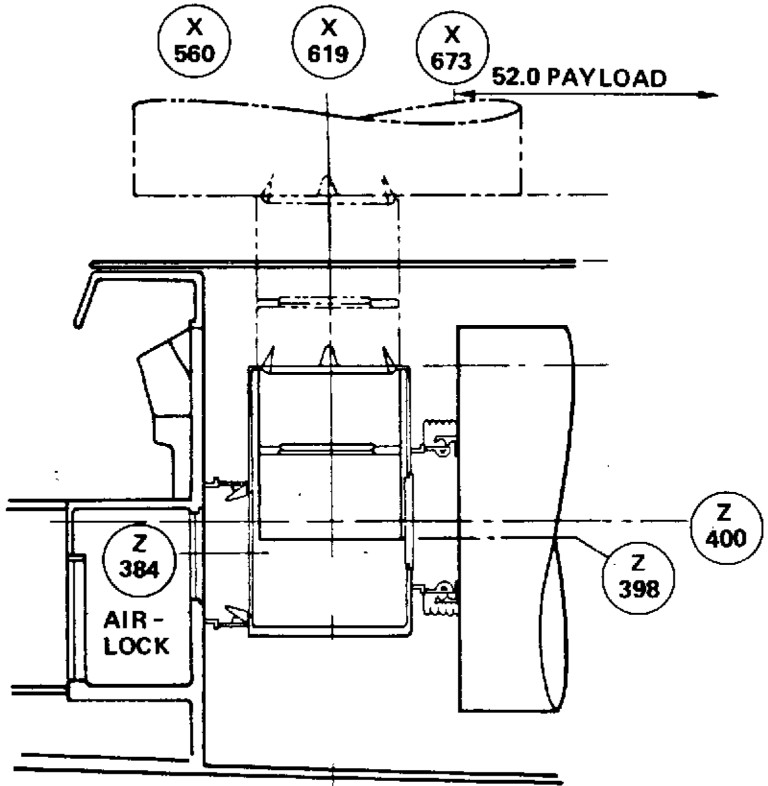
A. The docking module/airlock is located in the payload bay and performs both docking and airlock functions.
B. The airlock currently located in the crew compartment is not required and an additional operational volume of about 150 cu. ft. can be added to the lower deck of the crew compartment.
C. Shirtsleeve rescue can be accomplished for all Shuttle missions.

FIGURE D-18

DOCKING CONCEPTS

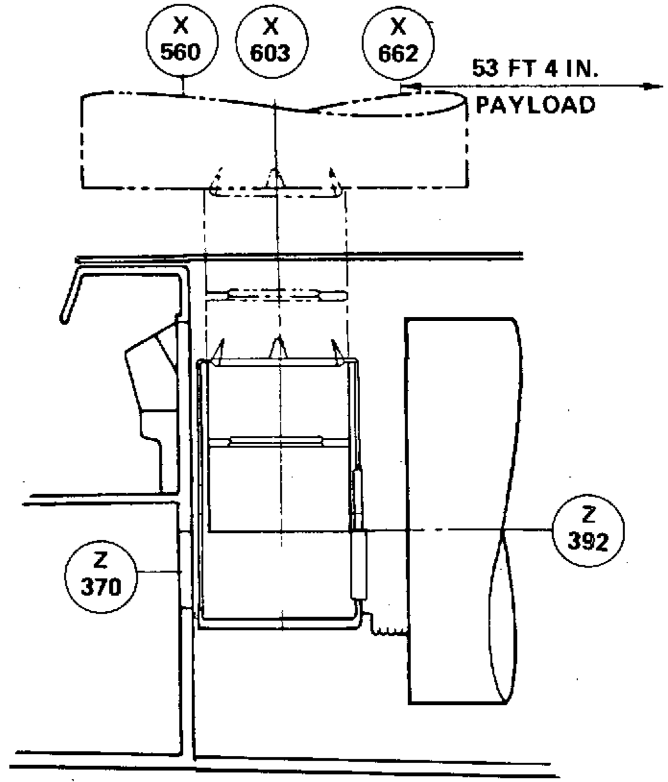
40418

BASELINE DOCKING MODULE



- FLOWN ONLY ON MISSIONS REQUIRING DOCKING
- SHIRTSLEEVE RESCUE REQUIRES JETTISON OF SOME PAYLOADS
- FOR DOCKING MISSIONS PAYLOADS IN BAY LIMITED TO 52 FT
- ON-PAD ADDESS THRU DOCKING MODULE NOT POSSIBLE
- SIMULTANEOUS EVA/IVA AND SHIRTSLEEVE OPS NOT RECOMMENDED
- PAYLOAD ACCESS ON CENTERLINE OF BAY

ALTERNATE IN-BAY DOCKING MODULE/AIRLOCK



- FLOWN ON ALL MISSIONS
- ALLOWS SHIRTSLEEVE RESCUE FOR ALL CASES – NO JETTISON REQD
- ALL PAYLOADS LIMITED TO 53 FT 4 IN.
- ON-PAD ACCESS THRU DOCKING MODULE POSSIBLE
- ELIMINATES AIRLOCK IN ORBITER LOWER DECK
- SIMULTANEOUS EVA/IVA AND SHIRTSLEEVE OPS NOT RECOMMENDED
- PAYLOAD ACCESS OFF CENTERLINE OF BAY

D. Direct "straight-through" Orbiter/payload access is possible.

E. On-pad access to payloads through the module is possible.

The alternate concept has the following drawbacks however.

A. The module must be flown on every Shuttle mission and payloads are limited to a maximum length of 53 ft. 4 in. As a result (Figure D-19), 47 (13%) of the non-DoD payloads scheduled for launch require length revision. Also, as in the case of the PRR Baseline docking module, 65 (27%) of the planned return-to-earth payloads cannot be accommodated due to excessive length.

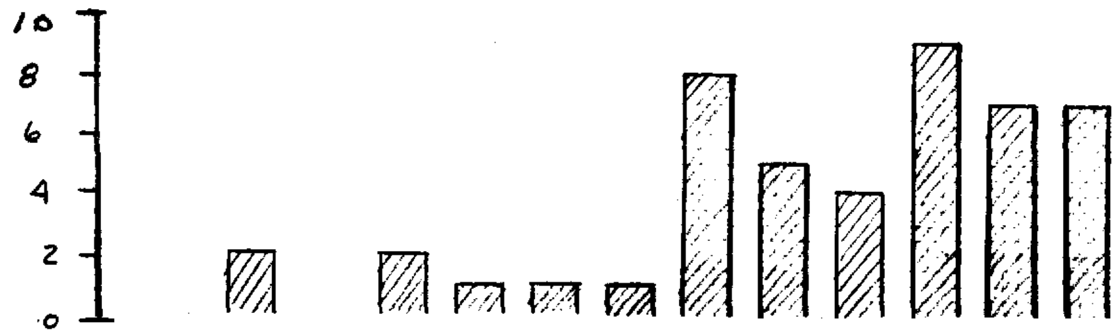
B. As in the case of the PRR Baseline docking module, concurrent EVA/IVA and shirtsleeve operations are not recommended because of crew safety considerations.

Seventy percent of the Shuttle missions in the NASA TM X-64731 Traffic Model on which DOD payloads are not launched do not require the use of a docking module and nearly 30 percent of these missions would require the jettison of a return payload to accomplish shirtsleeve rescue of a disabled Orbiter crew.

In the event that a payload cannot be jettisoned the crew cannot be rescued via the docking module (Figure D-20) and rescue operations must be affected via EVA. The Space Station Study performed by McDonnell Douglas identified a requirement that each operational volume occupied by the crew should have at least two escape routes available. Based on this requirement, it is recommended that the Orbiter crew compartment be provided with an EVA escape hatch in addition to the crew compartment/payload bay hatch.

FIGURE D-19

IMPACT OF ALTERNATE CONCEPT DOCKING MODULE/AIRLOCK ON SHUTTLE TRAFFIC MODEL



	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
LAUNCHED PAYLOADS WHICH INTERFERE WITH ALT. CONCEPT	2	—	2	1	1	1	8	5	4	9	7	7	47
SHUTTLE PAYLOADS LAUNCHED	8	22	27	22	28	24	44	30	40	38	44	39	366

- LENGTH OF 13% OF PLANNED PAYLOAD LAUNCHES INTERFERES WITH ALTERNATE CONCEPT DOCKING MODULE/AIRLOCK
- 27% OF PLANNED RETURN PAYLOADS CANNOT BE ACCOMMODATED DUE TO EXCESSIVE LENGTH

FIGURE D-20

40420

RESCUE ANALYSIS RESULTS

	(A) DOCKING MODULE RESCUE	(B) EVA RESCUE	RECOMMENDATION
PAYLOAD IN BAY ATTACHED NO DOCKING MODULE IN BAY	• REQUIRES PAYLOAD TO BE JETTISONED • DOCKING MODULE TRANSFER • SHIRTSLEEVE RESCUE	• REQUIRES PAYLOAD TO BE JETTISONED • EVA RESCUE	• PROVIDE PAYLOAD TRANSFER TUNNEL WITH BLOW-OUT EVA HATCH • IF CLEARANCE < 4 FT PROVIDE PAYLOAD WITH EVA HATCH • PROVIDE CREW COMPARTMENT WITH EMERGENCY EVA HATCH • EVA RESCUE RECOMMENDED
NO DOCKING MODULE IN BAY 8 FT TO 15 FT CLEARANCE WITH P/L BAY FWD BULKHEAD	• DOCKING MODULE TRANSFER • SHIRTSLEEVE RESCUE	• PERFORM NOMINAL EVA RESCUE	• PROVIDE ORBITER WITH AN IN-BAY AIRLOCK • PROVIDE CREW COMPARTMENT WITH EMERGENCY EVA HATCH • EVA RESCUE RECOMMENDED
PAYLOAD IN BAY NOT ATTACHED NO DOCKING MODULE < 8 FT TO 15 FT CLEARANCE WITH P/L BAY FWD BULKHEAD	• REQUIRES PAYLOAD TO BE JETTISONED • DOCKING MODULE TRANSFER • SHIRTSLEEVE RESCUE	• PERFORM NOMINAL EVA RESCUE	• ERECT PAYLOAD IF CLEARANCE < 4 FT • PROVIDE CREW COMPARTMENT WITH EMERGENCY EVA HATCH • EVA RESCUE RECOMMENDED

Appendix E

PAYLOAD VENTING REQUIREMENTS ANALYSIS

The payload venting analysis task consists of the definition of the Shuttle payload venting requirements. This is followed by the evaluation of the venting requirements and the analysis of the various methods of satisfying them. Resolution of the vent provisions results in impacts on the payload, the Shuttle or both.

Payload venting may be produced by outgassing, purging of the payload, or boil-off of payload gases for all phases of the Shuttle mission including Shuttle abort modes. The payload gases being vented are identified, including their amounts and state and the mission periods when venting occurs.

The general guidelines of the Space Shuttle system specification performance and design requirements document for expelling hazardous fluids were followed in defining the methods of venting payload fluids. The expected results of this task are definitions of the payload venting interface requirements and the impacts of the Orbiter interfaces upon the payloads.

Payload venting in Shuttle missions influences both the payload and the Shuttle design and operations. The magnitude of the impact is dependent upon the rigor of safety requirements and the Shuttle's capability for vent installations and operations constraints on venting. Safety requirements that call for all payload pressure vessels to provide pressure limiting relief vents are a key factor. Conditions where design conditions will permit no-vent operations may relieve some payload impacts. The definition of the Shuttle vent services to the payloads is an evolving activity with some basic features yet to be defined.

There are degrees of payload fluids venting impacts depending upon the fluid hazards and flows. Even some inert fluids may be limited in free vent in the payload bay due to Shuttle bay atmosphere conditions and bay door structure limitations.

E.1 TYPES OF PAYLOAD VENTING

Payload venting can occur under a wide variety of conditions and at various times during the mission. Three general classes of venting can exist: (1)

the pressure relief of tanked fluids to maintain safe operation, (2) scheduled flows of process fluids, and (3) unscheduled flows, Table E-1.

Pressure relief can involve planned tanked fluids that may require ground as well as flight tank vent discharges that can usually be scheduled to minimize undesirable side effects. Other, unscheduled venting infrequently occurs when unplanned tank pressure rise approaches unsafe conditions such as in the lifting of a pressure relief valve.

Scheduled flows frequently have limited venting at specific mission times. For example, the purge gas flows are usually ground-active. Flight-active purge is usually associated with a potential hazard event and is time-limited. Dumping of fluids in emergency situations to passivate the payload is a special condition where continued normal payload performance is discarded (frequently shared with venting provisions or with fill and drain lines).

More difficult venting to handle is unscheduled flows, particularly leaks and the outgassing. The flow rates can be kept low with proper attention to payload design. A more unmanageable situation that can occur is a damaged payload where a fluid system is ruptured.

E.1.1 Payload Effluent Discharge

The four payload mission classes have fluids that may require venting as listed in Table E-2. A fluid not listed for the Sortie Lab is the breathing atmosphere.

The impact of payload outgassing on the Orbiter payload bay is estimated to be negligible. Payload batteries may be a problem depending upon the battery design. Battery encapsulation appears to be the simplest solution. This may require the replacement of vented batteries where they are used.

The monopropellant hydrazine used for a number of payloads can present a venting problem while the payload is in the Orbiter payload bay. The hydrazine system is inactive during these bay periods and could be held at a low pressure. Another solution is to increase the hydrazine system design safety margins to 4.0 with the plan that no venting will be required. Should the impact on the satellite of this possibly heavier tank and piping system be undesirable, a design solution could be to use high-design-safety margin hydrazine holding

TABLE E-1

Types of Payload Venting

Pressure Relief of Tanked Fluids

- Planned Discharge
- Unscheduled for Tank Pressure Safety

Scheduled Flows of Process Fluids

- Purge Gas Disposal - Cooling Gas Disposal
- Cryogenic Fluid Control
- Experiment Operation
- Operations Dumps, i.e., EVA Coolants
- Propulsive Dumps
- Payload Passivation - Dumps
- Venting During Tank Filling

Unscheduled Flows

- Boil-Off of Fluids that are Unpressurized
- Leaks
- Fluid Vessel Catastrophe
- Outgassing
- Fluids Dump During Abort Mode

TABLE E-2

40465

PAYLOAD EFFLUENTS DISCHARGE

MISSION CLASS	PAYLOAD	PAYLOADS FLUIDS TYPES									REMARKS
		He	GN_2	GO_2	CO_2	HYDRAZINE	LH_2/LO_2	PURGE	BATTERIES	OUTGASSING	
I	EOS		YES			YES		YES	YES	YES	VENTS POSSIBLE
II	ATS					YES		YES	YES	YES	VENTS POSSIBLE
	SMS					YES		YES	YES	YES	VENTS POSSIBLE
	DSCS-II		YES			YES		YES	YES	YES	VENTS POSSIBLE
	TUG					POSSIBLE	YES	YES	YES	YES	VENT LINES
III	LST		YES					YES	YES	YES	VENT LINES PROBABLE
	ANCILLARY EQUIPMENT USED ON CLASSES I, II, III	YES	YES					YES		YES	VENTS POSSIBLE
IV	SORTIE LAB	YES	YES	YES	YES			YES	YES	YES	VENT LINES PROBABLE

tanks that remain in the payload bay and are capable of fully containing the hydrazine without the need for payload venting.

These same types of solutions are possible for many tanked fluids and in particular the small tanks. A payload tank of sufficient strength (and safety factor such as 4.0 or above) may be acceptable with no vent provisions. Other tanks can be operated in a two pressure level mode where the tank is kept "unchanged" - pressure wise - while Orbiter attached to achieve a similar "no vent" acceptability. Later, after the payload is safely clear of the Orbiter, the tank is pressure activated to its operational condition. Another "no-vent" type of solution is to utilize payload holding tanks carried in the payload bay which have sufficient volume and strength that the fluids are successfully managed without vent provisions in the Shuttle.

The stored gases: helium, nitrogen, and CO_2 would be expected to need venting only for emergency pressure-reducing safing. The quantities of oxygen in the spacecraft do not present large venting problems. The Space Tug is the exception needing large quantity venting, and the present Tug concepts recognize these vent needs by providing Tug vent piping to the Orbiter for appropriate overboard management. The Tug abort dumping plan to dump LO_2 and retain LH_2 as proposed in the SOAR-II analysis was retained.

E.1.2 Payload Effluent Flows

The payload flow conditions for the five spacecraft for which data are available is listed in Table E-3. Although hydrazine is a commonly used RCS propellant and the quantities are significant, 100 to 200 lbs, the existing RCS system designs are closed package systems not normally designed for venting in the conventional sense. In flight, an unsafe condition where venting could provide relief could be handled by hydrazine burn through the thrusters. The enforcement of a Shuttle requirement that the hydrazine pressurized tanks be ventable while in the Shuttle, and that the hydrazine be capable of unloading on the launch pad appears to involve new plumbing additions to the spacecraft and a potential reduction in the integrity of the tank-piping system of the present spacecraft.

E.2 TUG-SHUTTLE VENTING

The Tug is the major venting element in many of the payloads with its large

TABLE E-3
EFFLUENTS PROBLEM

SPACECRAFT	EFFLUENTS TYPE	EFFLUENTS AMOUNT (LBS)	EFFLUENTS TIME FLOWS	EFFLUENTS CONTROLLED VENTING
EOS LEN RABB, GSFC EOS PROJECT OFFICE	HYDRAZINE AND GN_2	100 50	• ORBIT TRIM (1/30 DAYS) • ATTITUDE CONTROL WITH COLD GAS • STATIONKEEPING WITH HYDRAZINE	THRUSTERS CAN BE FIRED AS NECESSARY TO USE UP REMAINING GAS
SMS GSFC PHASE-B STUDY JANUARY 1970	HYDRAZINE	72	INITIAL ADJUST = 6 # S/C ORIENT = 5 # E-W STATIONKEEP = 3 # N-S STATIONKEEP = 37 # NUTATION CONTROL = 15 # STATION RELOCATE = 5 #	BURN-OFF IS POSSIBLE
ATS-H-I ATS-H/I SYSTEM FEASIBILITY REPORT VOL II, JUNE 1972, LEWIS RES CENTER	HYDRAZINE SECONDARY SYSTEM	180	HYDRAZINE IS BACKUP SYSTEM FOR UNLOADING THE GYROS AND FOR 1 LONGITUDE REPOSITIONING MANEUVER, LIFE TIME IS 1 YR PLUS 1 REPOSITIONING, OR 2 YR W/O REPOSITIONING	BURN OFF IS POSSIBLE IN THEORY
LST NASA TM X-64726 PHASE-A FINAL REPORT, (VOL. 5), DECEMBER 1972	GN_2 (COLD GAS)	43	EMERGENCY/BACKUP SYSTEM ONLY. ALSO USED AS PRIMARY FOR DOCKING MANEUVER AGENA THRUSTERS USED	NO PROBLEM VENTING GAS BECAUSE COLD GAS THRUSTERS ARE INACTIVE (I.E., NO HEAT IS GENERATED)
DSCS-II DON SNOKE, DSCS-II AREA - TRW	HYDRAZINE	120/SAT.	AS NECESSARY. EVERY 21 DAYS AFTER ON-ORBIT. MOST FUEL USED FOR REPOSITIONING ON DEMAND. INITIAL STATION ACQUISITION = 22 #, STATIONKEEPING = 50-60 #	THRUSTERS CAN BE BURNED CONTINUOUSLY TO USE UP ALL FUEL

quantities of cryogenics including its hydrogen. The Tug fluid conditions and flow rates are listed in Table E-4 for all fluid events including vent. The Tug is mounted to a bifurcated cone tilt table for deployment out of the payload bay. Two umbilical disconnect panels are separated prior to tilt table deployment which cuts off the GO_2 vent connection to the Orbiter vent system, Figure E-1. After recovery of the Tug to the tilt table and a depleted Tug propellant load, the tilt table helium supply is available to purge the Tug at a tilt table umbilical connection. After the tilt table has returned, the Tug into the stowed position in the bay, the two previously disconnected umbilical panels are reconnected and the normal Tug vent is available through the Orbiter piping. The overall Tug services in the Orbiter including the propellant dumping and Tug venting is shown in Figure E-2.

E.2.1 Spacecraft Propellants Management Options

The payload venting needs can vary with different payload fluid loading plans. Current Shuttle specifications require that payload storable propellants be loaded before the payload is inserted into the Orbiter, Figure E-3. It would

TABLE E-4

Panel Functions	Line Size	Temp.	Interface Press.	Flow Rate	Remote Reconnect
LH_2 Tank Fill	2"	37 °F	22 psig	100-600 GPM	Yes
GH_2 Tank Vent	2"	37 °R	10 psig	10 lb/min	Yes
GH_2 Accum. Fill	1/2"	300 °R	500 psia	2 lb/min	No
Cold He Fill	1/2"	40 °R	3000 psia	2 lb/min	No
*Panel Purge Vent	1/4"	200 °R	15 psia	.02 lb/min	N/A
LO_2 Tank Fill	2"	163 °R	20 psig	55-150 GPM	Yes
GO_2 Tank Vent	2"	163 °R	9 psig	9 lb/min	Yes
GO_2 Accum. Fill	1/2"	500 °R	500 psia	4 lb/min	No
He Purge	1/2"	520 °R	500 psia	(TBD)	Yes
Ambient He Fill	1/2"	520 °R	4500 psia	4 lb/min	No
*Panel Purge Vent	1/4"	300 °R	15 psia	.07 lb/min	N/A
LO_2 Dump	7"	163 °R	23 psig	3,000 GPM	No

Note: LH_2 dump is not currently recommended in the SOAR II study. Spacecraft or interim Tug storable propellants not shown based on preloaded assumption.
*Aft bulkhead only.

FIGURE E-1
FLUID INTERFACE SCHEMATIC

38150

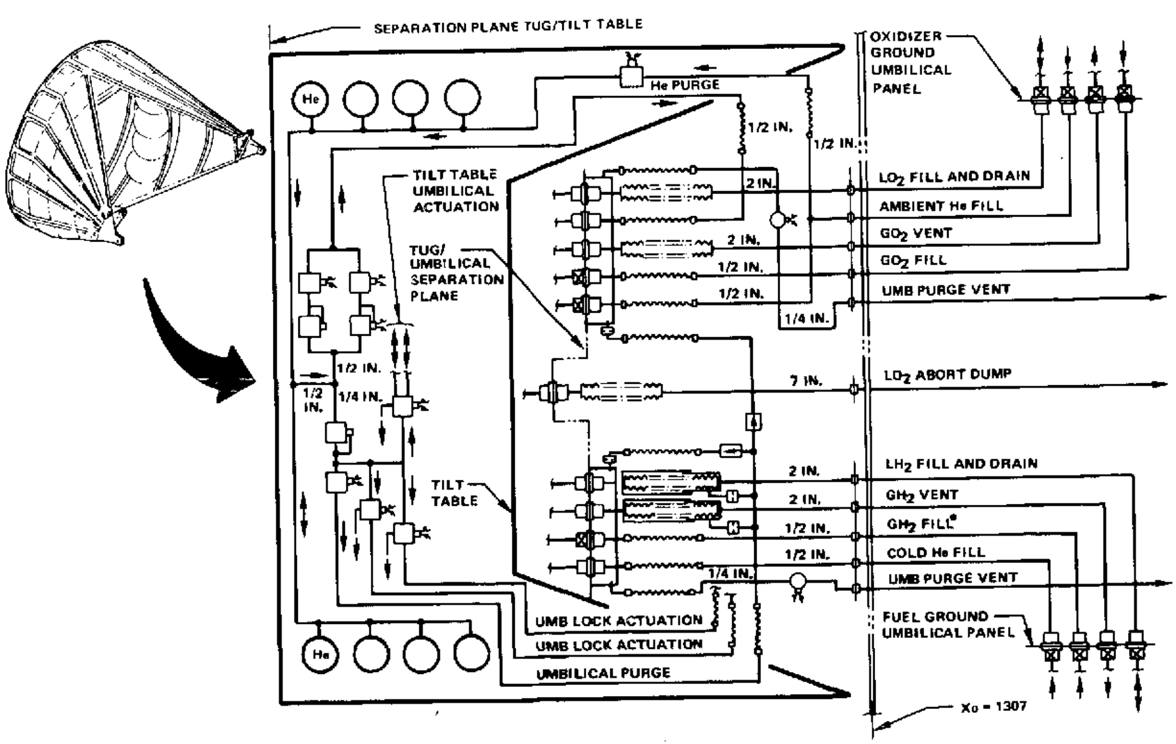


FIGURE E-2
TUG UMBILICAL INTERFACES

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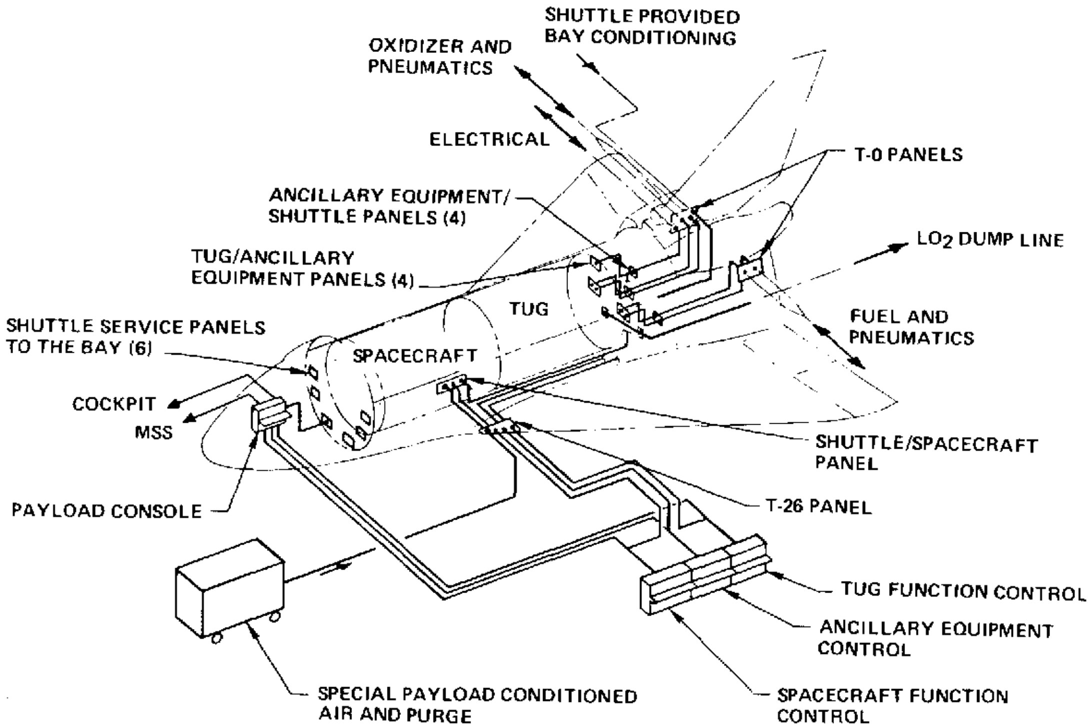


FIGURE E-3
SPACECRAFT PROPELLANTS MANAGEMENT OPTIONS

36887

LOAD PROPELLANT ON LAUNCH PAD	PRE-LOAD PROPELLANT BEFORE PAYLOAD BAY LOAD IN VAB
FILL, DRAIN AND VENT ON LAUNCH PAD VENT OR DUMP ON ORBIT IN SHUTTLE BAY	VENT AND DRAIN IN VAB, TRANSIT, LAUNCH PAD VENT OR DUMP ON ORBIT IN SHUTTLE BAY

CARGO BAY VENT OR DUMP OPTIONS

OPTION	CONSEQUENCES
DIRECT OVERBOARD	EXTERNAL PIPING - UMBILICALS, NO TIME RESTRAINTS
• VIA ORBITER	SPACECRAFT TO ORBITER HOOKUP • DISCONNECT SYSTEM
• VIA SPACE TUG	SPACECRAFT LINES THROUGH TUG
INDIRECT OVERBOARD	TIME INDEPENDENT, DRAIN HOOKUP OUTSIDE OF UMBILICALS
• HOLDING TANKS IN BAY	DIRECT SPACECRAFT CONNECTIONS
• HOLDING TANKS IN SPACE TUG	TUG PERFORMANCE PENALTY

be consistent therefore if all (except cryogens) payload fluid loading would be specified as pre-loaded. The Shuttle safety criteria for payloads with pre-loaded propellants has not been published. The two extremes possible when safety criteria are available, are: (1) the payload is expected to have safe tanks so that no vent or dump provisions are needed while the payload is in the Orbiter bay, or (2) payload vent and drain plumbing is required to be capable of operation at all times in the Orbiter bay.

Several options are available for the second case where vent and dump is required. Direct overboard piping may be lead from the spacecraft to the Orbiter bay wall or it may be directed from the spacecraft to the Tug and then to the Orbiter bay wall fittings.

Indirect overboard provisions where the fluids are held in the payload bay until it is convenient to discharge them overboard may be possible using fluid holding tanks. The tanks can provide the safety and the volume needed to remove the loads from the spacecraft. The holding tanks could be located on the Space Tug or in the payload bay. The latter location should minimize the impacts to other mission elements. Other vent provisions may be resolved by providing ground umbilical vent connections that are active for a limited period and on a one-time basis such as for fluid loading where tank venting for pre-load and load is required.

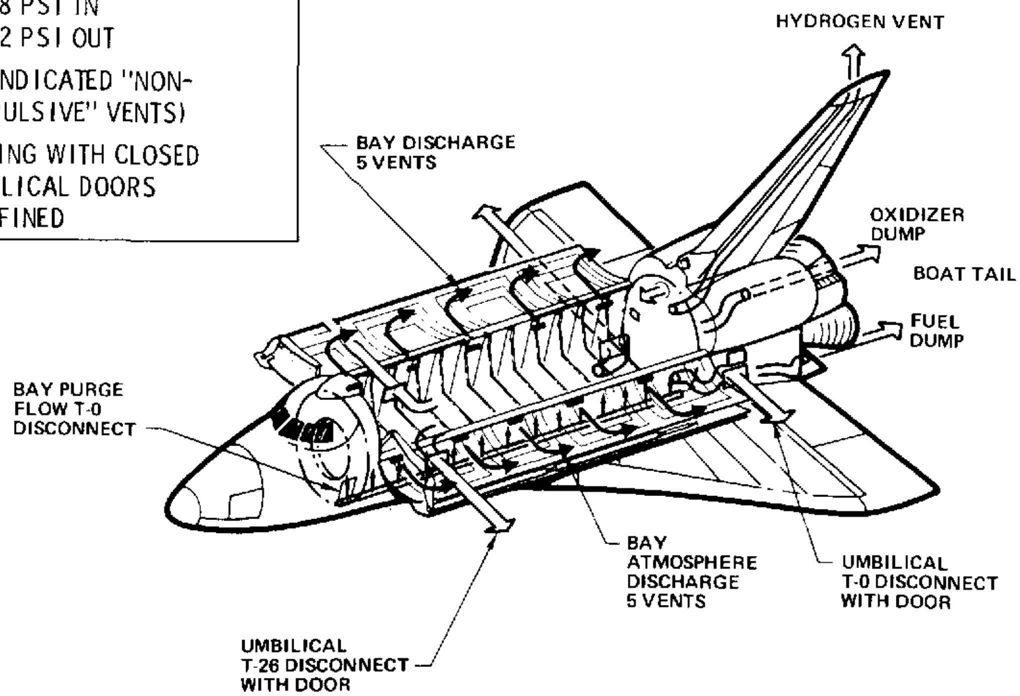
E.2.2 Orbiter Overboard Payload Venting

The Orbiter design concepts for payload venting have been identified to the detail shown in Figure E-4. Opportunities for payload piped vents exist in three places: one forward umbilical panel disconnected at T-26 minutes and two aft umbilical panels disconnected at T-0. All three of these umbilical panels appear to have door covers after the ground disconnect and the acceptability of venting under the closed door is unknown.

There are also propellant dump lines for the Orbiter in the aft boat-tail panel and it is expected that payload propellant dumps (Space Tug or Stage) also could utilize the boat-tail area. A hydrogen vent is also provided in the vertical fin.

FIGURE E-4
ORBITER OVERBOARD PAYLOAD VENTING

NOTE: BAY DOOR LOADS LIMITS
ΔP 0.8 PSI IN
ΔP 1.2 PSI OUT
- (NO INDICATED "NON-PROPULSIVE" VENTS)
- VENTING WITH CLOSED UMBILICAL DOORS UNDEFINED



The payload bay has ten discharge ports, five on each side spaced along the centerline. These vents nominally dump the bay atmosphere during ascent and allow atmosphere inflow during reentry. The port sizes and their flow capacity have not been published. The bay purge gas flows and any payload gas dumps in the bay could exit through these ten ports plus any bay door leakage through some 250 feet length of door seals. Adequate flow discharge is required to prevent excessive pressures within the closed bay and avoid overloading the doors which have a very limited pressure capability.

The present indications are that the cooling gas flow and purge gas during the launch pad operation is ducted into the bay along the bay keel and into the bay at the top centerline of one of the payload bay doors.

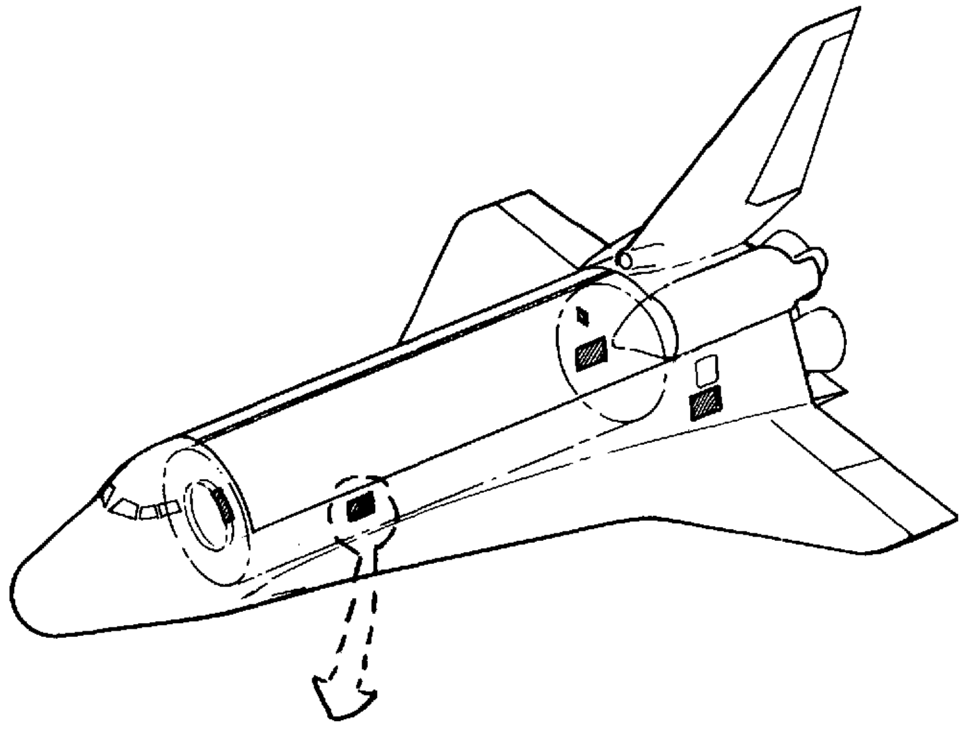
Although the Shuttle specification calls for nonpropulsive vents for payload gases, the concepts do not appear to vent under nonpropulsive conditions.

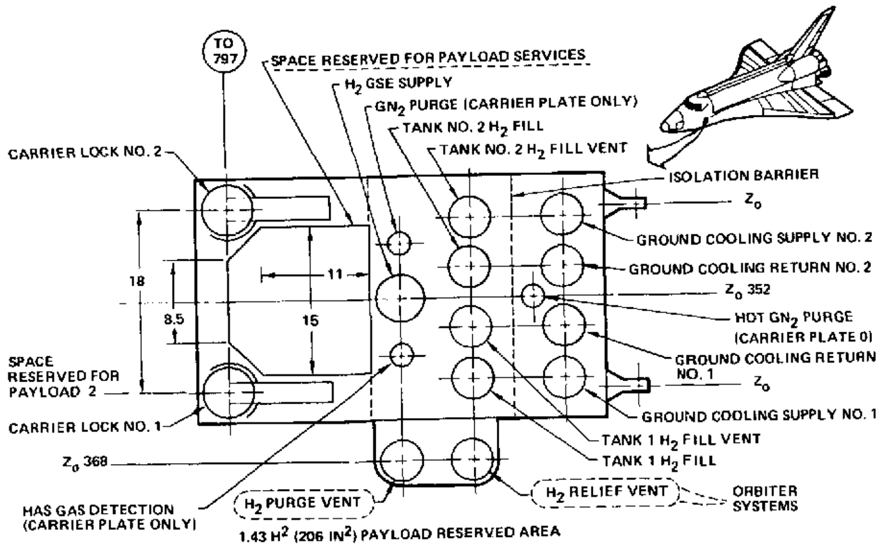
An example of a recent Orbiter design detail is shown in Figure E-5 where the left forward umbilical plate is detailed. This umbilical is disconnected at

FIGURE E-5

UMBILICAL PLATE VENTING FOR ORBITER

T-26 UMBILICAL DISCONNECT PLATE IS COVERED BY DOOR





T-26 minutes and a door closure is made over the plate. There are two vent outlets highlighted by "Orbiter systems" that appear to remain uncovered with the door closed. These hydrogen vents would appear to require separate vent stack piping prior to launch unless the associated tankage pressure is locked up prior to T-26 minutes and is not released until the Orbiter is clear of the sensible atmosphere. There is also an implied condition that suggests that all umbilical openings under the umbilical door are not properly usable as vent sources with door closed. If that is true, the space reserved for payload services would not allow payload venting with the door closed. There is a question as to whether it also applies to the two rear umbilical panels which also appear to have covering doors. Even in the event that some venting is permissible from beneath the door, the quantity probably is small and limited and the type of vented fluids are probably limited to non-hazardous fluids. If hydrogen venting exists for the Orbiter at the left forward umbilical panel, it also could be an attractive vent for the Tug hydrogen prior to launch.

The satellite provides on-the-pad cooling air flows into the payload bay from the T-0 umbilical connection. This flow is replaced by a nitrogen purge flow prior to the hydrogen/oxygen propellant loading. The general distribution of the gases into the bay and the uncertain quality and quantities at a particular payload location can lead to the use of customized payload gas flows supplied by dedicated payload umbilical connections as shown in Figure E-6. Another custom supply source could be from gas supply tank farms within the payload bay particularly for low flow rates, special gas needs, and for continuity of gas flow to the payload after liftoff and launch umbilical disconnect. The dumping of these custom flows into the payload bay could be limited by Shuttle bay flow rates, quality and location which have yet to be specified.

E.2.3 Spacecraft or Tug Venting

The spacecraft mounted to the Tug introduces possible venting complications in that the spacecraft venting lines would be conducted down the Tug and into the Orbiter as generally indicated in Figure E-7 or the vent lines are disconnected from the spacecraft prior to Tug-spacecraft deployment out of the payload bay. Added complexity is introduced when more than one spacecraft is carried by the Tug. Depending upon how the multiple spacecraft are mounted to the Tug, a vent

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FIGURE E-6
PAYLOAD GSE UMBILICAL INTERFACES

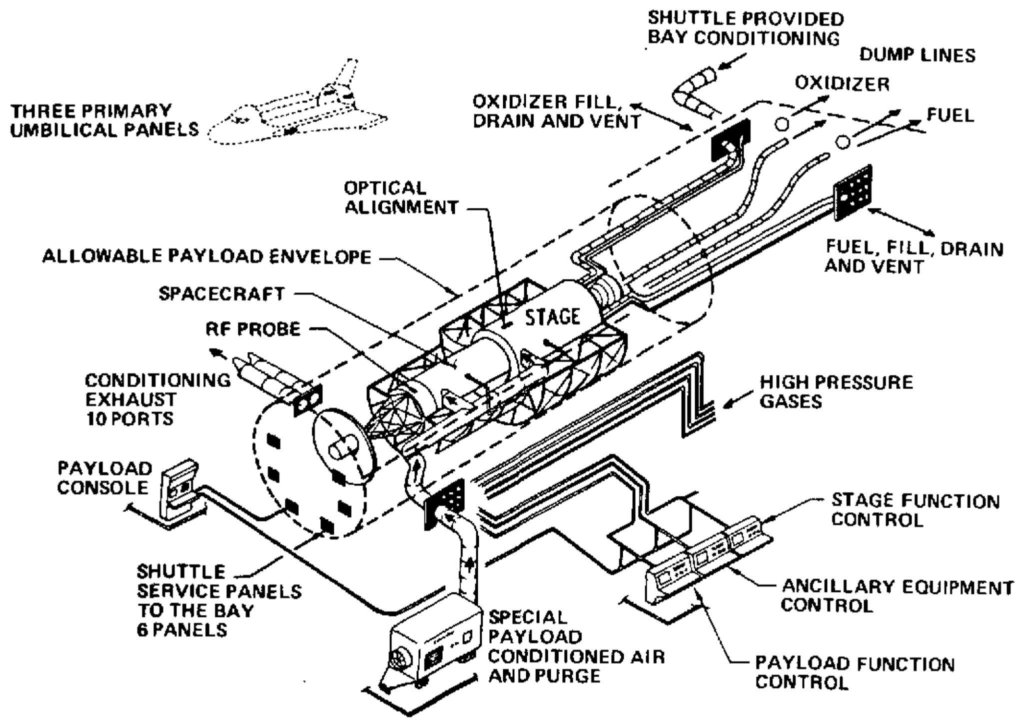

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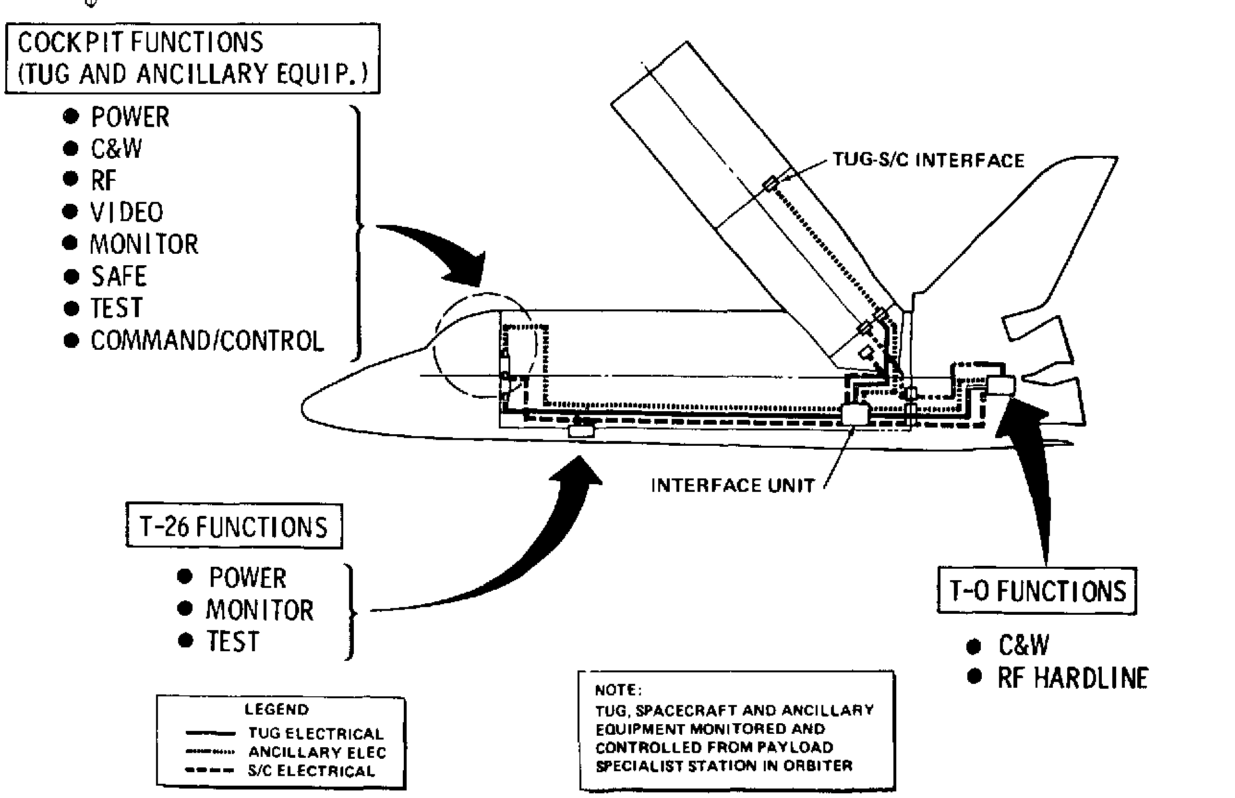
FIGURE E-7
ELECTRICAL DISTRIBUTION INTERFACES



line passage from one spacecraft across a second spacecraft to the Tug could be proposed. On the other hand, multiple payloads venting such as shown in Figure E-8 may be best handled by direct vent lines from each spacecraft to the Shuttle bay that are disconnected prior to Tug/spacecraft deployment out of the bay.

E.2.4 Payload Vent as a Bay Contaminant

The payload in the payload bay is one significant source of bay contamination if payload venting of any consequence is freely allowed. The bay contaminants from other sources are also significant and when the two sources are combined, the prospects to the payload in the bay are not pleasant as indicated in Figure E-9. Venting may only be a part of the payload shedding for particulant separation is probable and undesirable. Particulant and even debris material removal from the payload before Shuttle loading is closely associated with the payload cleanliness and housekeeping controls exercised and in the payload design of exterior materials and components.

E.2.5 Apparent Shuttle Venting Limitation

The general Shuttle concept description implies that there can be limitations on payload venting. These limitations can be applied differently for various fluids. Hazardous or corrosive fluids vents will always require positive management and associated plumbing connections. On the other hand, modest quantities of nitrogen or oxygen may be acceptably vented freely from the payload surface.

General venting in the VAB, and during Shuttle transport to the launch pad will possibly be limited or denied, Table E-5. Venting after launch can be denied for a short time period for fluids such as cryogenic hydrogen. Payload venting that results in propulsive reaction on the Orbiter could be detrimental to on-orbit fine pointing or to the Orbiter's ability to hold close station keeping on a payload target.

Payload venting in the payload bay can be limited when the bay doors are closed in order to avoid overpressurizing the bay doors. Likewise on-orbit venting of corrosive or hazardous payload fluids in the bay would be no more acceptable than it would be on the ground. Positive fluid management with plumbing is required.

FIGURE E-8
DSCS-II SUPPORT CONCEPT

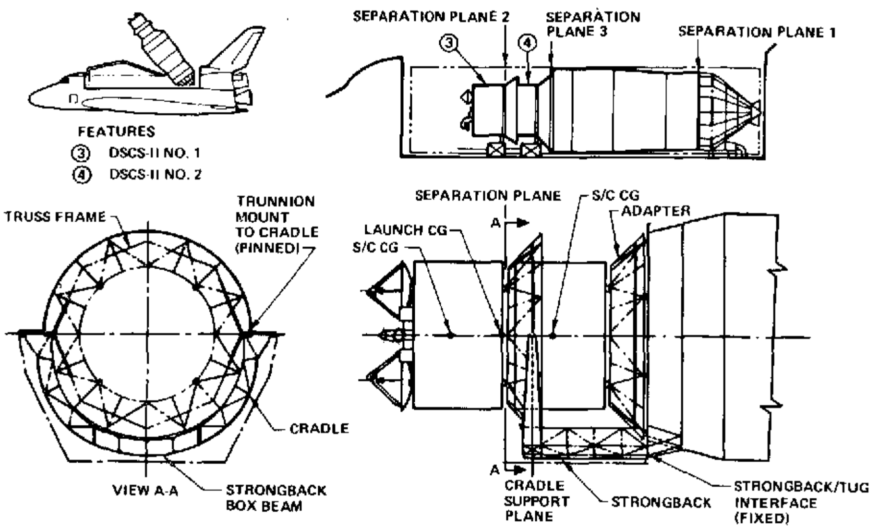


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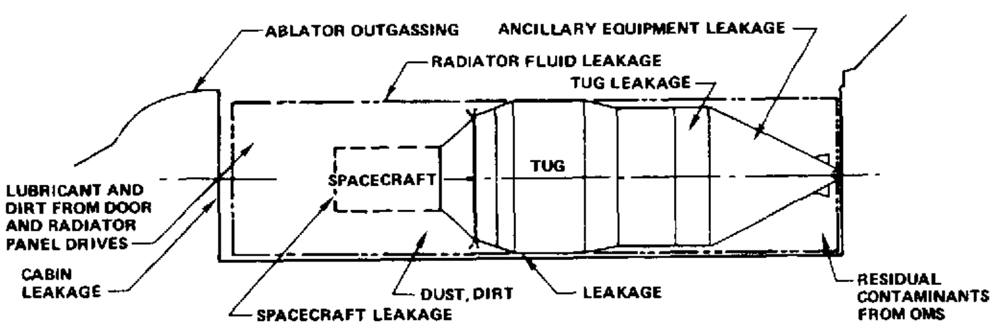
FIGURE E-9
CONTAMINANT SOURCES IN THE PAYLOAD BAY



PAD ENVIRONMENT:
- DUST
- DIRT-SAND
- MOISTURE
- SALT

OMS TANKAGE:
- MMH
- N_2O_2
- HELIUM
- NITROGEN

THERMAL CONTROL:
- FREON
- OTHER COOLING FLUIDS

ABLATOR OUTGASSING:
- SILICONE COMPOUNDS

SPACECRAFT:
- GASSES
- PROPELLANTS
- BATTERY FLUIDS

TUG:
- LO_2, GOX
- LH_2, GH_2
- MMH ?
- HELIUM
- NITROGEN
- BATTERY FLUIDS

CABIN LEAKAGE:
- NITROGEN
- WATER
- MAN EFFLUENTS

SHUTTLE SYSTEMS
- LO_2, GOX
- LH_2, GH_2

LEAKAGE AND DEBRIS FROM VARIOUS EQUIPMENTS, CLEANING, SHUTTLE REWORK AND INSTALLATION OPERATIONS

TABLE E-5

Apparent Shuttle Venting Limitations

OPERATIONS - NO VENT

- o VAB (TBD)
- o Orbiter to HO Tank Mating (TBD)
- o Shuttle Transport to Launch Pad
- o 60 (TBD) Seconds After Lift Off
- o Below 160,000 (TBD) Feet for LH_2 Dump
- o When Propulsive Vents During Orbiter Fine Pointing or Micro Station Keeping
- o During EVA

PAYLOAD BAY

- o Purge Gas Flows in Excess of (TBD) Orbiter Flow Limits
- o Reactant or Corrosive Fluid Discharges
- o During EVA

PAYLOAD DEPLOYED ON SAMS

- o Propulsive Venting in Excess of SAMS Loads or Moments (TBD)
- o During SAMS Release or Retrieval Operations
- o During EVA

Payloads deployed on the SAMS will have been disconnected from any vent plumbing in the bay. Unless the payload includes nonpropulsive vents, payload venting would produce forces and moments on the SAMS that could negate the SAMS movements. Vent forces, if excessive, could overload the SAMS even to the point of structural damage to the SAMS. Denial of payload venting while deployed on the SAMS for these reasons as well as to eliminate payload tipoff motions at release or capture appears to be reasonable. It may be difficult as the SAMS attach period is prolonged and when the Orbiter moves from sun to Earth shadow.

Payload venting denial during EVA operations, particularly where EVA is conducted close to the payload, is a reasonable requirement. The payload may have to have plumbing venting to allow venting during nearby EVA activity.

E.3 SHUTTLE ABORT PAYLOAD VENT

In achieving the objectives in a Shuttle abort case of Shuttle successful mission termination in which the crew, the Shuttle and the payload remains intact, the desirability of payload venting during abort can be an important consideration. The continuation of payload continuous or unscheduled venting has the potential of releasing hazardous gas. In the case of substantial venting through propulsive vents, there is also a risk of impacts on Shuttle controllability. A third impact could occur where substantial internal bay venting exists which when added to in-flowing atmosphere results in an internal pressure buildup with the possibility of exceeding the bay doors structural limits.

There are several payload differences in the Shuttle abort operations as compared to normal Shuttle reentry, de-orbit and landing. The payload fluids are largely or completely consumed in the course of a normal mission.

The result is that payload venting is infrequently involved on landing and in some cases can be a negative vent condition where atmosphere or a purge gas is entering the payload tanks. Shuttle abort usually connected with a launch malfunction is normally faced with a payload with full load of fluids and possibly a maximum vent flow rate condition with limited ability to limit or deny venting.

The full fluid tanks can result in payload weights in excess of normal Shuttle landing capabilities, in payload tanked weights that present reduced design safety factor conditions when exposed to abort and landing loads with the increased risk of payload structural failure, or in a payload C.G. location that is marginal or even unsafe for normal Shuttle landing maneuvers. These factors plus general prudential practice which calls for offloading all possible tanked fluids in abort results in a payload major fluid dump operation on orbit to reduce payload hazards to the Shuttle and to itself.

Some payload venting can then give way to some fluid dump. The propellants in propulsive stages in payloads are major dump candidates. Reducing pressure on high pressure storage systems is also desirable. The payload fluid dumps are constrained by available dump time, and allowable types of fluid dumps. The Space Tug concept recommends LOX dump but retains the LH_2 because of the much lower hydrogen structural loads and the longer times for hydrogen dump. The LH_2 vent is a continuing need and can be a major vent item. There has also been a concern about hydrogen dump in the sensible atmosphere, below 100,000 feet, with the burn/explosion risk. Hydrogen dump recirculation flow and possible ingestion into Orbiter voids has also been considered.

The possibility of large quantity propellant dumping during abort can emphasize the need for minimized propulsive dump/vent reactions or its limitations to longitudinal propulsive reactions. This vent/dump exit is Shuttle designed, however it may impact the payload as dump line length increases.

Venting during abort implies that venting will occur in the sensible atmosphere with in some cases high temperature orbiter skin conditions and flow fields at vent outlets that can dictate the Orbiter surface impingements of the vented fluids. Launch venting with fluid lockup until clear of the sensible atmosphere as in the case of the Tug LH_2 lockup, probably cannot be duplicated for the abort and landing phases due to the extended time period as well as the higher payload temperature environments. The maximum of payload fluids dumping even down to a partial tankload followed by a residual tank lockup to deny venting until on the ground appears to result in reduced risks in abort. The denial of venting during abort for those payload fluids that are not dumped is likewise desirable in order to reduce the payload active interactions with the Orbiter.

This schedule of non-vent operational periods can in some cases be a direct confrontation with the general Shuttle safety directive that all payload pressure vessels shall have pressure relief systems. There are in many cases similar pressure vessels in the Orbiter for which corresponding solutions will be needed.

E.4 PAYLOAD VENTING REQUIREMENTS

Most payloads have venting requirements during the Shuttle mission and within the mission mode the amount of venting on each mission is appreciable. The present Shuttle payload conceptual solutions for venting are only in the formative stages. The Table E-6 venting direction from the Shuttle Program is needed for payload conceptual definitions.

TABLE E-6

SHUTTLE CRITERIA FOR PAYLOAD VENTING

- o Definition of Pressure Vessel Criteria
  - Where Pressure Relief and Venting is Required
  - Where No Pressure Relief and No Venting is Required
  - Payload Caution and Warning Requirements, Diagnose Capability and Controls for Pressure Vessels
- o Definition of Vent Fluid Acceptability
  - No Quality Restrictions
  - Quality Restrictions
  - Quantity Restrictions

    Free Flows
    Piped Flows
    Bay Doors Closed
- o Operations Mode Vent Limitations
  - Prelaunch
  - Launch
  - Abort
  - Orbit
  - SAMS
  - EVA
  - Deorbit/Re-Entry
  - Post-Landing
- o Vent Outlet Limitations
  - Free Flow
  - Piped Flow

    Location
    Type of Vent
    Mission Mode Limitations
- o Payload Bay Vent System Interfaces
  - Piping Raceways

    Location/Size
    X Direction, YZ Direction
  - Wall Location/Size
  - Overboard Outlet

    Location/Size
    Features
  - Bay Liner Fluid Barrier

Appendix F

PAYLOAD PLACEMENT AND RETRIEVAL ANALYSIS

This task consists of the study of payload placement and retrieval operations from the Orbiter. The analysis includes examining the payload requirements and their comparison with the Shuttle capability. Two placement systems were examined, the Manipulator SAMS and the Swing Table (or Tilt Table) placement systems. Both active and passive satellite stabilization systems were considered in determining what payload tip-off disturbances can be tolerated.

Payload requirements upon release from the Orbiter placement system include the payload attitude reference and stabilization accuracy. The residual disturbances in the payload after release, the tip-off rates and dynamic transient overshoot characteristics and payload constraints were determined. The Shuttle performance characteristics were defined consistent with the current Shuttle interface specification.

The relative desirability of the manipulator arm, SAMS and the swing-table placement systems were examined compared to their payload placement and retrieval capabilities. Payload retrieval concept features were analyzed to determine if the offered Shuttle characteristics are adequate for the needed payload services.

The payload may expect to experience much lower tip-off disturbances from Shuttle departures, as much as 1/3 to 1/5 of those disturbances possible in the present expendable Launch Vehicles. This is partially due to the large mass and low impulse of the orbiter and partially due to the low force, moment acceleration and velocity performance of the manipulator SAMS. Likewise, the payload retrieval by the orbiter allows "soft docking" for much the same reasons. "Hard docking", the drawing of the shuttle into the Payload and capturing and latching by impulse systems is a contingency operation and should be no more severe than the previous CSM docking. The full extent of the soft docking performance is not reflected in the basic shuttle specification so that its feasibility is unclear.

The Swing Table Payload extension system is a more positive Payload manipulation system than the SAMS. Although its dexterity is much less than the

SAMS, the Payload extension and Restow functions are more positive. The extension rates and the features for hard docking are more flexible with much more growth potential than the SAMS.

The SAMS performance with large payload involves substantial elapsed times for Payload Placement and other payload movements. Payload Safe Separation from the Orbiter can also require extended elapsed time after payload release.

F.1 PAYLOAD PLACEMENT AND RETRIEVAL

For shuttle delivery, there is a basic need to place a payload in a specified orbit within some tolerance of altitude, orbit inclination, and orbit eccentricity, Table F-1. A few payloads are critical and require accurate orbit location and accurate position time. These usually involve propulsive stages and later flight maneuvers.

Payload attitude and sometimes reference platform and tracker lock-on are desired. Attitude for the gravity gradient stabilization vehicles is important.

Payload residual motions at release include disturbances which may produce tip-off rates in excess of payload recovery capability. Other intentional disturbances include payload separation velocities, and, in some cases, payload rotation for stabilization.

The residual motions become important when the elapsed time to payload activation is extensive. An inertial drift payload with even low angular velocity can change, and even rotate, if a large separation distance is desired for safety before payload activation.

As an example the simulation analysis of the LST Spacecraft to determine the sizing adequacy of the attitude control system considered the capability of the spacecraft to recover from a worst case tip-off condition of 3 degrees per second about each axis. As the RCS system removes the tip-off momentum and returns the Spacecraft to its critical attitude, peak angular excursions were 10, 28 and 66 degress about the roll, pitch and yaw axes respectfully. The total time for the system to converge for this worst case tip-off momentum

TABLE F-1
PAYLOAD PLACEMENT OBJECTIVES

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ORBIT: ALTITUDE - INCLINATION - ECCENTRICITY
ORBIT LOCATION: TRUE ANOMALY - TIME

PAYLOAD ATTITUDE: AXIS DIRECTIONS - STAR/SUN LOCK ON - EARTH HORIZON LOCK ON

PAYLOAD RESIDUAL MOTIONS
- DISTURBANCES
  - RESIDUAL RATES EACH AXIS EACH DIRECTION
- SEPARATION VELOCITIES
  - PAYLOAD FROM ORBITER
- ROTATION
  - STABILIZATION

PAYLOAD ELAPSED TIME TO ACTIVATION
- SEPARATION DISTANCE FOR
  - FUNCTIONAL ACTIVATION
  - SAFE ISOLATION FROM ORBITER

was 3 minutes. There was no loss of reference due to gyro separation; however, the RCS burn was initiated immediately after Spacecraft release. Had there been a wait period of several minutes, there would have been several revolutions of the Spacecraft. Tipoff rates of 3 degrees per second are over an order of magnitude greater than those expected from the Shuttle. Nevertheless, a prolonged wait after release before activation can be significant.

F.1.1 Mission Model Activity 1979-1990

An examination of the March 1973 Mission Model (excluding the DOD missions and the Sortie Lab Missions) shows that payload placement and retrieval has a high-frequency occurrence.

In payload placement, 363 missions involved one or more payload placements, Table F-2. Over a third of the missions were payload deliveries into low-earth orbit while the remainder were propulsive stage and satellite deliveries to low-earth orbit. These stage plus satellite missions included one third with the Tug and the other third divided between the Centaur stage and the Agena stage operating in an expendable mode. The peak year of placement

TABLE F-2

MISSION MODEL ACTIVITY 1979-1990
NASA TM X-64731, MARCH 1973

40454

DOES NOT INCLUDE SORTIE LAB MISSIONS OR DOD MISSIONS

PAYLOAD PLACEMENT (363 MISSIONS) PEAK YEAR 1985 - 44 EVENTS

- LOW EARTH ORBIT	37.5% OF MISSIONS
- SATELLITE PLUS STAGE	62.5% OF MISSIONS
• CENTAUR	12.4% OF MISSIONS
• AGENA	16.1% OF MISSIONS
• TUG (1985 INITIATION)	34.0% OF MISSIONS

PAYLOAD RETRIEVAL (237 OF 363 MISSIONS) PEAK YEAR 1989 - 39 EVENTS

- LOW EARTH ORBIT	31.5% OF MISSIONS
- TUG	33.9% OF MISSIONS
- NO PAYLOAD RETRIEVAL	34.6% OF MISSIONS

activity occurs in 1885 with 44 events for that year.

Payload retrieval missions occur for two thirds of the placement missions because not all satellites are recovered and because the expendable Centaur and Agena stages are not planned for retrieval.

The payload retrievals are about evenly divided between payloads in low Earth orbit retrievals and Space Tug retrievals. The Tug retrievals include some Tug-only retrievals and other Tug and satellite retrievals.

Payload placement and retrieval operations occur in a majority of the Shuttle missions and therefore are an important operational factor for which adequate Shuttle performance must be provided.

Future mission models can be expected to vary in number of missions as well as types. Even if there is a significant shift toward Sortie Lab missions, the NASA placement missions coupled with the omitted DOD missions which are heavily payload placement and retrieval oriented, should more than balance

NASA emphasis shifts. Placement and retrieval is a fundamental part of the Shuttle transportation concept.

F.1.2 Placement and Retrieval Classes

The four payload classes being studied in SOAR-IIS (Table F-3) all involve payload placement and retrieval except for the Sortie Module class missions.

The low Earth orbit EOS missions are transporting spacecraft that now utilize Titan IIIC and Delta Launch Vehicles. Their requirements of the Shuttle would be to not exceed the residual motions of these earlier launch vehicles.

The Tug, Class II, delivers and retrieves the ATS, the DSCS-II and the SMS satellites. Although the Tug can tolerate large disturbances at release, the rotational loads on the satellite attached to the Tug cannot tolerate large disturbances. In fact even the small disturbances such as satellite tip-off from the Tug may be marginal when the same Tug from Shuttle disturbance occurs due to the large satellite radius of gyration while Tug is attached.

The LST spacecraft generaly has self stabilization capabilities; however, the structural nature of the large telescope would dictate as low a residual disturbance as practicable upon LST release.

The three mission classes all involve active guidance payloads with a built-in degree of self recovery. The LDEF payload on the other hand with its passive stabilization system has definite limits as to the maximum disturbance from which it can successfully recover.

F.1.3 Historical Tip-Off Rates

Five of the Spacecraft in the Mission classes are currently planned or are flying on present expendable Launch Vehicles. The present maximum tip-off rates that these five Spacecraft could experience are listed below.

ATS-H/I

Ref: ATS-H/I System Feasibility Report, Vol. III, June 1972

- Configuration 'A' is the version preferred by Lewis Research Center

TABLE F-3
PLACEMENT AND RETRIEVAL PAYLOAD CLASS REQUIREMENTS

40453

CLASS		REQUIREMENT
I	EOS	EQUAL TO TITAN IIIC AND DELTA RATES
II	TUG WITH: ATS/ DSCS-II/ SMS	TBD (SATELLITE PLACEMENT BY TUG: DSCS-II TIP-OFF ≤ 0.5 DEG/SEC)
III	LST	TBD
IV	SORTIE MODULE	REMAINS ORBITER ATTACHED
OTHER	LDEF	TBD - PROBABLY LOW, ≤ 0.1 DEG/SEC DUE TO ONLY GRAVITY GRADIENT STABILIZATION

- Titan-IIIC is the selected booster
- Transtage injection errors: Roll 0.75°/sec
Pitch 0.45°/sec
Yaw 0.45°/sec

EOS

Ref: EOS Definition Phase Report, GSFC, August 1971

- Titan-IIIC for larger versions of EOS: Roll 0.75°/sec
Pitch 0.45°/sec
Yaw 0.45°/sec
- Delta 2910 for smaller versions of EOS: Roll 3°/sec
Pitch 3°/sec
Yaw 3°/sec

Note: The GSFC Study (p. 7-12) says that the ACS performs "acquisition of the desired earth-pointing orientation from any initial attitude, with initial rates of a few degrees per second".

SMS

100 RPM rotation rate prior to Tip-off

- Delta 2914

Injection accuracies for the Delta 2914 are quoted at 3° half-cone angle.

DSCS-II

- Titan-IIIC deploys both spacecraft: Roll 0.75°/sec
  Pitch 0.45°/sec
  Yaw 0.45°/sec

- Upon activation of the separation devices, compressed springs will impart a velocity to the satellite, relative to the transtage, of 1 ft/sec minimum. The torque-impulse of the separation springs shall be less than 35 in-lb-sec total in pitch and yaw combined with respect to the transtage longitudinal centerline. (Ref: IFS-STC-23100)

LST

Ref: LST Preliminary Study, MSFC, 25 February 1972 (p. 23)

- Titan-IIIC is considered for purposes of the Phase-A Study Roll 0.75°/sec
  Pitch 0.45°/sec
  Yaw 0.45°/sec

F.1.4 Shuttle Payload Placement

The major elements in payload placement include the payload deployment out of the payload bay, the payload release, and the payload separation from the Orbiter, Table F-4.

The Orbiter systems require time to complete the deployment, time to stabilize to the no-disturbance conditions for release, and planned operations for separation from the payload. In addition, there are associated events that can occur during or at the end of each placement.

These payload events may occur concurrently with the Orbiter events or in some cases they may need added time. Consequently, the total placement phase could become an extended-duration activity.

The Shuttle baseline concept involves the manipulator, SAMS, and withdrawal of the payload from the payload bay to the release position. Then, the SAMS releases the payload and the Shuttle RCS translates and rotates the Orbiter from the payload.

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TABLE F-4
SHUTTLE PAYLOAD PLACEMENT

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EVENT	SCOPE	ASSOCIATED EVENTS	BASELINE DEPLOYMENT CONCEPT
PAYLOAD DEPLOYMENT	FROM: PAYLOAD LATCHED IN PAYLOAD BAY TO: PAYLOAD READY FOR RELEASE	PAYLOAD: – ACTIVATION – EARTH LINK – STAR LINK – READINESS CHECKS	SHUTTLE MANIPULATOR
PAYLOAD RELEASE	FROM: PAYLOAD READINESS PLUS SHUTTLE READINESS TO: PAYLOAD RELEASE FROM SHUTTLE	SHUTTLE: – STABILIZATION – POINTING – UNLATCHING PAYLOAD: – STABILIZATION – RESIDUAL MOTIONS	MANIPULATOR UNLATCH
PAYLOAD SEPARATION FROM SHUTTLE	FROM: MOMENT OF RELEASE TO: SAFE SEPARATION DISTANCE FOR ACTIVATION OF PAYLOAD SYSTEMS	SHUTTLE: – CONTROL OF RCS EFFLUENTS – CONTROL OF OVER-BOARD DISCHARGES PAYLOAD: – CONTROL OF EFFLUENT IMPACTS ON SHUTTLE – CONTROL OF HAZARDOUS PAYLOAD SYSTEMS	ORBITER RCS TRANSLATION AND ROTATION FROM PAYLOAD

F.2 PAYLOAD PLACEMENT

Payload deployment for small payloads can be simple and timely; however, payloads that fill the entire 15 foot by 60 foot allowable envelope, and the full 65,000 pounds, require sequential planned movements in order to control and prevent undesired payload contact with the Orbiter or with the SAMS, as shown in Figure F-1. The payload vertical motion (1) of 8 feet will allow the SAMS to rotate the payload in the YZ plane through 180 degrees to the (2) position. The SAMS can then rotate 150 degrees forward to place the SAMS end effector directly over and 30 feet above the orbiter cockpit position (3)

This release and capture position for the payload is achieved after about 29 minutes for the SAMS full-load performance accelerations and velocities. The time may be shortened if step (3) and the last half of step (2) are simultaneously performed if the SAMS can do that (not specified in the documentation).

FIGURE F-1
PAYLOAD DEPLOYMENT
BASE LINE SAMS

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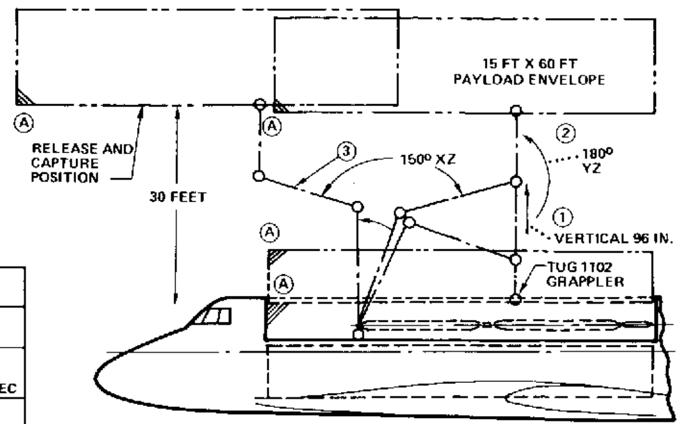

①	②	③
Z = 8 FT	YZ = 180°	XZ = 150°
VMAX 0.2 FT/SEC	0.2 DEG/SEC	0.2 DEG/SEC
1.2 MIN	15.2 MIN	13 MIN
TOTAL TIME TO DEPLOY 29.4 MINUTES		

F.2.1 SAMS Payload Deployment

The total deployment described in the previous figure involves a two-step payload withdrawal from the payload bay as indicated by Figure F-2. The payload cylinder is vertically withdrawn from the payload bay for a little over 8 feet, position a to e. The SAMS wrist can then rotate the payload cylinder to the side opposite the SAMS and clear of the bay door hinge line, f to h. This rotation continues for 180 degrees to clear the fore and aft bay bulkheads and remain clear of the SAMS. The SAMS end effector is located at the Space Tug grappler fitting in the previous figures at Tug station 1102. Other payloads with more forward grappler fitting locations will reduce the SAMS potential interference up to some point. The proximity of the SAMS to the payload path as it clears the bay introduces a degree of awkwardness for most payload grappler locations unless the payload volume is small.

F.2.2 Payload Micro-Separation

Once the payload has been deployed and the payload, the SAMS and the Orbiter motions are minimized, the SAMS grappler unlatches from the payload, which

FIGURE F-2
SAMS PAYLOAD DEPLOYMENT

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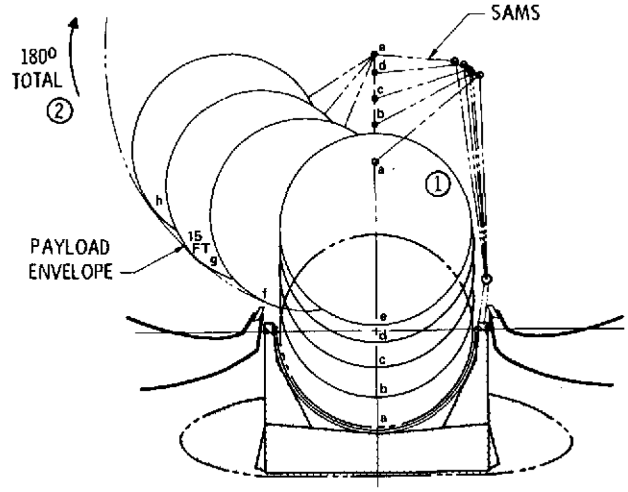
①	②
Z = 8 FT	YZ = 180°
V_{MAX} 0.2 FT/SEC	0.2 DEG/SEC
1.2 MIN	15.2 MIN



remains in an inertial drift mode, Figure F-3. The SAMS unloaded velocity after separation can attain 2 feet per second. Once the grappler is clear of the payload skin, the SAMS can begin rotation back into the payload bay. Unloaded, it can reach 2-degrees-per-second rotation.

The payload position relative to the Orbiter remains at the 30-foot separation established by the movements during deployment. The payload has no impulse loads applied except for the disturbances that occur at grappler release.

F.2.3 Payload Macro-Separation

After the SAMS micro-separation from the payload described in the previous figure, a second phase of separation is initiated when the Orbiter thrusts backwards (-X) with its RCS, Figure F-4. The duration of this thrusting will determine the Orbiter separation velocity and the speed of separation from the payload. An example of a 10-second burn for the Orbiter to reach a velocity of 2 feet per second would force back the Orbiter 90 feet in 50 seconds. This velocity and the 10-second burn may be in excess of the desired payload contamination risk.

FIGURE F-3

PAYLOAD MICRO-SEPERATION

BASELINE WITH SAMS

40464

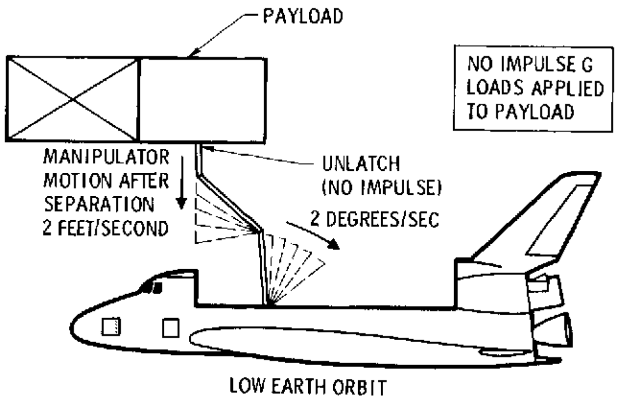


FIGURE F-4

PAYLOAD MACRO SEPARATION

BASE LINE WITH SAMS

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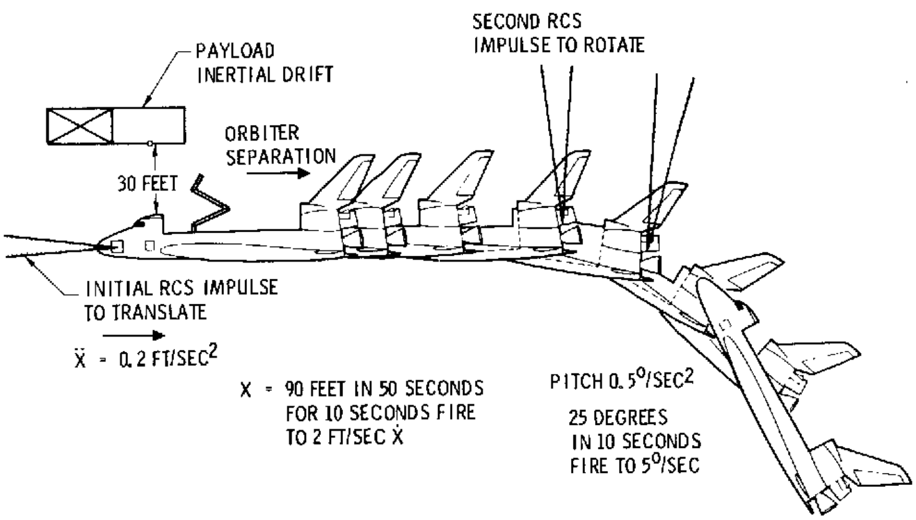

After the Orbiter has backed off a distance, a second RCS thrust in the Z direction will pitch the Orbiter and allow other RCS thrusting away from the desired payload and Orbiter maneuvers. Earlier studies indicated that a separation of 1,500 feet would be nominal before full activation of the payload. However, activation of payload RCS thrusters for coarse stabilization may be feasible earlier and at a much closer separation distance.

The on-orbit relationships between the Shuttle and its payload and the factors that would influence these relationships and the effects they might have at varying separation distances in low earth orbit are shown in Figure F-5. Considering the effects of each parameter in toto suggests a separation range of 1,500 ft for such activities as escort, checkout, testing, or loitering, and the following payload Propulsion system activation.

F.2.4 Payload Disturbing Motions

The Residual Motions of the Payload in its free-in-space conditions is one factor that determines how successful the Payload will be in the next phase of its operations. Payload Tip-off normally is characterized by roll rates about its axis, i.e., angular velocities, linear velocities can also be involved; however, the angular rates denote a possible tumbing state and one that requires attitude stabilization to correct. The linear velocities relatively small - only become of interest as separation velocities, or when associated with propellant settling accelerations, and both of these conditions involve from one up to five feet per second payload velocity differential which requires an impulse system - normally a spring or a stored energy device. These velocities are then not residual or error motions but distinct performance conditions.

Definitions of Payload Tip-off, Table F-5, include Payload Release Tip-off as well as Payload capture Tip-off situations.

F.2.5 Payload Tip-Off at Payload Release

Disturbing motions imparted to the payload at payload release by the SAMS (tip-off) can be traced to several motions. Basically, the Orbiter's instability can influence the entire system up to the point of payload release. Assuming that the Orbiter's RCS thrusters are maintaining attitude, the 900

34982

FIGURE F-5
SHUTTLE/PAYLOAD ESCORT (ORT) RANGE

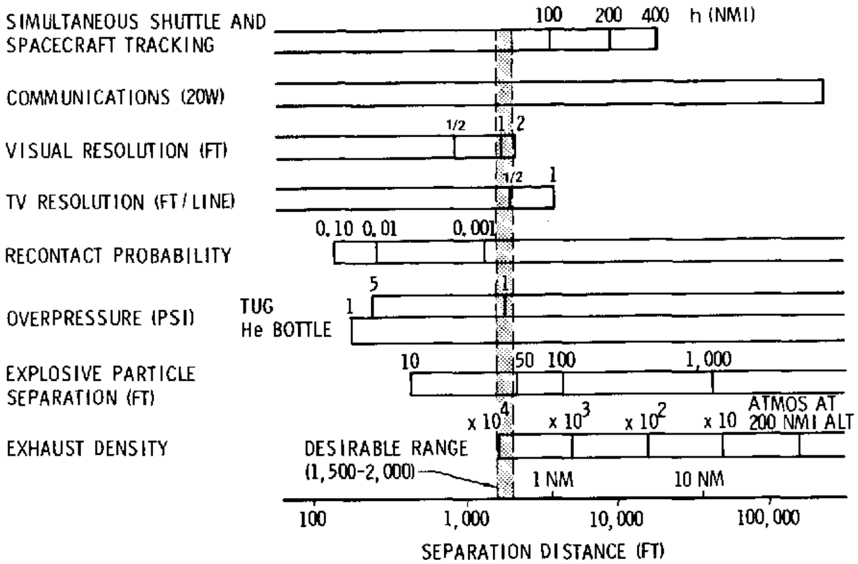

TABLE F-5
PAYLOAD TIP-OFF CONDITIONS

- PAYLOAD TIP-OFF

  PAYLOAD TIP-OFF IS THE RESIDUAL DYNAMIC CONDITION BETWEEN THE ORBITER AND THE PAYLOAD THAT INVOLVES PAYLOAD MOTION DISTURBANCES THAT IF UNLIMITED COULD LEAD TO UNCONTROLLED PAYLOAD MOVEMENTS (THE PAYLOAD BEING THE PASSIVE AND THE ORBITER THE ACTIVE VEHICLE)

- PAYLOAD RELEASE TIP-OFF

  RESIDUAL MOTIONS OF THE PAYLOAD AT SEPARATION FROM THE ORBITER (MANIPULATOR, TILT TABLE, OR DOCKING FITTING) THAT HAVE THE POTENTIAL OF PAYLOAD TUMBLING, OR OF PAYLOAD COLLISION WITH THE ORBITER

- PAYLOAD CAPTURE TIP-OFF

  RESIDUAL MOTIONS OF THE PAYLOAD AT INITIAL CONTACT AT THE DOCKING FACE OR CAPTURE FACE OF THE ORBITER (MANIPULATOR, TILT TABLE OR DOCKING FITTING) THAT HAVE THE POTENTIAL OF PAYLOAD JACK-KNIFING WITH THE ORBITER, OR OF PAYLOAD FAILURE TO COMPLETE THE CAPTURE ENGAGEMENT AND STROKE THE ATTENUATION SYSTEM pound thruster (baseline can hold 0.1 degree per second) and the 25 pound thrusters can reduce this to 0.01 degree.

The SAMS dynamic excitation could be a source of significant motion due to its limited stiffness. The excitations that lead to SAMS motion can be responses to Orbiter RCS firing or other Orbiter vibrations. The SAMS drive or braking motions can also contribute. SAMS structural distortions due to thermal changes and payload dynamic forces are also possible contributors to motion.

A separate source of motion excitation is the forces generated by opening the SAMS grappler jaw. The frictional forces of the jaw release and the effect of a one jaw hang-up could tip off the payload, Figure F-6.

Should the end effector be required to impart a separation velocity to the payload as is now specified in the Shuttle requirements, payload velocities of from 1 foot per second to 5 feet per second can represent substantial stored energy devices. SAMS design concepts do not now provide these payload separation velocities and should they be provided, the payload accelerations will need to be restricted so as not to exceed the forces or moment structural limits of the SAMS.

The residual motions of the payload will reflect these various sources. The resulting motion is generally meaningful to the payload in terms of inertial space for conditions occurring from payload release to free flight. Another motion reference can be important. The payload motion relative to the Orbiter immediately after release will indicate the risk of subsequent undesirable payload-Orbiter impact.

F.2.6 Constraints in Payload Release Tip-Off

The desired limits of payload tip-off motion are generally agreed to be 0.1 degree per second on any axis and 0.1 foot per second for a soft separation involving only inadvertent disturbing motions. On the other hand, specific payload separation velocities considered to be hard-separation conditions could be 1 foot per second for simple separation and up to 5 feet per second where payload propellant settling is desired, Table F-6.

FIGURE F-6
ELEMENTS OF PAYLOAD TIP-OFF AT PAYLOAD RELEASE

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RESIDUAL RATES IMPARTED TO DEPLOYED PAYLOAD BY SAMS

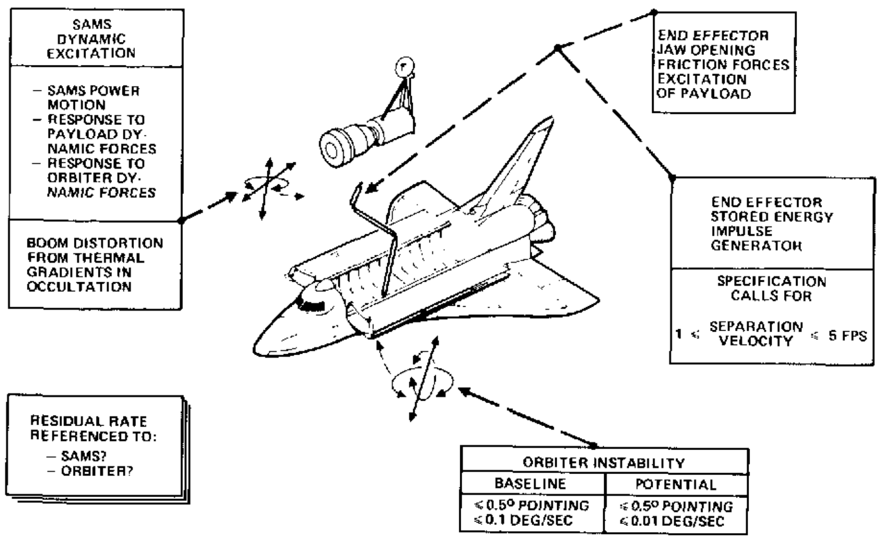


TABLE F-6

CONSTRAINTS IN PAYLOAD RELEASE TIP-OFF

- SOFT SEPARATION	< 0.1 DEG/SEC < 0.1 FT/SEC	HARD SEPARATION	< 1.0 DEG/SEC < 5.0 FT/SEC
- SHUTTLE SPECIFICATION	VOLUME X	< 0.75 DEG/SEC, SEPARATION VELOCITY ≥1≤5 FT/SEC	
	VOLUME XIV	< 0.10 DEG/SEC, SEPARATION VELOCITY ≥1≤5 FT/SEC	
- OPENING VELOCITY	o VEHICLE SEPARATION: 1.0 FT/SEC o VEHICLE PROPELLANT SETTLING: 5.0 FT/SEC		
- RELEASE ACCELERATION	< 0.1 FT/SEC^2	PERMITS SATELLITE BOOM, ANTENNA AND PANEL DEPLOYMENT BEFORE SEPARATION	

The 0.75 and 0.15 degree per second rates remain to be settled. Also, a clear distinction should be made between the disturbance limits and the intentional separation velocities, the 1 and 5 feet per second.

Payload accelerations limits at the moment of release are useful to ensure that the payload structure is adequate. An acceleration of less than 0.1 foot per second^2 is generally used. This permits payload booms and panels to be deployed at separation.

Payload residual motions after release, if excessive, can make the payload a difficult target in the event that the Orbiter captures the payload.

In general, the relatively low acceleration capabilities of the SAMS and the low acceleration capabilities of the Orbiter RCS indicate that even with intentional SAMS movements and Orbiter thrusting, the motions of the payload will be modest and residual motions - disturbances - likewise will be modest.

F.3 SWING-TABLE PAYLOAD DEPLOYMENT

The baseline Shuttle Payload Deployment system, the Manipulator SAMS described in the previous Sections, performs the basic functions of extending the payload out of the bay and releasing the payload. In the Payload retrieval mode, the SAMS captures the payload and stows the payload in the bay for earth return. There are a number of other possible functions and services suggested for the SAMS including payload services and shuttle services; however, the basic payload placement and retrieval functions are the justification for the SAMS. Other payload placement and retrieval concepts or the lack of such a payload need are possible and are recognized by the SAMS feature that allows the arm to be removed and not flown for selected missions.

The most frequently suggested concept in lieu of the SAMS is the Swing Table or Tilt-table, which can totally replace the SAMS fundamental services, or can be used in conjunction with SAMS as is presently proposed for the Space Tug. The Tilt table offers two improved services over the SAMS, one is the ability to retain significant umbilical connections with the Payload up to the point of separation from the Tilt table. The second is the greater structural capabilities (and alignment) and the more expeditious movement of the Payload out of and into the bay. The Tilt table provides essentially a "hard mount" for the payload to the Shuttle both in the bay and extended out of the bay. Two general tilt table approaches have been proposed. Figure F-7, where one is mounted in the forward end of the bay and other is mounted in the aft end of the bay. A third tilt table concept for smaller payload could be considered in conjunction with a Payload pallet such as drawn in Figure F-8. Tilt table detailed features such as manned pressure tunnels, docking mechanisms, large load capabilities and the angular movement, 90, 50, 45 degrees all relate to specific payload, mission and operation needs.

F.4 SPACE TUG TILT TABLE

The present space tug concept uses an aft tilt table that utilizes the SAMS to pick the tug off of the table. The lowest figure option of the options shown in Figure F-9. The SAMS also remounts the tug to the table on retrieval. The table thus only provides tug latch/unlatch functions and structurally only need to pivot the tug in and out of the bay. The SAMS tug attachment removes any tug-table docking/redocking functions. Therefore tug release and capture is performed by the SAMS in the shuttle baseline mode. Other concepts using tilt tables without the SAMS involve release and separation from the payload such as shown in Figure F-10. Although a payload unlatch from the tilt table and an orbiter "fly-away" from the inertially drifting payload, or the opposite mode, where the payload could fly-away from the orbiter is possible, present separation techniques suggests that the tilt table impart a separation velocity of about one foot per second to the payload at release from the tilt table. The SAMS concept thus involves "soft release" and a passive payload where virtually no payload release tip off disturbances appear to be possible.

The Non-SAMS release probably involves a "hard release" with the potential of greater residual tip-off disturbances.

F.5 ELEMENTS OF SHUTTLE PAYLOAD RETRIEVAL

Payload retrieval is based upon a sequence of events in which the payload and the Orbiter initially perform readiness and gross location actions. Thereafter, the Orbiter is the active element and the payload is a passive, cooperative target, Table F-7. The relative separation of the two are closed to 30 feet for this baseline concept. The SAMS is then brought up to the payload

FIGURE F-7

SWINGTABLE AFT MOUNTING ATTACH POINTS

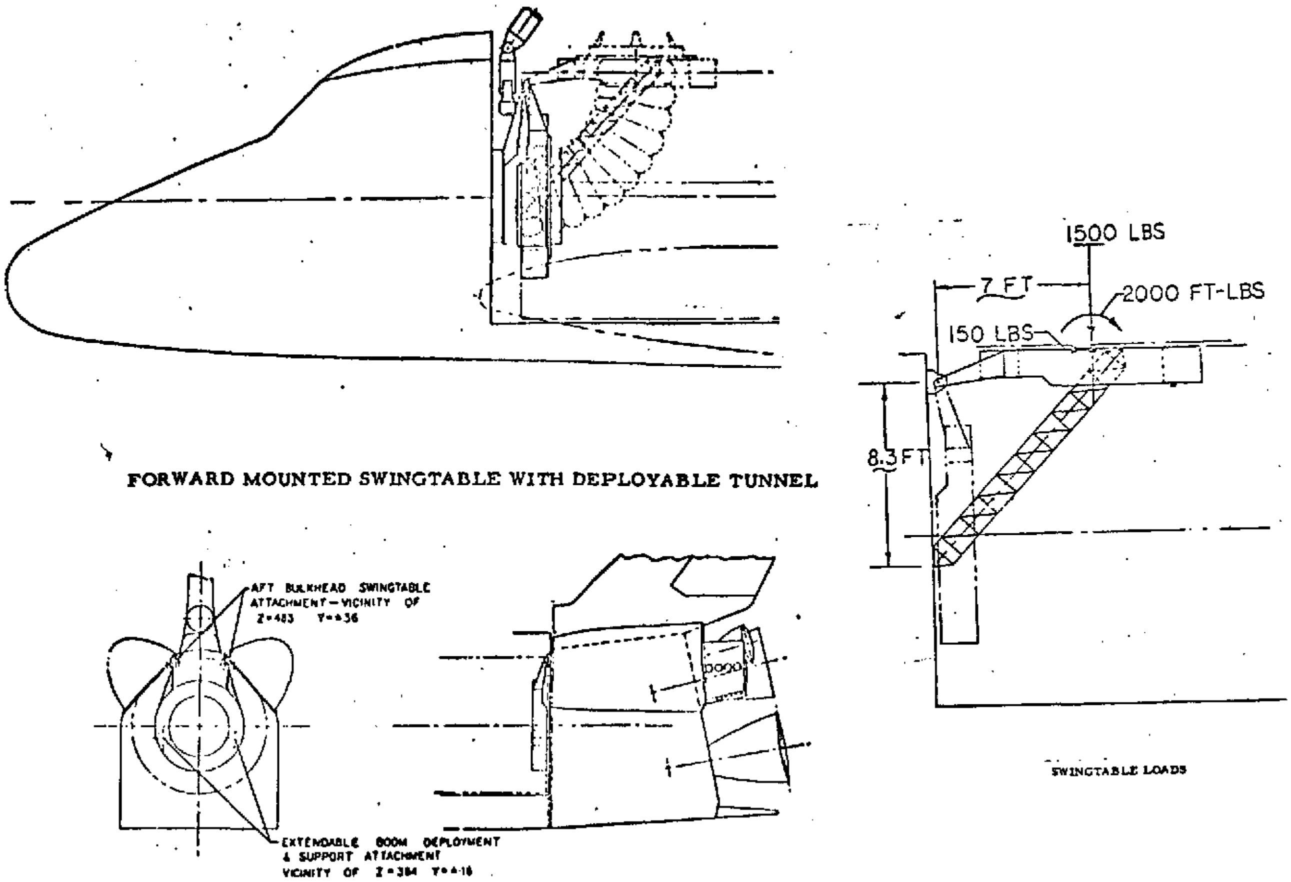


FIGURE F-8

PALLET SWING TABLE

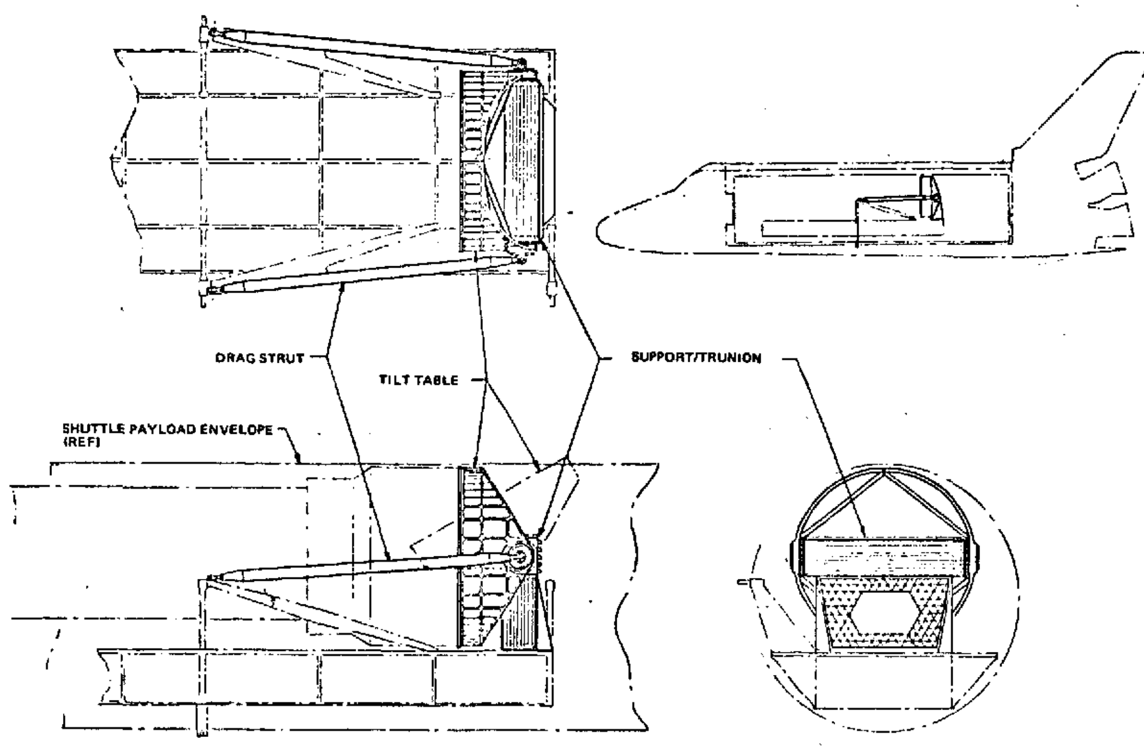
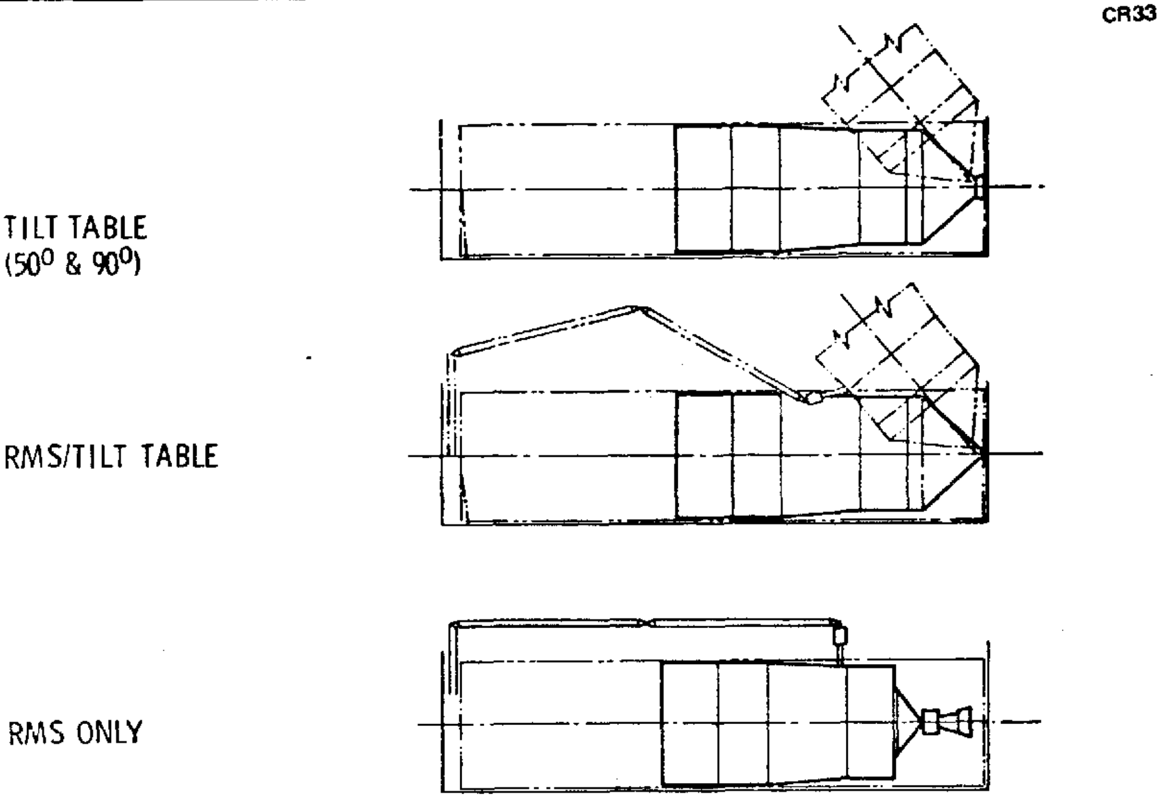


FIGURE F-9

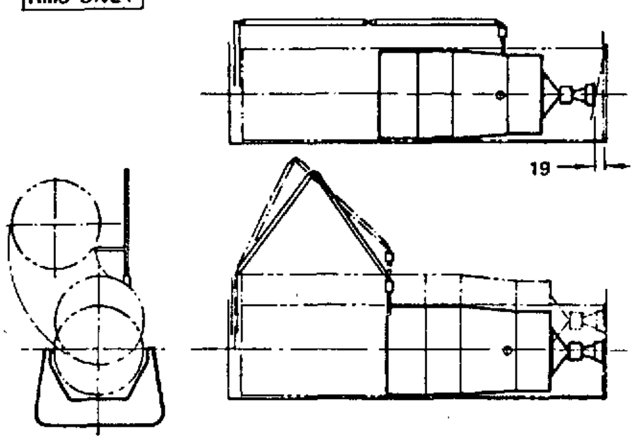
MANIPULATOR DEPLOYMENT AND RETRIEVAL OPTIONS



Tug Deployment/Retrieval Concepts

CR3

RMS ONLY



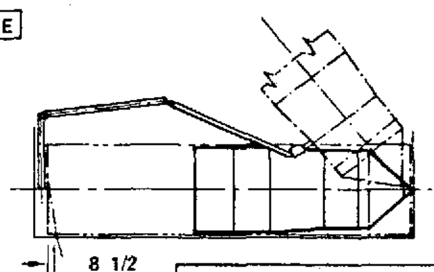
ATTACH AT CG

- PIVOT ABOUT SHOULDER REDUCES P/L LENGTH
- VISUAL INTERFACE IMPAIRED FOR STOWING
- AFT MOUNT OPTIONS
  - ✓ NO ADAPTER – TUG WT PENALTY
  - ✓ ADAPTER – MUST ACCOMMODATE DEPLOYMENT

ATTACH AT FORWARD FRAME

- TRANSLATE TO 6 FT LEVEL AND SWING OUT
- TIP FORCE RESTRICTED TO 7 1/2 LBS BY 150 FT-LB ALLOWABLE TORQUE AT WRIST
- AFT MOUNT OPTIONS (SAME AS ABOVE)

RMS/TILT TABLE



- RMS INTERFACE AT TUG CG
- OPTIMUM PIVOT POINT FOR ROTATIONAL DEPLOYMENT
- GOOD POSITIONAL ACCURACY FOR DEPLOYMENT AND STOWAGE
- ADAPTER SERVES AS TILT TABLE
- GOOD VISUAL INTERFACE

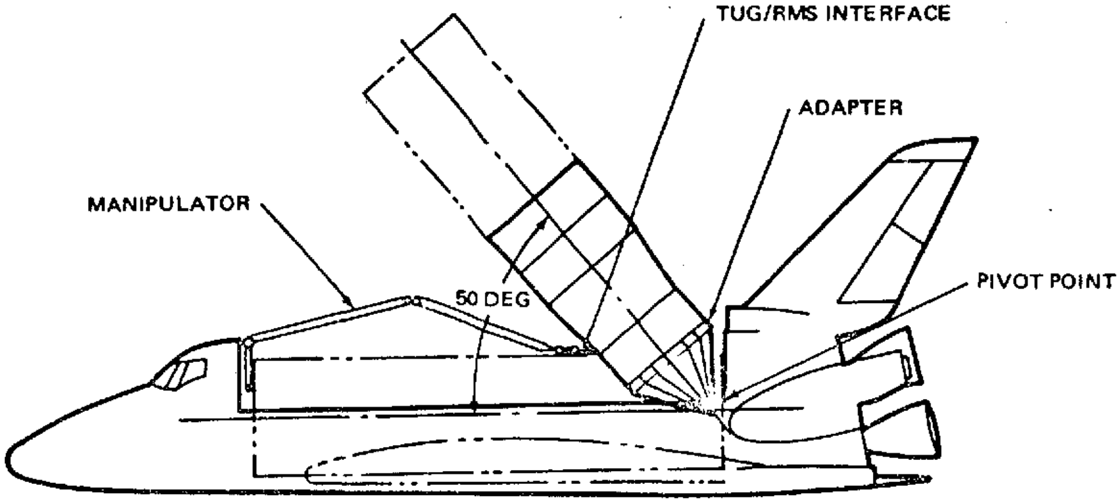
RECOMMENDATION: RMS/TILT TABLE

Manipulator Deployment/Retrieval Options

FIGURE F-10

TILT TABLE RELEASE OPTIONS

CR36



Tug Deployment SAMS RELEASE AFTER TILT TABLE SEPARATION

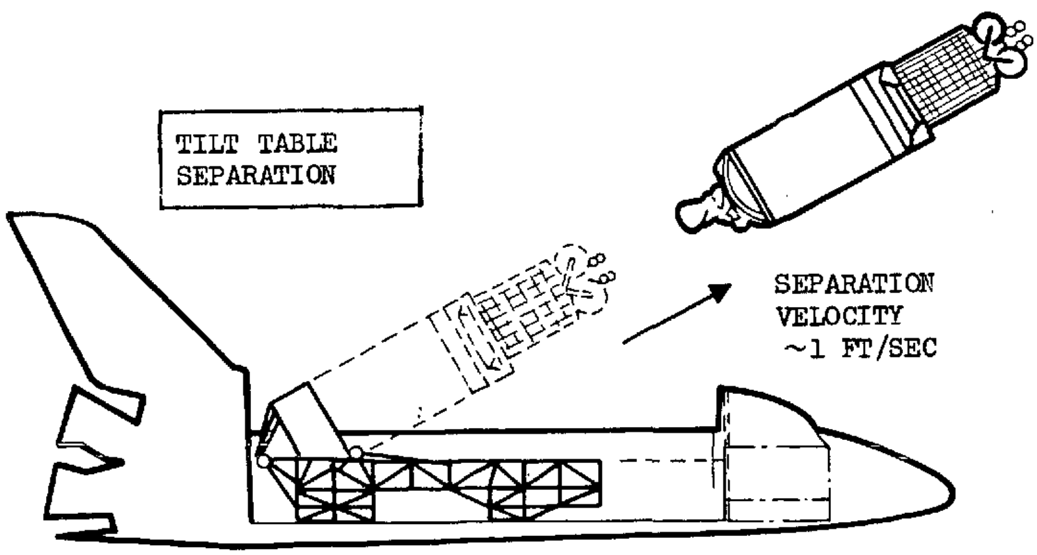


TABLE F-7

ELEMENTS OF SHUTTLE PAYLOAD RETRIEVAL

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EVENT	SCOPE	ASSOCIATED EVENTS	BASELINE RETRIEVAL CONCEPT
PAYLOAD MACRO RENDEZVOUS	FROM: INITIAL PAYLOAD LOCATION (UP TO 24 MILES) TO: PAYLOAD LOCATED WITHIN ONE MILE OF ORBITER	PAYLOAD BEACON, PAYLOAD: – POSITION KEEPING – STABILIZATION – COMMAND LINK – PAYLOAD CONTROL TRANSFER FROM GROUND TO ORBITER ORBITER MANEUVERS	TUG CLOSING ΔV 70 NMI TO 24 NMI ORBITER CLOSING 24 NMI TO 1 NMI
PAYLOAD –READINESS FOR CAPTURE	PAYLOAD: – STABILIZATION – COOPERATION – PASSIVATION	ORBITER: STATUS LINK – READINESS TEST COMPLETION – *FINAL APPROACH TO* 30 FEET	PAYLOAD: SELF SAFING – COMMANDED FROM GROUND – COMMANDED FROM ORBITER
PAYLOAD MICRO RENDEZVOUS	FROM: PAYLOAD ABOUT 1 MI TO: PAYLOAD FITTING 2 FT ENVELOPE	ORBITER: – MANEUVERS TO 30 FT UP TO ONE TENTH FPS	– ORBITER CLOSES 1 MI TO 30 FT – MANIPULATOR CLOSES 30 FT TO 2 FT
PAYLOAD CAPTURE	FROM: ORBITER SYNCHRONIZATION OF PAYLOAD MOTIONS TO: MANIPULATOR TO PAYLOAD ENGAGEMENT AND CAPTURE	ORBITER – 2 FT SPHERE ENVELOPE – ONE 0.01° PER SECOND ERRORS MANIPULATOR – CLOSE AND LATCH	– MANIPULATOR CLOSES 2 FEET
PAYLOAD STATUS READINESS FOR *MOUNTING/STORAGE*	PAYLOAD: – SYSTEMS PASSIVATION *INDEXING* FOR MOUNTS – APPENDAGES STOWAGE – SAFETY INSPECTION	ORBITER: – LIMITATIONS ON MANEUVERS – LIMITATIONS OF MANIPULATOR LOCATIONS	PAYLOAD: – AUTOMATIC SEQUENCING – RF ACCESS – NO HARDWIRE
PAYLOAD MOUNTING IN PAYLOAD BAY	PAYLOAD DE-DEPLOYMENT, MOUNTING AND LATCHING	MANIPULATOR MOTIONS PAYLOAD FSE ACTIVATION	PAYLOAD: – UMBILICALS MATED AFTER MOUNTING

grapple fitting. The Orbiter maintains a very close stationkeeping with this fitting by keeping the SAMS grappler within a foot of the payload fitting. The velocity error of the SAMS grappler to the payload will not exceed 0.1 foot per second and 0.1 degree per second about any axis. Thus, the SAMS is only required to complete its capture within these distance and motion limits - a soft capture.

There are a number of associated events in the various phases of payload retrieval, including the acquisition, capture and subsequent stowage of the payload in the bay.

F.6 PAYLOAD ORBITER CAPTURE

The baseline Orbiter capture operation discussed in the previous section utilizes the SAMS to make a soft capture (dock) of the payload after the Orbiter has closed-to and kept the micro-station on the payload grapple fitting.

Other capture options are possible, Figure F-11, and the hard-docking of the Orbiter to the target payload with the Orbiter docking module installed is a planned alternate for the Shuttle program.

Other studies have suggested concepts in which the tilt table in the payload bay is used as a docking system to capture a target payload. The docking clearances close to the Orbiter would seem to make the concept hazardous; however, if the Orbiter has in fact the payload target micro-stationkeeping capabilities presently being specified, the tilt table docking may be no more hazardous than the SAMS payload insertion into the payload bay.

In a similar concept review, if the Orbiter micro-stationkeeping motion limits are normally maintained in payload capture, the final motion and distance errors that the SAMS must correct in order to complete the capture are so minor compared with the SAMS general motion capabilities that a question arises as to the need for SAMS for payload capture.

Simulation tests have shown that a simpler linear actuator or a boom with small pitch and haw motion can capture a payload target within the specified Orbiter stationkeeping conditions. Except for the SAMS deployment of a payload out of the payload bay and stowage in the payload bay functions, the payload capture supporting equipment can be simplified.

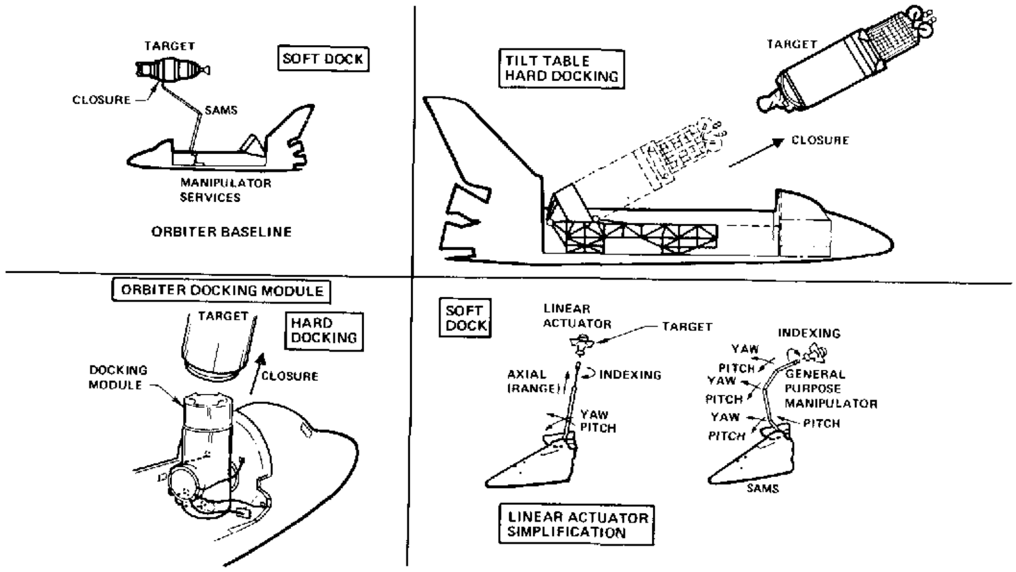
F.6.1 Payload Capture

Some values of target and Orbiter motions during payload capture have been quantified in various Shuttle documents. Other values have been developed in other operations studies. In the hard-docking operation, the allowable misalignments have been listed in earlier Shuttle documents; however, most recent documents have omitted them. Payload motions limits have not yet been published in Shuttle documents.

The stand-off distance of 30 feet that the Orbiter establishes with the target payload in the Shuttle baseline payload capture concept, where the SAMS performs the capture, may be changed with the hard-docking mode. For example, a closer stand-off distance could be considered with the listed Orbiter micro-stationkeeping capability.

FIGURE F-11
PAYLOAD CAPTURE OPTIONS
ACTIVE ORBITER

40481



The soft-docking conditions associated with the baseline payload capture operation where the SAMS completes the capture has performance values listed in various Shuttle documents including the SAMS specification, Table F-8. The Orbiter micro-stationkeeping performance in the SAMS capture mode appear to be demanding on the Orbiter both in the ability to detect target relative position and the relative motions of the Orbiter and the target payload grappler target fitting located at a point 30 feet above the Orbiter cockpit. The SAMS grappler tip may be of some use as a reference when the SAMS has been moved up to the proximity of the target grappler fitting, Figure F-12.

In the SAMS soft docking grapple capture, the inertial drifting Target Motion (Payload Motion) needs to be minimal if the orbiter is to be capable of attaining the Micro-Stationkeeping Performance. The basic orbiter specification does not yet list this Micro-Stationkeeping performance requirement.

TABLE F-8
SPECIFIED SHUTTLE PERFORMANCE

RCS

$\ddot{X}$ 0.2 FT/SEC^2
PITCH 0.5 DEG/SEC^2

ORBITER MICRO-STATION KEEPING(A)

(TARGET 30 FEET ABOVE COCKPIT)

± 1 FT. POSITION ENVELOPE
0.1 FT/SEC RELATIVE VELOCITY
0.01 DEGREES/SEC RELATIVE RATE
± 0.1 DEGREE DEADBAND

STABILITY

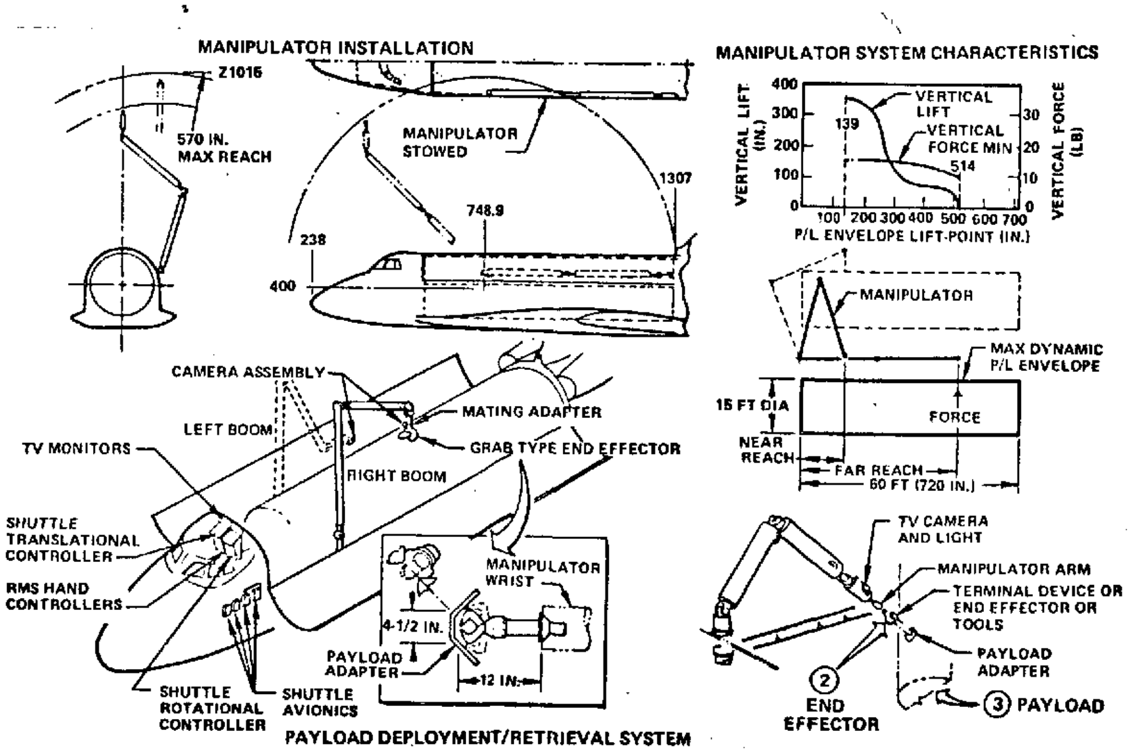
900 LB THRUSTERS
≤ 0.5 DEG POINTING
≤ 0.1 DEG/SEC

25 LB THRUSTERS - VERNIER
≤ 0.5 DEG POINTING
≤ 0.01 DEG/SEC

SAMS(A)	65,000 LBS	UNLOADED
TRANSLATION	0.2 FT/SEC	2.0 FT/SEC
ROTATION	0.2 DEG/SEC	2.0 DEG/SEC
TIP ACCELERATION	0.006 FT/SEC^2	0.6 FT/SEC^2
TIP DECELERATION	0.006 FT/SEC^2	1.25 FT/SEC^2
POSITION ACCURACY	± 2 INCHES	± 2 INCHES
FORCE	10 LBS. MAX.	10 LBS. MAX.
STALL TORQUE	200 FT LBS. WRIST	200 LBS. WRIST
DEFLECTION	0.1 IN/LB TIP FORCE	

(A) SAMS REQUIREMENTS IDRD NO. SE-493T

FIGURE F-12
SAMS-SHUTTLE ATTACHED MANIPULATOR SYSTEM



F.6.2 Payload Capture by Hard Docking

Although the Shuttle baseline involves SAMS capture of the payload under soft docking conditions, an alternate payload capture features are provided when the Shuttle docking module is used. Two modes are possible. One, the baseline SAMS capture and placement on the Docking Module Face and Latch System, and two, the direct Payload docking to the Docking Module without SAMS involvement. This latter mode will require Hard Docking and its characteristics listed in Table F-9. Two features of this Module Harddock system and the Payload latch system have not been published; however, the hard docking conditions, the Engagement Velocities, the Impulse attenuation system stroking values, the Misalignment correcting forces and if involved the latching force would appear to be in excess of the SAMS with Payload dynamics capabilities. It would, therefore, appear that a Two Mode docking system will be involved, one compatible with the SAMS, the other compatible with Hard docking dynamics. Another approach is to install a SAMS Payload Latch ring on the Docking Module or a Harddocking ring for the planned Mission Mode.

F.6.3 Constraints in Payload Capture Tip-Off

Orbiter hard-docking to a payload target places great emphasis on achieving the maximum mating potential with no damage. This involves bringing the docking planes together so that the jackknifing angle is reduced to zero and the rates are reduced to zero, Figure F-13.

There must be sufficient energy between the Orbiter and the payload that will stroke the attenuation system, which normally includes the motion of the payload needed to remove the docking misalignments as well as to arrest the motions.

The energy is expressed as velocities and the motion misalignments can be expressed as lateral velocity ratios and angular velocity ratios. Simulation analyses in other studies have indicated that lateral velocity ratios in excess of 15/100 and angular velocity ratios in excess of 0.1 will maximize the mating potential. The linear contact velocity, V_c, is a major factor in completing the attenuation system stroke.

TABLE F-9
PAYLOAD CAPTURE

40483

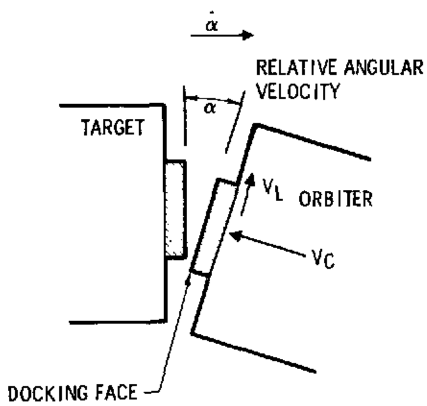
HARD DOCKING	SOFT DOCKING
ORBITER CLOSING	SAMS CLOSING
• APPROACH VELOCITY 0.5 FT/SEC ANGULAR $\leq$ 1.0 DEG/SEC	CONTACT VELOCITY >0.8 FT/SEC ANGULAR $\leq$ 0.1 DEG/SEC
• CONTACT CLOSING VELOCITY $0.3 \leq V_C \leq 0.5$ FT/SEC LATERAL VELOCITY $V_L > 0.045$ TO 0.075 FT/SEC	ORBITER STATION KEEPING ≈±1 FOOT RELATIVE POSITION <0.35 FT/SEC RELATIVE VELOCITY <45 FEET TARGET FROM ORBITER CG
PAYLOAD MOTION $\leq$0.1 DEG/SEC (ANY AXIS) <1 DEG AMPLITUDE >1.5 FT CORRIDOR	PAYLOAD MOTION $\leq$0.01 DEG/SEC <1 DEGREE AMPLITUDE (ANY AXIS)
MISALIGNMENT LATERAL ±0.5 FEET ANGULAR ±5 DEGREE ROLL 7 DEGREE	MISALIGNMENT - SAMS JAW LATERAL ±2 INCHES ANGULAR SMALL (TBD) ROLL SMALL (TBD)
STAND-OFF DISTANCE (WHEN SAMS COMPLETES CAPTURE WITH A SOFT DOCK) $\geq$30 FEET (<45 FEET FROM CG)	STAND-OFF DISTANCE AND MOTION (ORBITER STATION KEEPING ENVELOPE) < ±1 FOOT <0.01 DEG/SEC (ANY AXIS) <0.1 FT/SEC

FIGURE F-13
CONSTRAINTS IN PAYLOAD CAPTURE TIP-OFF
HARD DOCKING

40455

OBJECTIVE - MAXIMIZE THE MATING POTENTIAL

- BRING DOCKING PLANES TOGETHER
  - JACK-KNIFE ANGLE REDUCED TO ZERO
  - RATES REDUCED TO ZERO
- MAINTAIN SUFFICIENT ENERGY TO STROKE THE MECHANISM ATTENUATION SYSTEM
- TOLERANCE TO LATERAL AND ANGULAR VELOCITIES DURING CONTACT DEPENDS ON:
  - LATERAL VELOCITY RATIO: V_L/V_C 0.15
  - ANGULAR VELOCITY RATIO: $\dot{\alpha}/V_C$ 0.1
- LINEAR CONTACT VELOCITY: V_C IS MAJOR FACTOR IN ATTENUATION SYSTEM STROKE



The payload target configuration can influence the tendency for the payload to jackknife on docking contact. A long, thin payload with the docking face on the end is less desirable.

As the hard-docking misalignments tolerances are reduced, the docking difficulty is reduced. If the previously discussed Orbiter Micro-stationkeeping with the target payload are general operational conditions, the hard-docking misalignment tolerances may be reexamined in an effort to reduce and simplify hard-docking requirements. Soft Docking conditions could then be used with the Tilt Table or the Docking Module as well as in the baseline SAMS capture mode providing the docking system is effective for the much lower dynamics of Soft Docking. The soft docking system may involve a remotely controlled docking latch activity similar to the SAMS grappler capture concepts.

F.7 ROTATING PAYLOADS

The information concerning placement and retrieval of rotating payloads is given in succeeding paragraphs.

F.7.1 Rotating Payloads Release

Some Payloads rely upon rotation for general attitude stabilization. The rotation can be established before Payload Release or in some cases may be initiated immediately after Release. In the first case the required rotation system may be payload self contained or Shuttle deployment system mounted. Such a system does not exist on the baseline SAMS or in the Tilt table concept.

The dynamically balanced Payload spin up while attached to the SAMS has a potential hazard to overloading the SAMS should an imbalance develop. The Tilt table, on the other hand, could be structurally adequate for a considerable imbalance risk.

In the second case, Payload self rotation immediately after release could expose the orbiter to contamination or to impact risks should imbalance develop. Some self rotating payloads deploy booms and panels before initiating rotation, thus, their swept volume in rotation can influence Orbiter Separation distances.

Payload disturbances in rotation generally are small with wobble angles, substantially less than one fourth of a degree. Differences in dynamic conditions can change the disturbance particularly where considerable Payload Mass changes occur such as in the Solid propellant burn of an apogee motor attached to the satellite. Present Delta launch vehicles release many varieties of rotating Spacecraft with and without impulse motors and the payloads are able to tolerate up to the Delta limit of 3 degrees half cone angle of wobble tip-off disturbance.

Direct rotating spacecraft release from the orbiter in low earth orbit is expected to be an infrequent occurrence. When spacecraft rotation is required, it may be readily initiated after orbiter release and separation.

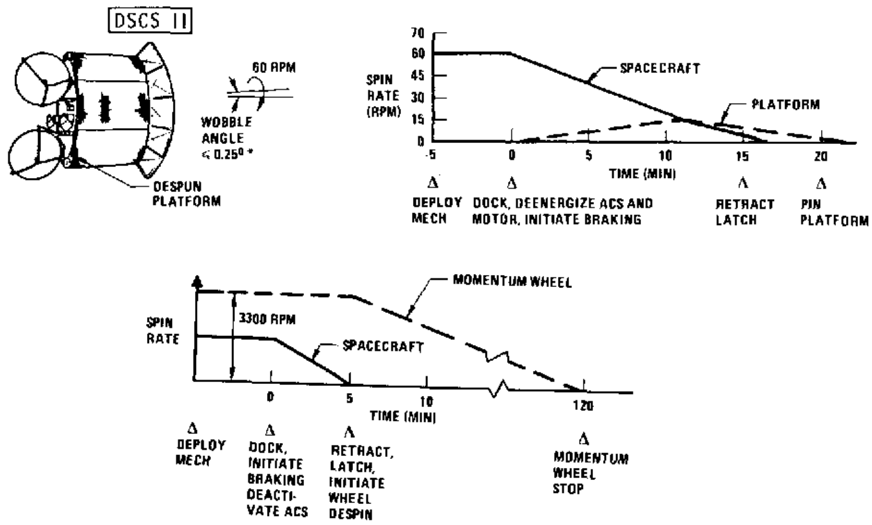
F.7.2 Rotating Payloads Retrieval

Some payloads to be retrieved may be in a spinning mode for stabilization and would be in danger of tumbling should an attempt be made to despin before Micro-rendezvous and orbiter capture. Capture of a spinning spacecraft involves a capture engagement system that makes the initial engagement and a system for despinning the spacecraft after capture so that it can be prepared and stowed in the Payload Bay. This spinning capture grappler and the despin system are not incorporated in the SAMS or in the Tilt-table concepts.

A number of spinning spacecraft involve a spacecraft spinning element and another spacecraft element that is non-rotating such as despun platform. A similar condition exists where a non-spinning spacecraft has on board momentum wheels. The difference is primarily whether the spacecraft capture fitting is stationary or is rotating and thus what orbiter capture system will match. Examples of spacecraft of each type are shown in Figure F-14.

The DSCS-II spacecraft spins at about 60 RPM and has an antenna platform that is despun. Spacecraft capture occurs on the spinning element. After the spinning portion is captured and the spin rate is decreased, the de-spun platform will start to rotate due to friction after its electric spin motor is off. Once the spin rates of the spacecraft coincides with the platform rate, the platform starts to despin and after some 20 minutes both elements come to rest. During this time a maximum platform rate of 15 RPM is attained.

FIGURE F-14
DOCKING OPERATIONS



The second example shown in the figure is a slow spinning spacecraft with a high speed momentum wheel. Once the capture has been made the low spin rate of the spacecraft can be braked in about 5 minutes. However, it is necessary to use the electric spin motor as a brake to stop the momentum wheel in a reasonable length of time. This takes about 2 hours to protect the wheel bearings. During this time the spacecraft attitude rates must be held to less than 0.2 deg/sec with up to 3 deg/sec rates acceptable for short periods of up to a few minutes in order to not damage the momentum wheels.

Both of these example spacecraft are Space Tug retrieval from Geosynchronous orbit cases. Should they be representative of low earth orbit retrievals, the extended spin down periods 20 minutes and 2 hours present problems for SAMS capture and retrieval. The SAMS forces and moments capabilities could be reduced or could even be overpowered by Spacecraft gryoscopic reactions if spacecraft angular movements are large while rotating. The alternative of SAMS capture and remaining inertially fixed for one third up to 2 hours borders on the impractical. Another factor is the potential risk of introducing imbalance in the rotating payload while attached to the SAMS with the possibility of overloading the SAMS.

F.7.3 Rotating Tip-Off at Capture

The low wobble angles and attitude rates listed in the figure are well within capture closure capabilities. The question then is whether the capture activity introduces disturbing forces that seriously aggrevate the wobble rate. The characteristics of the special design grapple for rotation capture will determine whether a risk exists. The large area cone engagement concept shown on the DSCS II in Figure F-14 will minimize these disturbances.

ERRATA NOTE FOR APPENDIX G

The Safety portion of this report includes MDAC interpretations of the NASA safety requirements contained in an early draft version of Section 11, Vol. XIV, JSC 07700, and does not necessarily reflect the NASA position. Subsequent to the analysis in this section, the JSC Safety Office has advised that Shuttle safety criteria have been extensively revised. The latest NASA documents should be consulted for the current safety criteria.

Appendix G

PAYLOAD SHUTTLE SAFETY ANALYSIS

This task involves the determination of the impacts of Shuttle safety criteria on payloads. The available criteria were considered for all regimes of Shuttle flight, including payload ferry flight, as well as operational phases including loading, mating, delay launch, and unloading of the payload. The impacts of multiple flights of the same payload were evaluated with respect to the Shuttle safety criteria. The task results consist of definitions of Shuttle safety criteria impacts on payload system design, systems functions, and system instrumentation.

The trend in Shuttle safety criteria definition indicates that significant safety management problems exist including the payload line of responsibility and the authority interactions between major payload elements. Payload management procedures are beginning to evolve and can influence payload costs in the degree of safety documentation, testing, demonstrations and reviews. Procedures and process time are also important. A second area of payload impact is the design impacts and the operations impacts of particular criteria items. In the evolving criteria items there are several significant design impact areas, some appear to be more stringent than the Shuttle, and others may develop as more criteria evolve. Some payload impacts are not clearly Shuttle safety oriented. Considerable criteria work remains to be done in definitions, performance objectives and correlation with other Shuttle documents. Payload impacts for the various flight modes will depend upon later criteria development since the present criteria are primarily launch and flight oriented. Recommended payload safety criteria are proposed.

G.1 SHUTTLE SAFETY PAYLOAD EVOLUTION

The evolving Shuttle definitions and documentations are dynamic, partially complete and not always detail coordinated; however, sufficient insight into the thrust of safety criteria is available to usefully examine possible payload impacts.

Table G-1, with the publication of the Shuttle Level II requirements in the JSC 07700 documents, Ref. G-1, payload safety considerations are beginning to

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TABLE G-1
SHUTTLE PAYLOAD SAFETY EVOLUTION-1973

SHUTTLE LEVEL II JSC 07700 REQUIREMENTS:

- VOLUME XIV PAYLOAD ACCOMMODATIONS
  - SECTION 11.0 ADDED STATING "PAYLOAD SUPPLIERS MEET NASA SAFETY REQUIREMENTS."
  - PAYLOAD SUPPLIERS RESPONSIBLE TO NASA FOR:
    - A. DETERMINE HAZARDS, TAKE CORRECTIVE ACTIONS
    - B. ASSURE COMPATIBILITY OF PAYLOAD AND SHUTTLE INTERFACES
    - C. DETERMINE RESIDUAL HAZARDS AND INTERFACE INCOMPATIBILITIES
  - ORBITER SAFETY EQUIPMENT AND CAPABILITIES TBD
- VOLUME XIII SAFETY, RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS
  - HEADQUARTERS NHB 5300.4 (1D) BECOMES VOLUME XIII
  - NHB 5300.4 (1D) SETS FORTH SAFETY PROGRAM PROCEDURES
  - ITEMS NOT COVERED INCLUDE:
    - PAYLOAD SAFETY CRITERIA
    - PAYLOAD CRITERIA RELATIVE TO SHUTTLE CRITERIA, I.E. SAFETY FACTORS, ETC
    - PAYLOAD DOCUMENTATION PROCESSING FLOW AND SCHEDULES
- VOLUME X FLIGHT AND GROUND SYSTEM SPECIFICATION
  - 3.2.2.1.5.2 ULTIMATE FACTORS OF SAFETY FOR PRESSURE VESSESL – PRESSURE ALONE WAS REDUCED FROM > 2.0 TO ≥ 1.5
  - 3.2.1.1.11 RESULTANT FLIGHT LOADS – THE 3.0 G LOAD FACTORS DO NOT INCLUDE DYNAMIC EFFECTS AND DO NOT APPLY TO ABORT MODES
  - 3.3.1.3.3.2 FLUID SYSTEM INTERFACE – EARTH STORABLE PROPELLANTS SHALL BE LOADED PRIOR TO INSTALLING THE PAYLOAD INTO THE PAYLOAD BAY

be defined. Volume XIV initiates payload safety recognition in Section 11.0, Reference G-1b. Later expansions of Section 11.0 will guide payload designs and palnning. Since the payload is to a degree dependent upon Orbiter safety equipment and capabilities, the yet-to-be published Orbiter data are anticipated.

Volume XIII, Draft Reference G-1c, has been distributed which is a carbon copy of the NASA Headquarters NHB 5300.4 (1D), Reference G-2. These publications set forth only program procedures for only NASA centers and NASA contractors. There is a need for payload safety criteria, Shuttle-related safety factors, and safety documentation and procedure flows, which are not covered in either Reference G-1c or G-2.

The NASA NHB 5300.4 (1D) and Volume XIII calls out the safety procedures for NASA centers and for NASA-contracted payloads. Presumably, it will also apply to NASA-contracted payload integrated activities.

There are non-NASA-contracted payloads called for in mission models that may be integrated at NASA-contracted payload integration centers or could be integrated at other payload integration centers. The applicability of Shuttle payload safety criteria to these non-NASA activities and the method of applying the criteria are uncertain and unspecified at this time. It would be reasonable to assume that they would parallel those of NASA-contracted activities.

Volume X, Reference G-1a, the Orbiter specification, has three items that influence payload safety design. One is the reduction of safety factors for pressure vessels from 2.0 to 1.5 which could relieve some payload vessel weights. Second, the dynamic effects and the abort-mode flight loads on payloads are not specified; this presently precludes payload verification of structural adequacy. Third, the specification of storable propellant preloading before the payload is mounted in the Orbiter can influence vent and dumping provisions that could affect payload tank design safety margins.

Orbiter performance for the micro-stationkeeping specified for the SAMS is not included in Volume X, which could influence the certainty of what may be a demanding performance objective.

The greatest detail available on safety criteria appears in the Draft Version, 7 June, for Volume XIV JSC 07700, Section 11.0, "Safety Assurance for Space Shuttle Payloads," Reference G-3. This draft is under active coordination and can be expected to substantially change soon. For these reasons, the details of the draft may be soft, however, the general philosophy and the general directions appear to be representative.

The draft Section 11.0 addresses two major safety criteria areas: (1) payload safety management, and (2) payload safety design constraints, Table G-2. In the management discussion, the responsibility for payload safety is discussed, the scope of payload safety is broached and considerable detail of payload safety accountability activities are covered. A major portion of the draft Section 11.0 contains payload design constraints that ellicit particulars in expected payload safety provisions.

TABLE G-2

SHUTTLE PAYLOAD SAFETY CRITERIA

PAYLOAD SAFETY MANAGEMENT

- RESPONSIBILITY PATH
- SAFETY SCOPE
  - SHUTTLE SAFETY
  - ELEMENTS CONSIDERED
- ACCOUNTABILITY ACTIVITIES
  - ANALYSIS
  - CORRECTIVE ACTION
    - DESIGN
    - VERIFICATION
    - TESTS
  - DOCUMENTATION
  - REVIEWS

DESIGN CONSTRAINTS

- PERFORMANCE
- DESIGN SOLUTIONS
- DESIGN PROHIBITIONS

REF: 7 JUNE DRAFT SECTION 11.0
VOL XIV JSC 0770

G.1.1 Total Shuttle Payloads Safety Responsibility

The total payload responsibility for safety includes hazards control that are potential risks to:

a. The Shuttle's capability to successfully terminate the mission which includes the intact crew, Shuttle and payload land recovery.

b. The payload's capability to successfully carry out its mission including its ability to successfully terminate the mission with intact payload landing.

c. The payload hazard control of industrial operations associated with the payload activities.

d. The payload hazard control of public safety associated with the payload activities.

The hazards of interest are those that present the risks of:

- Loss of life	crew, ground personnel, public
- Injury	crew, ground personnel, public
- Property loss	Shuttle, Payload, GSE, facilities, public's property
- Property damage	Shuttle, Payload, GSE, facilities, public's property

The payload safety provisions are required for the various mission phases as shown in Figure G-1. The safety criteria coverage in the 7 June Draft, Section 11.0, covers the two areas blocked out in Figure G-1.

There are major overlapping effects of payload safety features that are incorporated for one mission phase in many other mission phases either in partial risk or total risk control. The launch complex safety considerations are substantially enhanced by the payload design and flight safety actions. However, the Launch Program Office is the management control for the functions boxed in by the dashed lines. These requirements and their solutions may or may not be concurrently resolved along with the flight safety features. Past practice has been that the launch complex resolves their safety criteria on the flight hardware presented for flight and can redo previous safety provisions. During the Shuttle era, a goal is to solve these issues prior to being sent to the launch site.

The NASA as an organization has an interest in all of the payload safety provisions checked in the figure. The NASA management of the un-boxed items is unclear at this time.

G.1.2 Shuttle Safety Management for Payloads

The safety management plan, Figure G-2, is based upon a two-party integration, the Space Shuttle Program Office on one hand, and the Payload supplier on the other hand. Recognition of a slightly different situation for multiple payloads in a mission is resolved by appointing one of the owner/operators to represent the integrated payload to the Shuttle Program Office. This two-party integration calls for the payload supplier (the owner/operator) to be accountable for the entire payload. This accountability required (1) the performance of payload hazard analysis with its follow-up, (2) hazard resolution, (3)

FIGURE G-1

41410

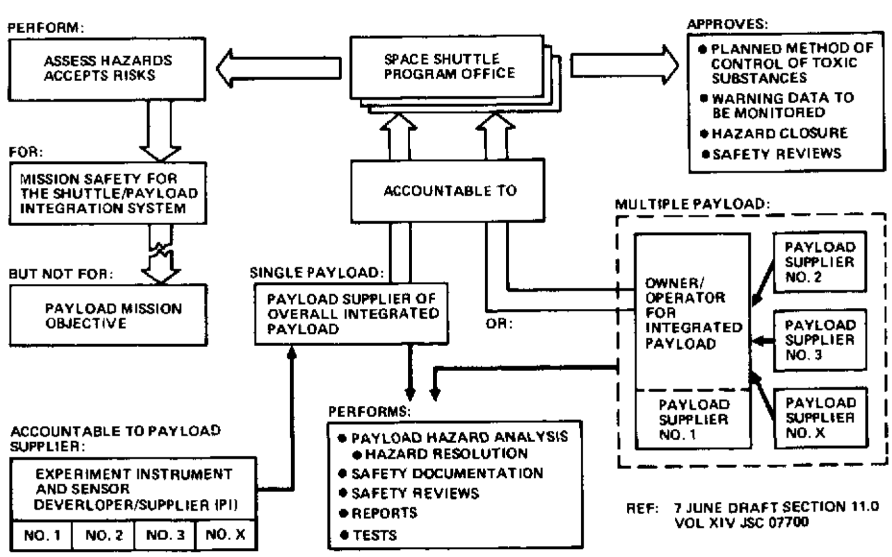
TOTAL SHUTTLE PAYLOADS SAFETY RESPONSIBILITY

		PAYLOAD TOTAL SAFETY PROVISION FOR:			
SAFETY MANAGEMENT	MISSION PHASE	SHUTTLE SAFETY INTACT CREW, ORBITER & PAYLOAD	PAYLOAD SAFETY MISSION SUCCESS	INDUSTRIAL SAFETY	PUBLIC SAFETY
SPACE SHUTTLE PROGRAM OFFICE HAZARDS ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	PAYLOAD ELEMENT DESIGN AND DEVELOPMENT	X	X	X	
	PAYLOAD PACKAGING	X	X	X	
	PAYLOAD FERRY FLIGHT		X	X	X
LAUNCH PROGRAM OFFICE: HAZARD ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	PAYLOAD PACKAGING	X	X	X	
	PAYLOAD FINAL INTEGRATION AND CHECKOUT	X	X	X	
	PAYLOAD LOADING	X	X	X	
	SHUTTLE LOADING	X	X	X	
	SHUTTLE MATE	X	X	X	
	SHUTTLE TRANSPORT	X	X	X	
	LAUNCH PAD LOAD AND CHECKOUT	X	X	X	
	PAYLOAD CHANGEOUT	X	X	X	
SPACE SHUTTLE PROGRAM OFFICE: HAZARDS ANALYSIS, HAZARDS REDUCTION, TESTS, DOCUMENTATION	LAUNCH	X	X		X
	ORBIT OPERATIONS	X	X		X
	RETRIEVAL	X	X		X
	DEORBIT	X	X		X
	PAYLOAD UNLOAD	X	X		
	PAYLOAD DISASSEMBLY		X	X	
	PAYLOAD MAINTENANCE AND REFURBISHMENT	X	X	X	

FIGURE G-2

41409

SHUTTLE SAFETY MANAGEMENT FOR PAYLOADS



REF: 7 JUNE DRAFT SECTION 11.0 VOL XIV JSC 07700 preparation of safety documentation, (4) condition of safety reviews, and (5) completing reports and tests.

The payload supplier is directly accountable to the Shuttle Program Office. The experiment developer/supplier (PI), on the other hand, is answerable only to the payload supplier. The Volume XIV criteria draft, Section 11.0, specifically states that it is not the intent to impose the criteria upon the experiment developer/supplier. Also there is no requirement for safety traceability of the criteria beyond the payload supplier. The extent of the criteria application by the payload supplier to the experiment developer/ supplier is thus soft and uncertain.

G.2 PAYLOAD CARRIERS

The Draft Section 11.0 safety criteria requirements are levied upon the payload carriers in their design and development. Since these carriers include the Sortie Lab/Space Lab, pallets, Tug, propulsive stages and free-flyers (presumed to be spacecraft and satellites less their sensors), the criticality of the compliance of the experiment, instrument and sensor/developer/ supplier is tempered by their transport and support on the payload carriers.

Many of the payload carriers will be NASA Contract developed and procured, hence, safety criteria applications will be a matter for contract performance. There could be some payload carriers, Space Lab, and some propulsive stages and spacecraft that are not NASA contract developments. These could present some safety compliance problems especially where the criteria have significant impact and where new requirements are being introduced.

The Space Shuttle Program Office relationship to the payload supplier is that of assessing the payload hazards and accepting the payload risks. These payload hazards and risks are those associated with the mission safety of the Shuttle/payload integration system only. Those other hazards or risks only associated with payload mission objective achievements are not of concern to the Shuttle Program Office. There are certain Shuttle Program Office approvals required of the payload supplier's safety activities as listed in Figure G-2.

No criteria or advice is offered (in the draft, Section 11.0) to guide the payload supplier toward other safety compliance activities, other than the Shuttle mission safety, that may be required of the payload in fulfilling other NASA safety obligations.

G.2.1 Payload Accountability

The responsibility of the payload supplier to the Shuttle Program Office is defined in the criteria draft, Section 11.0, in some detail for the five categories previously listed. These five groups are detailed in Figure G-3. The specified analysis appear to follow the standard hazard analysis procedures with the exception that a separate "safety analysis" is specified but is not defined. The hazard analysis then becomes the guide to payload corrective actions in hazard resolution which follows the standard NASA procedures. Documentation of these analyses and corrective actions plus the associated instructions, reports, and etc. is also a payload supplier activity as well as the requirement that he conduct hazard reduction verifications in the area of tests, analysis and demonstrations. The eventual formal safety reviews/assessments are also conducted by the payload supplier. When all of these accountability activities are acceptable to the Shuttle Program Office, the approvals listed in Figure G-2 will complete the preflight safety preparation actions for the Shuttle Program Office.

G.2.2 Criteria Design Constraints

The Draft Section 11.0 criteria has a major emphasis on design for safety that is organized into a general listing of design items and a subsystems design item listing. Some of the design items are performance oriented, others are in effect design solutions while others are design prohibitions. The listings are partially complete and thus can be considered to be samples/examples.

There is a broad sprinkling of the manned rating requirements throughout and a significant emphasis on nuclear systems. The design constraints in effect define the design hazards that are of concern to the Shuttle which the payloads are expected to resolve before flight. There is no listing of operational constraints although some design constraints have operational implications.

FIGURE G-3

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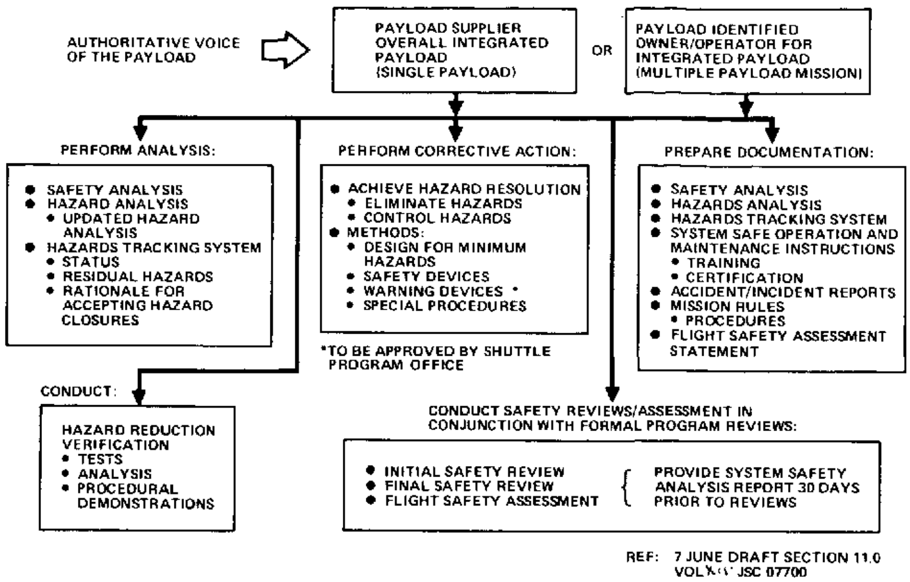
PAYLOAD ACCOUNTABILITY TO THE SHUTTLE PROGRAM



G.2.3 Safety Criteria Management Impacts on Payloads

The Draft Section 11.0 safety criteria management concept calls for a single payload spokesman to be accountable to the Shuttle Program Office. The identity of this spokesman could vary with different payload Shuttle Program concepts.

G.2.4 Payload Integration

One concept involves the "ship and shoot" solution where the total payload package is assembled at a remote facility. Another concept calls for the total payload package to be assembled at the Shuttle launch complex such as for Tug missions. It appears that even with ship and shoot, there will be final total payload package integration activity at the Shuttle site before the total payload package can be loaded in the Shuttle. It is possible that some total payload packaging will take place at one or more remote sites while other payloads will be packaged at the launch complex. It would then be conceivable that a final integration of each of these total payload packages at the launch complex is required before Shuttle loading. It is likewise possible that each packager and each integrator is a distinct organization group that becomes specialists because of the need for low costs, timely performance and expertize in achieving flight readiness. Is the single payload spokesman then the total payload packager or the final payload integrator?

The magnitude of the final integration activity at the launch complex that is required to place a total payload package in the Shuttle will influence the relative importance of the final integrator vs. the total payload packager. A combination of limited payload GSE, significant ground tests and the frequent use of common FSE from mission to mission will enlarge the final integration activities and will have safety related impacts.

G.2.5 Payload Liability

Another factor in the responsibility of a single payload spokesman, in addition to the payload liability for technical and operational safety, is the payload liability for costs arising from payload involved Shuttle damage or even a Shuttle catastrophe. As the Shuttle Program tends to seek compensation for actual services rendered from a wide range of payloads, a definition of the conditions under which a payload is held harmless becomes important. Technical and financial risks to the single payload spokesman influences the depth of his activities and his costs. If the final integrator is relieved of this liability, then the spokesman may be the total payload packager.

G.3 SATELLITE DEVELOPER

In any event the satellite developer/supplier is unlikely to be the total payload packager and most certainly will not be the final integrator. Therefore, under the draft Section 11.0 criteria, the satellite developer/supplier is responsible to the single payload spokesman for such safety criteria as the spokesman elects to levy. This uncertainty impacts safety management and could lead to varying responsiveness to safety criteria at the satellite design level. Clarification of the applicability of Shuttle safety criteria down to the design responsible levels will assist the payload spokesman and the satellite developer and contribute to the Shuttle Program Office eventual desire for hazard tracking and traceability.

The satellite developer/supplier in present missions selects and oversees the satellite integration with the expendable launch vehicle. One concept in the Shuttle-Tug era calls for the Tug being responsible for satellite integration with the Tug and Tug integration with the Shuttle. This reversal of the satellite developer/supplier role with the stage would tend to further depress the satellite position within the Shuttle mission hierarchy. Furthermore the Tug taking over dominate spokesman status with the Shuttle can raise issues. Direct access of the satellite developer/supplier to the final Shuttle integration process can be a factor influencing whether a single payload spokesman can be workable or whether a payload group speaks to the Shuttle on safety matters.

G.3.1 Safety Documentation

Adequate safety documentation is necessary in a complex multi-element activity as in the Shuttle missions and a multi-layer of payload elements under the single spokesman must be managed to avoid self serving documentation. Documentation examples and depth definition will materially assist in delegating safety documentation to the sources of data with a minimum of duplication. Documentation timeliness and expeditious processing will also be assisted by guidelines in document flow and flow timelines.

G.3.2 Hazard Reduction Verification

Hazard reduction actions in most cases will be performed by a payload developer rather than the single payload spokesman. These actions are directly associated with the hazard analysis and with the hazards tracking system. Temperance in calling for tests, analysis and demonstrations will assist in timely corrective actions and help control costs. The payload impacts can be reduced by the availability of carefully prepared safety performance criteria and in the maintenance of lists of qualified systems, procedures, and design solutions to safety.

G.3.3 Safety Reviews

Formal program reviews for each Shuttle mission will develop a highly experienced Shuttle cadre. Their impact on infrequent or one time payload spokesman has potential complications at formal safety reviews. Experienced continuing participant single spokesman such as the total payload packager or the final integrator should produce routine reviews providing that the analysis, verification and documentation has been managed.

G.3.4 Management Impacts Review

An examination of the responsible payload groups representing: (1) the sources - the Sortie Lab, the Spacecraft/Satellite, the Space Tug, Propulsive Stages, Flight Support Equipment and the Experiments and sensors, (2) the handlers - the payload packager, the payload integrator, the payload refurbisher, and (3) the major payload sponsor such as NASA Centers, DOD and etc., points up the variety of payload safety interested parties. Some aspects of payloads safety are treated early in the genesis - design solutions, others are confirmed or demonstrated in tests at various development and packaging/integration stages. It therefore is not readily evident that a single payload spokesman on safety can be practical.

The uncertainty of a single spokesman for payload safety opens up the question of whether also a single spokesman can be assured for the space transportation system, Figure G-4. The possible sources of safety direction and payload safety reviews may be eventually focused into one authority so that the draft criteria objective for a two-party safety operation could be realized. At present, the scope of the draft criteria as generalized previously in Figure G-1, does not appear to cover the total safety needs.

When total payload effectiveness and liability are considered as well as payload costs in procedures, documentation and time, payload safety can become a significant management problem as suggested in Figure G-5 for only the Shuttle-related safety. The payload safety workload is appreciable in the analysis, resolutions, reviews, and demonstrations even when it is accomplished "on-line." If redo or retro work is involved especially where some sources of safety direction only become active later in the flight readiness schedule, work and schedule impacts become serious. Likewise documentation and liabilities will influence safety costs particularly for missions that involve several major payload components as suggested in Figure G-4.

FIGURE G-4

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SAFETY MANAGEMENT INVOLVEMENTS

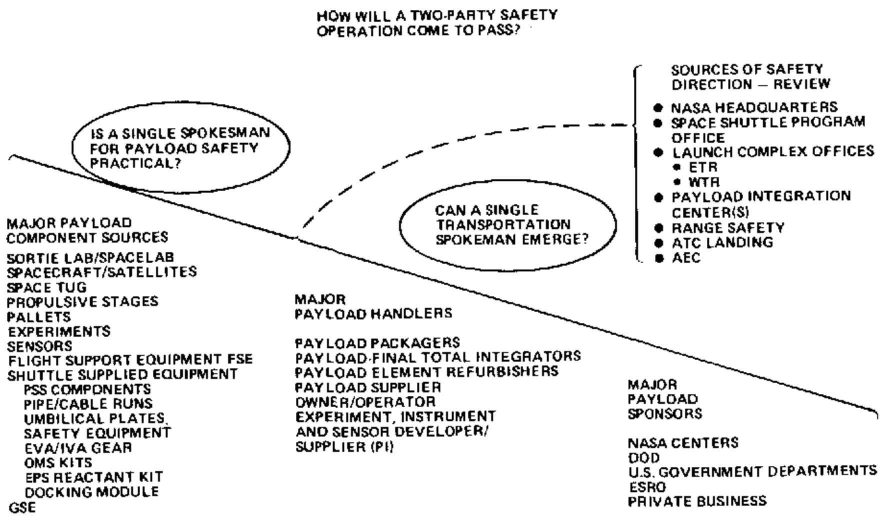

FIGURE G-5

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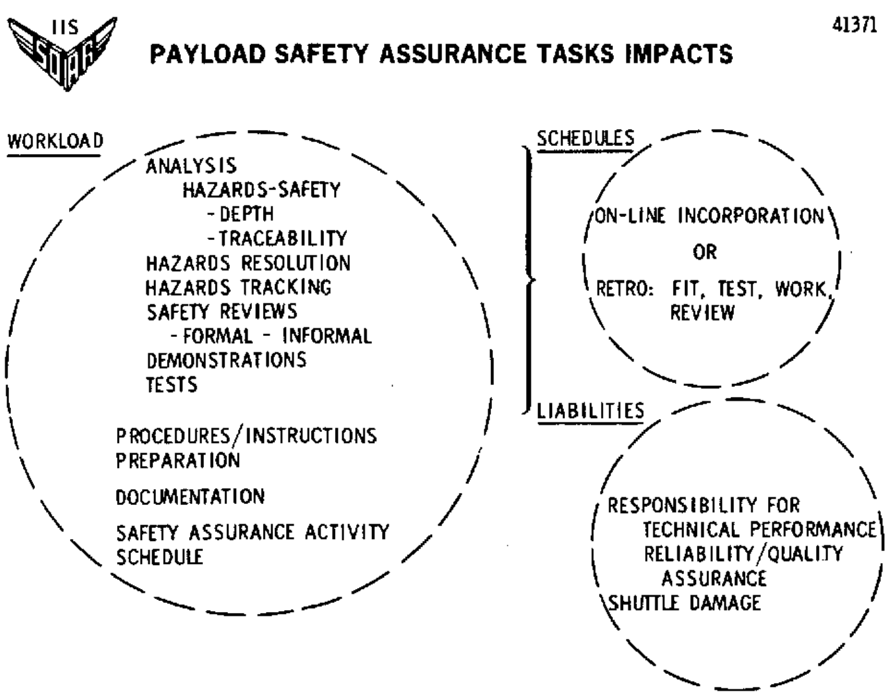
PAYLOAD SAFETY ASSURANCE TASKS IMPACTS



G.3.5 Impacts of Shuttle Safety Criteria Payload Hardware

The draft Section 11.0 criteria has a major portion of its criteria items lists devoted to "subsystem safety design requirements." These requirements can be expected to be refined, consolidated and clarified in the on-going coordination of the draft; therefore, only the most general criteria items impacts are detailed here. Also many of the listed manned flight criteria appear to be basic design considerations that will be inherently included thus design impacts are not examined. Likewise most of the nuclear systems items appear to be basic design considerations that will be inherently included; thus no design impacts are listed. These criteria, however, are proper to the listing in order to establish the foundation for safe system designs.

G.3.6 Specific Design Impacts

A number of the payload design impacts have been anticipated from the basic Shuttle requirements such as a payload caution and warning system for Shuttle monitor and control and these are included in Table G-3. Payloads fluids management are also covered including venting, dumping and launch pad unloading. Other design safety requirements are new and in some respects demanding, Table G-4. For example, the requirement for payload caution and warning surveillance and control after separation from the Orbiter could require a new RF two way communications system for most payloads as well as the Space Tug or other stages for status of the propulsion system and the start system logic. The Shuttle specification calls for payload hardwired caution and warning signals and control capability. No mention is made of RF payload caution and warning surveillance in Reference G1-a. Similarly, no reference to payload jettison is made in this Shuttle specification Reference G1-a; therefore it could be assumed that the required payload jettison provisions must be wholly contained within payload systems which could require remote unlatch provisions, umbilical and wiring and piping severence systems and possibly even a payload provided deployment system.

Another example of safety criteria that appears to exceed the needs for protection of the Shuttle is the general criteria for payload design for minimum hazard which specifies a major goal is for payload features that fail

TABLE G-3
PAYLOAD DESIGN IMPACTS

CRITERIA ITEM	DESIGN IMPACTS	ELEMENT IMPACTED
Caution & Warning System - Monitoring parameters - Commands to control	New sensors and wiring New controls	- Payload carrier - Experiments - FSE
Payload attached: Deployment Retraction/retrieval Launch and reentry (On-orbit not covered)	Umbilical or RF Umbilical or RF Bay wiring raceway	- Payload carrier
Payload detached	New two-way communication system with data and command links and crew station (Orbiter spec only requires hardwired C&W)	- Payload carrier - FSE
Payload jettison provisions	New attachment fittings and mechanical actuators (Orbiter has no jettison function spec requirements)	- Payload carrier - FSE
Fluids dump or contained in crash landing	Dump system new or beef-up fluid tanks and plumbing	- Payload carrier - Experiments - FSE
Vent control during EVA	Add vent controls or plumbing to direct venting	- Payload carrier - Experiments - FSE
Integrated checkout and test safety critical payload systems - Prior to installation - Verify after installation	 Add test simulations Add verification tests	- Payload carriers - Experiments - GSE
Remote activate, disable and control hazard systems - Deployment - Retrieval - EVA operations	Add activate and disable controls (related to C&W item)	- Payload carriers - Experiments
Prohibit stage firing or propellant dump in payload bay	Add: interlock on engine start, interlock and dump valves, or pipe dump lines to Orbiter overboard dump	- Payload carrier - Orbiter
Flammable or corrosive fluids vent	Add piping to Orbiter vents	- Payload carrier - Experiments - Orbiter
Time limited dump or vent of fluids (TBD) seconds	When time established, some fluid systems may have enlarged plumbing	- Payload carrier - Experiments - FSE - Orbiter
Payload tanks automatic maximum pressure limits	Add relief or vent valves and plumbing	- Payload carrier - Experiments - FSE - Orbiter
Redundancy fluid lines and wiring	Separate location from primary line (Orbiter interfaces not defined as separate)	- Payload carrier - Experiments - FSE - Orbiter
Positive sealing disconnected pressurized fluid lines	Add sealing fitting	- Payload carrier - FSE
Tanks, tunnel, pressure vessel (TBD) design factors of safety	Structural beef-up	- Payload carrier - Experiments - FSE
Post deployment activation propellant pressurization to system operating pressures	Add two level controls, valving and vent system	- Propulsive stages - RCS payload carriers
Emergency removal of propellants	Add dump system and umbilicals	- Payload carriers - FSE - GSE
Valve lockout from induced flight loads (ground loads not specified)	Add valve lockout features	- Payload carrier - Experiments - FSE

TABLE G-3 (CONTINUED)
PAYLOAD DESIGN IMPACTS

CRITERIA ITEM	DESIGN IMPACTS	ELEMENT IMPACTED
Propulsion start logic status and valve positions	New RF communication link to Orbiter with data, add sensors for status	- Propulsive stages
Battery vents	Add vented batteries and plumbing to Orbiter	- Payload carrier - Experiments - FSE - GSE
Eleectrical umbilical disconnect separated from hazardous fluids disconnects	Payload ability to comply at Orbiter umbilical panel dependent on Orbiter isolation	- FSE - GSE
Payload caution and warning alarms audible	Add new audible alarm system in addition to Shuttle alarm signal lights	- Payload carrier - FSE
Available in Orbiter and EVA personnel	Unclear how payload can comply	Uncertain
Module noise level to not exceed 72.5 db	Add acoustical attenuation to isolate module from Orbiter environment	- Payload carrier
Thermal control nuclear payloads	Add thermal loops and umbilical	- Payload carrier - FSE - GSE

TABLE G-4
PAYLOAD SAFETY REQUIREMENTS POSSIBLY IN EXCESS OF SHUTTLE SPECIFICATION

CRITERIA ITEM	SHUTTLE REQUIREMENT	DESIGN IMPACTS	ELEMENT IMPACTED
Caution and warning safety critical parameter detached payloads	C&W hardwire to light matrix	RF two-way link Payload to Orbiter detached	- Payload carrier - Experiments
Caution and warning audible signal Orbiter and EVA	C&W hardwire to light matrix	New audible units power	- Payload carrier - Experiments
Payload jettison provisions	Silent	New attach fittings actuators	- Payload carrier - FSE
Payload tanks automatic maximum pressure limits	Silent safe operation	New vent on some tanks	- Payload carrier - Experiments - FSE
Redundant fluid lines and wiring separation	T-0 umbilical only separation	Separation from primary lines	- Payload carrier - Experiments - FSE - Orbiter
Post deployment activation propellant press. to operating pressure	Silent	Add two level controls, valving and vent system	- Propulsive stages - RCS payload carrier
Electrical umbilical disconnect separated from hazardous fluids disconnect	Orbiter panel details limited	Separate umbilical panels	- FSE - GSE - Orbiter
Module noise level to not exceed 72.5 db	Shuttle environment in bay 145 OASPL	Payload sound attenuation	- Payload carrier

operational/fail safe, Reference G-3, para. 11.2.2.3.a, when in fact payloads that fail safe satisfy the Shuttle needs for successful mission termination, Reference G-3, para. 11.2.3.1.a.

G.3.7 Redundant Lines

Redundant fluid lines and wiring for payloads and their reasonable location separation is a nominal safety design, but it is meaningless unless the Shuttle provides matching separated redundant interfaces and bay raceways. Confirmation of that Shuttle provision has been missing except for the umblical plates at T-0 on the aft fuselage quarter panels. Another new-beyond the Shuttle specification is the requirement for an "audible" warning alarm. The Shuttle called for an alarm light matrix. The payload ability to provide audible alarms in the Orbiter and for EVA personnel is unclear. Also the need for 72.5 db level in payloads when it is unclear that the Shuttle can provide that low a level could call for special payload performance.

G.4 PAYLOAD SELF-SAFE

The general requirements that the payload be fail safe and that it provide various safe design features are consistent with the general objectives of the Space Tug which is planned to be totally safe while in the Shuttle and consequently will have no potential hazards for which Shuttle caution and warning alarms would be needed. If the Shuttle calls for Tug caution and warning alarms, it will be for the Shuttle information objectives and would not be related to potential Shuttle hazards. Tug compliance with the combination of the draft Section 11.0 criteria items specifically directed toward the Tug could result in such a totally safe Tug. For example: (1) Tug isolated from Orbiter support shall be in a safe condition, (2) Tug designed to operate in a quiescent mode during launch and reentry phases, (3) interlocks to prevent propulsion system firing or propellants dumping in the payload bay, (4) passive Tug with post separation and safe distance activation of systems and pressurization of propellants, (5) induced flight loads cannot initiate Tug valve control events, and (6) Tug propulsion system start sequence logic status and valve positions shall be monitored and signals provided to the Orbiter.

Tug compliance with the first five criteria should result in there being no potential hazard to the Shuttle and thus the data required for item 6 appears to not be caution and warning data (it is not so worded in the criteria); but represents general information to the Shuttle. If Tug start sequence logic status and valve positions are considered to be Orbiter safety critical parameters, then the draft Section 11.0 general requirement would call for Orbiter monitor and control of the Tug parameters under detached deployment conditions.

G.4.1 Caution and Warning

Other Orbiter caution and warning monitor and control conditions may force payloads to provide RF link caution and warning services while attached to the Orbiter. Payload deployment to a release position by the SAMS (manipulator) would require either a payload umbilical to the Orbiter or an RF link for the deployment criteria item. The umbilical concept poses a problem in the umbilical separation action and umbilical management. A swing arm umbilical could be one concept; however, if the C&W monitor and control is enforced for detached payloads, an RF link would be required and the umbilical becomes duplication.

A separate facet in the caution and warning system is the new requirement for audible alarms in the Orbiter and to EVA. The type of audible system and the electrical power needed to drive it influences the payload caution and warning system. The payload audible annunciators also must be intimately located within the Orbiter and within the EVA system. Reduction of impacts of this requirement would be achieved by requiring the payload to produce the caution and warning signals to power a light matrix in the Orbiter and to power a master caution and warning light. The Orbiter can then manage these light signals as desired to produce the Orbiter and EVA audible alarms.

A third impact on the payload caution and warning concept is the criteria objective to "kill payload power" under emergency conditions. The power to operate the caution and warning sensors and power the alarm lights in the Orbiter should be a separate power system that remains active in emergencies.

A redundant caution and warning system could be improved by its own dedicated power system. Separate power may also be desired for the caution and warning diagnostic measurements and for the caution and warning controls that arrest or solve a developing hazard. The desired payload passivation by powering down would appear to be a sequential action with the caution and warning system power, one of the last power systems to be powered down.

G.4.2 Design Impacts Review

These design criteria are subject to ongoing changes; however, they can be generalized into three areas as follows and as outlined in Table G-5. Certain of the criteria appear to exceed Shuttle features. This greater level of payload safety in itself may not be undesirable especially considering the isolated in payload bay conditions. However, some criteria can impact Shuttle interfaces such as the caution and warning audible signal or the need for a payload dedicated ground return wire where the Shuttle uses a structural return. Also, where payload safety generates non productive payload complexities and added costs, the payload sponsor can challenge the need for a two-class safety arrangement, Shuttle class and payload class.

Another group of criteria appear to require payload safety performance in excess of the Shuttle needs. The Shuttle needs are to manage payload hazards to Shuttle successful mission termination, Table G-5. A fail safe payload appears to satisfy the basic requirement of the Shuttle on the payload. A higher level of payload safety performance such as fail operational/fail safe or even fail safe/fail safe would appear to not enhance the Shuttle's capability to successful mission termination. Payload fail operational/fail safe features appear to be outside of the Shuttle safety area of formal concern although the payload feature may be desired by NASA or others for other performance/assurance reasons. Likewise, payload fail safe/fail safe appears to go beyond Shuttle formal concerns. A fail safe payload that is required to be jettisoned is being jettisoned for reasons other than payload hazards to the Shuttle arising from a payload initiated hazard. The fail safe/fail safe concept is so broad that unproductive payload safety effort may be involved, hence a workable arrangement would be where specific fail safe/fail safe features are only levied on the payload; for example, a double walled sealed pressure vessel to contain micro-biological experiments while in the Orbiter.

TABLE G-5
SHUTTLE PAYLOAD SAFETY CRITERIA

CRITERIA MAY EXCEED SHUTTLE FEATURES	SHUTTLE SPECIFIED
PAYLOAD CAUTION AND WARNING	
– DETACHED PAYLOAD ACTIVE	SILENT
– AUDIBLE SIGNAL	LIGHT MATRIX
PAYLOAD JETTISON	SILENT – ABORT LANDING WITH PAYLOAD
AUTOMATIC PRESSURE LIMITS – PAYLOAD TANKS	SILENT
REDUNDANT FLUID LINES – WIRING	PARTIAL
UMBILICAL ELECTRICAL	
– SEPARATION FROM FLUIDS	PARTIAL
– DEDICATED GROUND WIRE	NO
NOISE LEVEL 72.5 DB	145 DB OASPL
VENT PAYLOAD FLUIDS	UNRESTRICTED VENT UNCLEAR
REMOTE PROPELLANT PRESSURIZATION	SILENT – SHUTTLE HAS ACTIVE RCS AND OMS

SCOPE OF CRITERIA UNCLEAR

SHUTTLE SAFETY OBJECTIVES:	CRITERIA STATES:
ABILITY TO SUCCESSFULLY TERMINATE MISSION	SILENT
– INTACT CREW	INFERRED
– INTACT SHUTTLE	SILENT
– INTACT PAYLOAD	SILENT
REUSABLE SHUTTLE	SILENT
OPERATIONS SAFETY	PARTIAL
ASSOCIATED FUNCTIONS/ELEMENTS:	
GROUND SAFETY	PARTIAL
INDUSTRIAL SAFETY	SILENT
POPULATION SAFETY	SILENT
PROPERTY SAFETY	SILENT

PERFORMANCE POSSIBLY EXCEEDS SHUTTLE SAFETY NEEDS

PAYLOAD:	COMMENT
FAIL SAFE	BASIC PAYLOAD REQUIREMENT FOR SHUTTLE SAFETY
FAIL OPERATIONAL/ FAIL SAFE	WHEN DOES PAYLOAD RESIDUAL OPERATIONAL CONDITION RELATE TO SHUTTLE SAFETY?
FAIL SAFE/FAIL SAFE	SPECIFIC SOLUTIONS RATHER THAN GENERAL
JETTISON PAYLOAD (PAYLOAD IS BASICALLY SAFE) REMOTE PROPELLANT PRESSURIZATION MICRO-BIOLOGICAL EXPERIMENTS	
SELF SAFING	NOT COVERED

A third area is the uncertainty in scope of the criteria, Table G-5. Shuttle safety objectives are documented in Shuttle specifications, a one for one correlation with the draft criteria is missing. Also other areas of mission safety are not covered in the draft design criteria.

It is improper to be conclusive about the draft criteria and their payload impacts except to observe that payload safety management is important and deserves close attention. Likewise design and operations criteria are important and warrant early refinements.

The draft Section 11.0 subsystem design criteria may be undergoing substantial modification through coordination with the result that many of these impacts have been resolved. Those criteria that remain, if they result in these types of impacts, appear to include the following features.

a. Payload designs are substantially influenced by the criteria in that new features and some new systems may be added.

b. The extent to which a number of the criteria are addressed to payload hazards to the Shuttle is unclear since: (1) the Shuttle safety objectives are incompletely stated and vary from one Shuttle document to another; (2) some of the criteria dictate design without clearly specifying the expected performance; (3) some payload hazards are incompletely covered, i.e., structural integrity.

c. Some of the criteria appear to establish new and/or additional safety requirements on the payload in excess of those provided in the Shuttle.

d. Some payload safety related Shuttle systems definitions remain incomplete which constrains interpretation of payload compliance impacts. Some of these are: (1) the payload utilities interfaces in the orbiter; (2) the payload umbilical system in the Orbiter including vent, dump and purge provisions; (3) the Orbiter caution and warning system; and (4) the constraints on the payload deployment and retrieval and mounting system.

G.4.3 Impacts of Shuttle Safety Criteria in Payload Operations

The Draft Section 11.0 criteria are not organized in a format that groups certain criteria into "operational safety criteria" although various criteria items do have operations aspects. Payload safe operations must be considered from prior to loading to after ground unloading. There may be periods of denial of payload functions when other Shuttle operations are scheduled. Although the criteria calls for all payload tanks to have relief valves and vent capability, venting could be prohibited at certain operational periods.

An important safety feature is a definition of the considerations the safe distance for Orbiter separation from the payload before acceptable payload activation is acceptable. For example, a simple, cold gas, limited performance, coarse attitude hold mode may be acceptable in the payload shortly after release from the SAMS, say within a hundred feet of the Orbiter. On the other hand, full activation of the propulsive stage, the Tug could be denied until possibly 1,500 feet separation is achieved. Even though these distances are subject to refinement, a general indication would be helpful including the elapse of time, say "1,500 feet (TBD) separation and not less than 300 seconds (TBD) after release."

G.5 SHUTTLE SAFETY IMPACTS ON FLIGHT REGIMES

The payload flight regimes covered in the draft Section 11.0 criteria are primarily the flight mode with a few references to launch pad features such as the ability for emergency removal of payload propellants. The flight mode impacts are probably the most demanding in that the payload is fully loaded, the Shuttle flight environment is relatively severe and the emergency provisions for Shuttle successful mission termination are limited and dependent upon precise operational performance.

Payload ferry flight and payload unloading involve a relatively quiescent payload normally without propellant and able to utilize conservative support for improved safety with impacts only on the GSE. Payload safety impact for launch complex total packaging, final integration, Shuttle loading, Shuttle mating, Shuttle transport, and launch pad operations including pad payload checkout is dependent upon the launch facilities center safety criteria which have not been disseminated. If these launch safety criteria can be included in the Space Shuttle Program safety criteria and joint center management of hazard analysis, hazard reduction and hazard tracking, it would be possible to incorporate accepted hazard reductions in the course of payload design and development. If joint safety approvals cannot be obtained, there will be a launch complex safety design, review, documentation and approval conducted to the launch center's criteria in addition to and after the program office criteria accommodation.

Payload safety criteria related to Apollo and to Skylab could be involved and rework of safety features to the program office criteria could occur. Areas of safety impacts would also be expected in payload preloaded propellants and the complexity of safety services for a variety of payload movement, Shuttle loading, Shuttle mating and transport. The ability to vent, emergency unload and etc. may be intermittent and limited. Another impact could be the thermal, purge and cleanliness environment of prelaunch activities from the point of loading to launch. A third safety impact could be in the area of the limited access to the payload prior to launch with the limited visual inspection and timely access in case of an alarm. Last minute loading of time critical and in some cases hazardous elements such as the nuclear elements RTG's as well as pyrotechnics processing places a stress on safety. Safety criteria need to be developed for all flight regimes to complete the Shuttle advice to payloads.

G.6 RECOMMENDED SHUTTLE SAFETY CRITERIA FOR PAYLOADS

The following safety criteria (Table G-6) developed in the SOAR-II study for payloads are recommended for dissemination as Shuttle payload criteria.

TABLE G-6
PAYLOAD SAFETY CRITERIA

The following payload safety criteria are postulated to give general guidance to developing safety requirements.

Goal - No single or combination of events or malfunctions shall result in hazardous conditions to personnel or damage to the shuttle or payload.

A. The payload shall not degrade the safety of the Space Shuttle. Payloads shall be Shuttle-rated for flights in Shuttle missions.

B. Hazard management features shall provide safe conditions for the crew, Shuttle, and the payload in that order or precedence.

   1. The payload shall be fail/safe for Shuttle crew survival after any single payload failure.
   2. The payload shall be capable of being rendered safe in the event of an abort.
   3. The payload shall not hazard the Shuttle as a result of a Shuttle crash landing, by excursion of payload components or fluids outside of the allowable payload envelope.
   4. The payload shall provide self-safing arrangements for payload-generated hazards to the Shuttle.

C. Crew survivability involving escape shall be given priority in the form of weight, cargo bay volume, and bay-location dedications from payload allowables.

D. The payload shall manage hazards generated through interaction within the payload, with the Shuttle, or with any other program elements.

General Provisions

A. Catastrophic and critical payload hazards shall be eliminated or reduced to controlled hazards.

B. All payload components, subsystem, and operations, except primary structure and pressure vessels, shall be designed to be fail-safe for Shuttle crew survival after any single payload failure.

C. Payload elements and subsystems that contain hazardous devices or material or hazardous operational procedures shall have safety provisions in the form of emergency procedures, suitable marking, and identification and self-contained automatic or self-contained manual protection devices against all payload-generated hazards and positive verification of hazard management while the payload is mounted to or in the immediate vicinity of the Orbiter.

D. For those payload hazards that may result in time-critical emergencies (an emergency whose occurrence must be detected and corrective action taken within five minutes or less to prevent failure of a critical function), provisions shall be made for automatic switching to a safe mode and to display caution and warning to Shuttle personnel.

E. The fail/safe provisions against payload hazards shall be provided for payload ground operations, normal Shuttle flight regimes, post-flight operations, and Shuttle abort conditions.

F. The payload shall provide for its primary structural integrity and containment of its tanked fluids when exposed to Shuttle crash-landing loads.

G. All payload subsystems incorporating redundancies which can influence Shuttle safety shall include a means of verifying satisfactory operations of each redundant path.

Fire Protection Requirements

A. Materials used in pressurized payloads shall be subjected to the same flammability control procedures as those used within the Orbiter pressurized volumes.

B. Fire- and heat-resistant protection shall be provided to payload command and instrumentation interfaces between Orbiter and payload.

C. Ignition sources in the Orbiter payload bay, such as switches and relays, shall be sealed or otherwise contained so as not to cause ignition of flammable fluids.

Electromagnetic Protection Requirements

A. Capability shall be provided to switch off all electrical power to payload from the Orbiter, except emergency power that may be required to maintain a safed payload, or safely shut it down.

B. Adequate protection shall be provided for all high-voltage terminals, leads and equipment and all other equipment emanating radiation fields, such as nuclear isotope heat sources.

Ordnance Protection Requirements

A. Destruct charges shall not be incorporated in any payloads when launched in the Orbiter.

B. Explosive charges shall be contained to prevent damage in the event of inadvertent detonation.

Payload Manipulation Safety

A. Capability to release, eject, or extend the payload shall be provided so as to prevent damage to the Orbiter at the expense of the payload.

B. No undesirable torques shall be imparted to the spacecraft or the propulsive-stage vehicle by the separation and/or deployment mechanism.

C. Redundancy shall be provided in the means for separating the propulsive stage vehicle. No single failure shall result in uncontrolled motion of the propulsive-stage vehicle.

Special Payload Components Safety Design

A. Large-Momentum Wheels operations with the payload attached to the Orbiter shall be limited to operational readiness tests:

(1) with the wheel operational

(2) with wheel-speed monitoring provided in the form of an audio/visual alarm

(3) with wheel speed emergency control (hardline) capability.

(4) with emergency shut-down procedures.

Payload Safety Devices Requirements

Payload Toxicity, Corrosive, and Fire Safety Devices

A. Manually and remotely controlled means shall be provided in Orbiter payloads for identifying, alerting, controlling and extinguishing fires.

B. Toxic, flammable, or corrosive fluid containers shall be located in unpressurized volumes of pressurized payloads, or shall be double-walled contained with the capability of dumping the fluid into space or off-loading to another double-walled container, and of venting the space between the two containers to space.

C. Special protective garments and equipment shall be provided for personnel working in a toxic environment or near potentially toxic environment or near potentially toxic payload elements.

D. Means shall be provided for the local application of radiant or other type of heat remotely or by personnel in IVA or EVA activity to evaporate accumulations of frozen fluids from critical areas.

Payload structural Safety Devices

A. Capability shall be provided to relieve atmospheric pressure from an Orbiter payload so as to prevent pressurization beyond the payload structural limits. This capability shall be automatic when the payload is not manned, and under control of the occupants when manned. The maximum dump rate if the atmosphere is dumped into the bay shall not exceed the venting capability of the Orbiter cargo bay with the cargo bay doors closed.

B. Capability shall be provided for the Orbiter crew to selectively pressurize or vent each tank of a propulsive stage vehicle if the tanks have a common bulkhead, this requirement is subject to the limitations outlined in the following paragraph. This capability shall be available with the Orbiter cargo bay doors open or closed.

Payload Fluids Safety Devices

A. Relief capability shall be provided for pressurized tanks which automatically limit maximum pressure. Venting shall be to space or to a tank at lower pressure, and shall be arranged so that mutually reactive fluids cannot mix and result in a fire or explosion.

B. Payload propellants shall be dumped prior to landing in theOrbiter.

TABLE G-6 (CONTINUED)

Payload Special Emphasis Safety Devices

A. Ordnance:

(1) Housings, interlocks, redundancy, grounding, isolation and safety devices shall be provided on explosive charges so that no single detectable failure or combination of undetectable failures shall result in premature detonation.

(2) Contaminant-free separation techniques shall be used for component separations that take place in or near the Shuttle.

B. Manipulation:

A restraint system shall be provided for the propulsive-stage vehicles in the Orbiter cargo bay which prevents contact of the vehicle with Orbiter structure or equipment in the event of partial or total release from the attachment points.

C. Radioactive Material:

Spare-shielded containers shall be available in which radioactive materials can be temporarily stored in the event of an accident.

Payload Safety Warning Devices

Payload Caution and Warning to the Orbiter - The payload shall provide such information to the Orbiter as is necessary to indicate its status as a payload to ensure safe Orbiter operations. This information shall include payload status and caution and warning data.

A. Provisions shall be made for presenting immediately to the Shuttle crew and personnel, hazardous/emergency warning for conditions originating within the payload while the payload is mounted to or in the Orbiter.

B. All payload subsystems incorporating redundancies shall include a means of verifying satisfactory operations of each redundant path.

C. Provisions shall be made for presenting to the Shuttle crew, payload status data that indicate safe payload conditions and potentially hazardous payload conditions. The payload is responsible for locating sensors within the allowable payload envelope sufficient to monitor the conditions of the payload and to detect potentially hazardous payload conditions.

D. Potentially hazardous conditions that may exist at the interface between the Orbiter and the payload will normally be sensed by and controlled by the Orbiter. The payload shall provide sensing of potentially hazardous conditions at the Orbiter interface.

Payload Toxicity, Corrosive, and Fire Warning Devices

A. Capability shall be provided to detect potential tank failures by measurement of fluid pressures, temperatures, tank strans, etc.

B. For propulsive stage vehicles with propulsion tanks using common bulkheads, differential pressure between the two tanks, common bulkhead strain, or other indications of potential failure, shall be monitored by the Orbiter crew.

C. Payload propellant temperatures and pressures shall be monitored.

TABLE G-6 (CONTINUED)

Payload Safety Operations Requirements

Payload Fluids Safe Operations

A. Emergency procedures shall be available for handling, containing, and disposing of spilled hazardous fluids or material so as to safeguard the personnel, Orbiter, and payload, in that order.

B. Mutually reactive fluids shall not be handled or transferred simultaneously, except when handled as a prepackaged module.

C. Transfer lines in pressurized areas, including double-walled lines, shall be purged and cleaned after the transfer of hazardous fluids and before breaking plumbing connections.

D. Dumping of propellants and pressurants from a retrieved propulsive stage vehicle shall be accomplished before initiation of the Shuttle Orbiter deorbit maneuver. Means of verification of the dump shall be provided.

E. Pressurizing gas on propulsive-stage vehicles shall be isolated from the stage tanks until immediately prior to release of the vehicle from the Orbiter.

F. Procedures shall be available for extravehicular inspection and release or re-attachment of partially released or depressurized propulsive stage vehicles in orbit.

G. Cleanliness of the propellants and all materials and components in normal contact with the fluids shall be controlled so that spontaneous decomposition in normal and emergency environments is not possible.

Payload Manipulation and Management Safe Operations

A. Capability shall be provided for visual inspection of an Orbiter payload before initiating deployment from or retrieval and loading into the Orbiter cargo bay.

B. Positive indication shall be provided to the Orbiter crew that a retrieved payload has been properly secured in the cargo bay before closing the cargo bay doors.

C. Emergency procedures shall be available for the release, handling, and transportation of remotely controlled payload components in the event of failure of the handling mechanism, or of damage to the packaging of payload components.

Payload Safety Design Requirements

Structural Strength

A. All payload primary structure shall be designed to be fail/safe by remaining integrally attached and remain within the 15- by 60-ft allowable payload envelope after any single payload failure and after being subjected to Shuttle Orbiter crash-landing loads.

B. All payload pressure vessels shall be designed to be fail-safe by remaining unruptured and be able to contain any fluids in the vessels after any single payload failure and after being subjected to Shuttle Orbiter crash-landing loads.

C. All payload pressure-stabilized structures shall be designed to be fail-safe as defined for primary structure and pressure vessels above after loss of stabilizing pressure.

D. The support structure for pressure-stabilized payload elements within the Orbiter shall allow Orbiter de-orbit, re-entry, and landing following loss of pressurization in the pressure-stabilized payload element while in the Orbiter payload bay in orbit.

TABLE G-6 (CONTINUED)

E. The factors of safety of payload pressure vessels while in or near the Orbiter shall be at least equal to the factors of safety for Orbiter pressure vessels.

F. Propulsive-stage vehicle pressures shall be limited while in or near the Orbiter so that the factors of safety are at least equal to the factors of safety for Orbiter pressure vessels.

G. Gaseous content of pressurized containers and tanks shall be small enough so that rapid isentropic expansion into the Orbiter cargo bay will not result in overpressure of the bay.

H. Plumbing connections for hazardous fluid transfer in pressurized areas shall be double-walled contained with the capability of venting the space between the two containers to (1) space while in flight, and (2) to GSE holding tanks or vents while on the ground.

I. The propulsive-stage vehicle shall be supported within the Orbiter so that failure of any one structural support member will not jeopardize support of the propulsive-stage vehicle during return to earth and/or during any other mission phase.

J. High-pressure vessels shall be protected to avoid abnormal mechanical impacts. Instrumentation to signal and record undesired mechanical contacts will be considered.

K. Pressure vessels shall be qualified in ground testing to Shuttle-induced operational environment levels, including the applicable safety factors.

Fluids Management

A. Separate lines distinctly marked and keyed shall be used for the transfer of fuel and oxidizer. They shall be separated by a sufficient distance to prevent mixing of reactant fluids in space whn close to the Orbiter.

B. Capability shall be provided to purge or dump into space a toxicant, contaminated, corrosive, or flammable atmosphere from a pressurized Orbiter payload.

C. Capability shall be provided for the Orbiter crew to vent and dump pressurized, flammable, or hazardous payload fluid into space within the time constraints imposed by any credible abort situation. This capability shall be available with the payload bay doors open or closed.

D. Toxic, flammable, or corrosive fluid containers shall be located in unpressurized volumes of pressurized payloads, or shall be double-walled contained with the capability of dumping the fluid into space or off-loading to another double-walled container, and of venting the space between the two containers to: (1) space, and (2) to GSE holding tanks while on the ground.

Propulsive-Stage Requirements

A. Propellant shut-off valves shall be provided upstream from all start valves so that inadvertent start-valve opening would not start engines on propulsive-stage vehicles in or near the Orbiter.

B. The design of the propulsive-stage vehicle control system shall only allow supply of electrical energy to the start valves of the rocket engines following positive action by the Orbiter crew and/or ground crew during stage vehicle countdown in orbit.

C. A backup means shall be provided for the Orbiter crew to vent or pressurize propulsive-stage vehicles with a pressure-stabilized structure.

D. All pressure vessels shall be capable of being vented to control pressures in the event of a pressure rise above their rated pressures.

E. For propulsive-stage vehicles with propulsion systems using common bulkheads, the design of the prouplsion system shall not allow pressurization of both tanks to occur so as to exceed the allowable differential pressure between tanks.

F. All payload propellant tanks shall have the capability of dumping the propellant without hazard to the Shuttle and Shuttle equipment.

G.7 MULTIPLE REUSE OF THE SAME SPACECRAFT

The hazard analysis of a spacecraft utilized for a single mission and the hazard reduction and residual hazard management have been covered in the SOAR-II reports and in part in these other safety discussions. They consider all of the operations and the design potential hazards to the Shuttle and to the Tug when it is used. All missions have the potential of an abort and of a crash landing. Some missions are planned for satellite survival upon Earth return and landing and it is these latter satellite types that may be refurbished and reused for later missions.

Potentially reusable spacecraft can vary in complexity of systems all the way from the simple LDEF with no active systems to the advanced technology satellite with new sets of experiments and some subsystems for each mission. The degree of design for refurbishment and reuse can be expected to vary especially since reuse design features are generally not now used. System accessibility, short life component replacement and the like will be used in the reliability and quality assurance activities before each satellite reuse.

Safety assurance along with quality and reliability will be a factor in decisions to fly a reworked satellite. The preciseness will depend upon the actual knowledge of the reworked condition of the satellite. This is in part made up of the condition of the reworked systems and otherwise derives from the satellite condition assessment after the previous flight. This condition assessment is the critical refurbishment factor and is a key to safety.

Satellite subsystems that are not readily accessible for assessment such as tanks, piping, multi-layer insulation, and some structure, present assessment problems and their reasons for inaccessibility may also be a factor in not being designed for refurbishment. Rework costs control can discourage substantial tear down and replacements. If the satellite design is limited for refurbishment so that interior examinations would involve basic disassembly of complex systems or the breaking of primary flow paths, the system status for safety assurance may be uncertain unless added sensors and data are taken for system status and assessment.

To be suitable for the next mission, the satellite must be confirmed and selected components reworked or replaced to equal or exceed its minimum preflight condition of reliability and it must be verified by quality assurance that the original components and systems as well as the refurbished ones meet or exceed the minimums. In attaining this physical state, the satellite safety provisions can be achieved. Several satellite refurbishment actions are potentially evident; the condition monitor that covers in-flight performance as well as in-flight environment with sufficient data to recap the data trends can lead to greater on-board instrumentation as well as greater quantity of telemetry and the possibility of on-board records, Table G-7. Correlation of preflight tests with mission operations would be a part of the data trend analysis.

Correspondingly, improvements should be made in satellite subsystem accessibility for condition assessment as well as refurbishment. The segregation of high-maintenance components can affect many areas if the satellite recycle costs and time are to be held to a minimum. Less than complete satellite upgrading will be reflected in increased risks to the mission effectiveness and to the the Tug and Shuttle safety. Specific knowledge of these risks may make the new flight readiness review more crucial.

Additive components that will contribute to the capability of assessing the satellite condition and in some cases will enhance the depth of the caution and warning or provide precursor advice of preventative maintenance needs or the need for special examinations could include the features listed in Table G-8. Much of the data generated would be by telemetry or recorded because of the interpretive load; however, caution data would be of direct interest to the Shuttle. In a sense, some of these data are added to provide confidence in the level of risk of using a refurbished satellite in the mission. Other data are sought to provide for an assessment of satellite condition toward the required level of refurbishment for the subsequent satellite mission.

The satellite environment recorded history can be important where exposure to temperatures outside of the temperature tolerances could result in substantial electronic component replacements. These data, analysis and refurbishment action are properly refurbishment-oriented and reflects in reliability and quality assurance. It does directly reflect on safety assurance where the satellite condition is uncertain or where the point in life span of a component is unclear.

TABLE G-7
INTERFACE IMPACTS OF SAFETY

ACTION	FUNCTION	INTERFACES
Condition monitor	In-flight performance monitor	Telemetry and onboard recorders
	In-flight environment monitor	Telemetry and onboard recorders FSE equipment monitors FSE on-board monitors
	Data trend analysis	Preflight testing Subsystems tests System readiness Integrated payload preload tests
Improved Satellite subsystems accessibility for assessment	Condition inspection at refurbishment	Access openings Redundant interconnects Partial disassembly Component redesign for access
Refurbishment based upon condition monitor	Analysis of condition monitor data and rework-retest decisions	Increased data monitor Increased testing to confirm condition
Improved Satellite design for refurbishment	Segregate high-maintenance components	Structure Subsystem components Tanks Insulation

TABLE G-8

POTENTIAL SAFETY INTERFACE COMPONENTS SATELLITE

PRIMARY STRUCTURE	Strain gage monitors Accelerometers Temperature surveys
TANK STRUCTURE	Strain gage monitors Accelerometers Temperature surveys Acoustical emission monitors Pressure surveys Leak detectors
SUBSYSTEMS	Thermal history Vibration pickups Mechanical systems monitors
GENERAL	Contamination Overpressure sensors

G.8 REFERENCES

G1. Space Shuttle Program Level II Program Requirements, JSC-07700.

a. Volume X, Flight and Ground System Specification, 20 March 1973.

b. Volume XIV, Payload Accommodations, 13 April 1973.

c. Volume XIII, Safety Reliability and Quality Assurance Requirements

G2. NASA Headquarters Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program, NHB 5300.4(1D), December, 1972.

G3. JSC Letter, NA/73-M-L50-LA-1-119, 18 June 1973, enclosing Draft Section 11.0, Volume XIV, JSC-07700, "Safety Assurance for Space Shuttle Payloads," dated 7 June 1973.

G4. AIAA Paper No. 73-615, "A Concept for Space Shuttle Payload Ground Operations," Gene McCoy, KSC/NASA, July 1973.

Appendix H

PAYLOAD CONTAMINATION ANALYSIS

Prospective payloads for the Space Shuttle have cleanliness requirements significantly greater than are presently being considered for the orbiter bay. In addition, delivery vehicles of the past have been a concern for only the first few minutes of flight. The Shuttle, with its revisit and servicing capability, will extend contamination control concerns beyond what occurs in the payload bay. Consideration must now be given to what the orbiter does to the spacecraft as it is deployed or retrieved and what it does to the general environment in the payload vicinity.

The purpose of this analysis is to expand on the contamination control requirements identified in the SOAR-II study for payloads identified as involving 10,000 class cleanliness standards. Imposing a 10,000 class cleanliness on the orbiter is not necessarily the most practical or perhaps even a possible way of meeting these requirements. The approach taken in this analysis has been to examine two representative spacecraft, the Large Space Telescope (LST) and Earth Observatory Satellite (EOS), in some depth to discern what the cleanliness drivers are, and then to formulate suitable contamination control concepts. These control concepts were synthesized from techniques evolved for Skylab and the Apollo Telescope Mount (ATM), techniques proposed for LST, and successful past practices. An attempt was made to identify the most suitable manner in which to institute the proposed control methods, i.e., how should the task be divided between the orbiter and payload, and when is hardware design more effective than operations or procedures and vice versa.

The critical contamination control areas of the LST are shown in Figure H-1. The most critical areas are the Scientific Instrument Package (SIP) and Optical Telescope Assembly (OTA) in which the spacecraft sensor optics are contained. Thermal control surfaces and solar arrays are contamination-critical to a lesser degree, however, they involve all the external surfaces of the spacecraft. The area within the Spacecraft Service Module (SSM) contains equipment such as gyros, electronics, and valves which are either heremetically sealed or otherwise relatively insensitive to contamination compared to the other

FIGURE H-1

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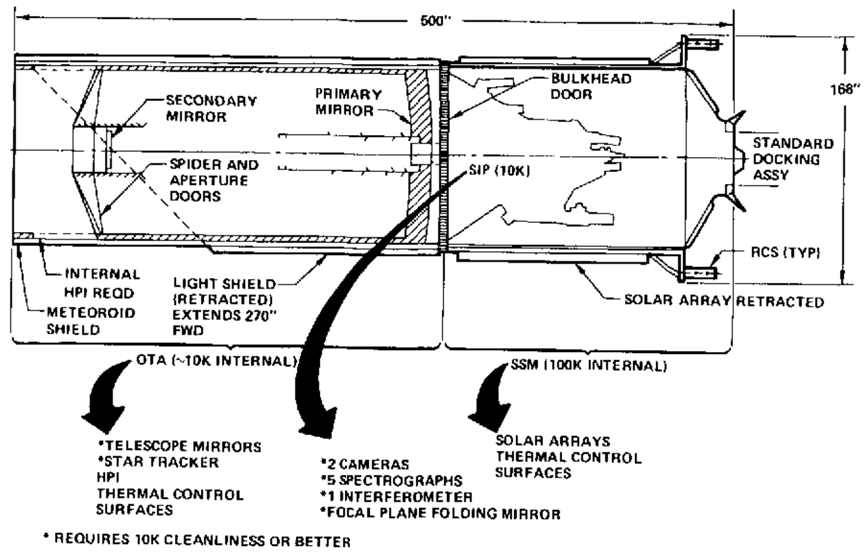
LST CRITICAL CONTAMINATION CONTROL AREAS



items mentioned.

Likewise, Figure H-2 shows the EOS and its contamination-critical areas. Again the optics are most critical with the Thematic Mapper probably being the most susceptible to degradation. Detector coolers are used on the EOS and are thermal control areas especially sensitive to ice or frost. The other external thermal control surfaces, solar arrays, and antennas are also of concern but to a lesser degree.

Table H-1 presents an overview summary of the contamination control methods proposed for these spacecraft. These techniques require little more of the orbiter than is currently specified in the Space Shuttle System Payload Accommodations document, JSC-07700. Table H-2 summarizes the suggested orbiter contamination control requirements.

Both LST and EOS conceptual and Phase A studies have specified particulate contamination control to the 10,000 class level. In addition, non-particulate contamination levels of 10 PPM for low vapor pressure materials and 15 PPM

FIGURE H-2

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EOS CRITICAL CONTAMINATION CONTROL AREAS

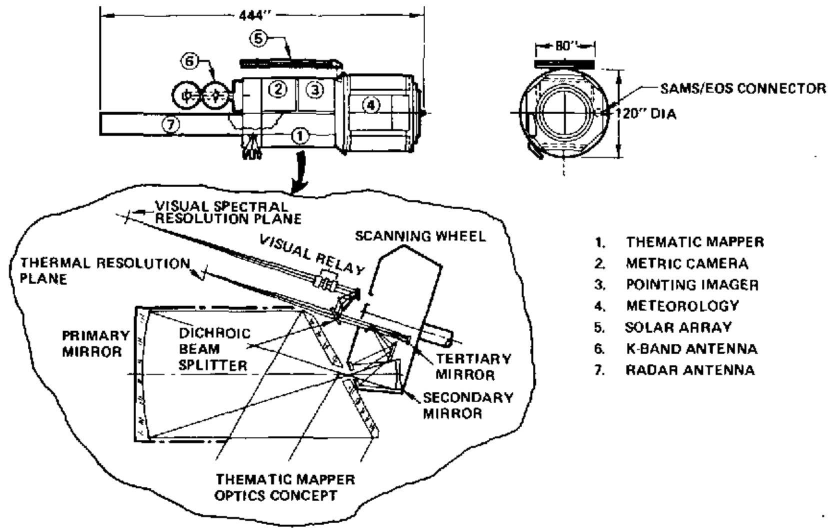

TABLE H-1

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SUGGESTED LST AND EOS CONTAMINATION CONTROL METHODS

LST	EOS	
X		POSITIVE INTERNAL ΔP EXCEPT WHEN OPERATING
X		10K CLASS CLEAN, 30% HUMIDITY AIR PURGE WHEN MANNED
X		10K CLASS CLEAN, DRY GN_2 PURGE WHEN UNMANNED
X	X	CLEAN BAG USED DURING GROUND HANDLING
X	X	INHIBIT ORBITER DUMP, VENT, AND RCS (IF PRACTICAL)
X	X	AUTOMATED PROTECTIVE COVERS USED ON CRITICAL SENSORS
X	X	SPACECRAFT APPROACHED BY ORBITER FROM SELECTED DIRECTION
X	X	ALLOW SEVERAL DAYS FOR OUTGASSING AND CLOUD DISPERSAL

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TABLE H-2
SUGGESTED ORBITER CONTAMINATION CONTROL REQUIREMENTS

- PAYLOAD BAY
  - 100,000 CLASS CLEAN ATMOSPHERE
  - *VISUALLY CLEAN SURFACES (SMOOTH LINING PREFERRED)
  - *50% MAX RELATIVE HUMIDITY
- PAYLOAD MANNED SERVICE PROVISIONS
  - 100,000 CLASS CLEAN ATMOSPHERE
  - *10 PPM LOW VAPOR PRESSURE (10^{-2} MM HG) NON-PARTICULATES
  - *15 PPM HIGH VAPOR PRESSURE, HARD TO OXIDIZE NON-PARTICULATES
  - *30% MAX RELATIVE HUMIDITY
  - 100,000 CLASS CLEAN AREA (E.G. DOCKING MODULE)
- ORBITER EFFLUENTS
  - NO DUMPING OR VENTING NEAR PAYLOAD
  - *RCS INHIBIT DURING CRITICAL MAINTENANCE PERIODS
  - SMALLER (25 LBF) THRUSTERS AND/OR LARGER ATTITUDE DEAD BAND

*NEW OR MORE STRINGENT THAN EXISTING REQUIREMENT

for high vapor pressure materials have been used in the LST contamination control system concept of Reference H1.

It has been determined that the experiment optical surfaces are most contamination critical, followed by certain spacecraft sensors such as star trackers. Thermal control surfaces and solar arrays are sensitive only to relatively gross levels of contamination.

Experiment optics are affected by both surface contamination and clouds which may surround the spacecraft. For both the LST and EOS, surface contamination is the more serious because it is persistent whereas a cloud of outgassed molecules or particles will soon be swept clear of the spacecraft. Surface contamination may be deposited in particulate form (dust, water droplets, RCS unburned propellant, etc.) or non-particulate form (films of oil, frost, soot, etc.).

Particulate deposits tend to scatter incident radiation, thereby obscurring faint objects (which are a major source of interest for LST). It is to be noted that particulate build-up is a function of time and that optics left in a 10K clean room a sufficient period can exhibit 100K clean room contamination levels. This was amply demonstrated during the oTM two-year development period. Although the entire ATM was constantly kept in a 10K clean environment during this two-year period, only those experiments further protected by aperture covers and a class 100 air purge did not require recleaning prior to launch. The experience of ATM would suggest that 10K class cleanliness is probably too stringent for an entire spacecraft while it is inadequate for sensitive optics.

Non-particulate contamination in the form of surface films is especially deleterious to optical surfaces intended to transmit or reflect short wavelength (i.e. ultraviolet) radiation. Degradation of object brightness and resolution, and loss of spectrum bandwidth are the result of surface films. Non-particulates are usually produced by material outgassing and effluents introduced into the surrounding atmosphere. Films of these non-particulates will form through condensation and adhesion. Important considerations are therefore atmospheric dew point, optics surface temperature, contaminant vapor pressure and concentration. Non-particulates caused by outgassing can be effectively controlled by proper material selection during design and adequate bake-out and cleaning during fabrication. Humidity and temperature control of the atmosphere surrounding the spacecraft will eliminate water condensation problems. (Regarding this matter, if the orbiter bay temperature and humidity levels specified in JSC-07700 are simultaneously 43°F and 43 grains/pount of dry air, respectively, the dewpoint will be exceeded.) However, the effect of humidity in conjunction with trace contaminants such as ammonia may create compounds (e.g. ammonium hydroxide) which will chemically attach surfaces more readily than either non-particulate alone. Localized dry GN_2 purges are effective in controlling this problem. Controlling relative humidity to 50 percent or less has been found effective in suppressing electronics arcing and chemical action.

The above contamination mechanisms and control techniques are understood by industry and are common to expendable booster operation. The Shuttle however extends contamination concern to orbital operations. Orbiter outgassing, venting, dumping and RCS operation must now be controlled to avoid contaminating thermal control, and optical surfaces on orbit. Outgassing control is essentially a design problem, however, orienting the orbiter such that the payload is upstream will assist in reducing the outgassed constituent level at the payload. Control of other effluents may best be approached through operational procedures.

Orbiter venting and dumping should be completely inhibited during payload deployment, rendezvous and critical servicing periods. An example of the latter is when optics are exposed during automated replacement of instruments. Inhibition of RCS operation is probably not feasible during docking or deployment, rather the use of smaller thrusters and/or a selective orbiter approach direction is preferred. The latter technique should be effective since RCS contaminant deposition on surfaces occurs essentially in line-of-sight situations.

In summary, there appears to be no justification for pursuing more stringent orbiter bay atmosphere cleanliness requirements than proposed in JSC-07700. However, an orbiter bay surface cleanliness level or cleaning procedure compatible with assurance of a 100K cleanliness atmosphere should be specified.

Past experience with clean rooms indicates that 100,000 class cleanliness can be maintained with reasonable care if the room has been properly designed. Nooks and crannies, ledges, insulation and other such particle collectors and generators could render a 100K class clean objective practically impossible. Therefore, careful consideration should be given to this matter during design of the orbiter bay.

Where more stringent payload cleanliness requirements have been found, they appear to be a reaction to very stringent cleanliness requirements of optical surfaces which themselves usually cannot tolerate a 10K environment. Therefore, it appears that a more practical approach is to keep the spacecraft as clean as the 100K orbiter environment permits, and provide localized protective covers and purges where necessary. These localized areas are relatively small compared to the rest of the spacecraft. The covers will also be utilized for protection during spacecraft deployment and revisit by the Shuttle. They should be RF commandable, well sealed and provide an internal dry GN_2 purge. The spacecraft on-board purge system need not be large if, during periods it is not free-flying, the orbiter or GSE would supply the purge gas.

H.1 TECHNICAL ANALYSIS

In general, spacecraft cleanliness requirements tend to become more stringent as program definition progresses. This trend was evident during the SOAR studies where seven baseline spacecraft increased in cleanliness requirements while none decreased. Experience with past programs such as Skylab has shown that unless contamination control techniques are introduced at the design definition phase, significant schedule and funding impact may be encountered.

Hence, it is the purpose of this analysis to contribute to the definition of Shuttle contamination control requirements as early as possible in its program timeframe. During the course of the SOAR-II study the most stringent spacecraft cleanliness requirement identified was class 10,000 per Federal Standard 209A - Clean Room and Work Station Requirements, Controlled Environment. A review of the SOAR-II payloads reveals three spacecraft which require 10K cleanliness: the Large Space Telescope (LST), Earth Observatory Satellite (EOS), and High Energy Astronomy Observatory-C mission (HEAO-C). Program and configuration definitions of HEAO-C have undergone major changes since its evaluation in SOAR-II; therefore, this payload was not included in the detailed examination afforded the other two spacecraft.

The SOAR-II studies identified potential contaminant sources, examined orbiter effluent discharges, and identified methods of controlling spacecraft contamination. Since 10 different spacecraft were considered, the contamination control measures were general in nature in order to be all-encompassing. In this report the cleanliness requirements of the LST and EOS have been examined in greater detail and recommendations made specifically for these two spacecraft. These specific control measures are the most stringent to be encountered; however, many subsystem elements such as star trackers and radiometers are common to other spacecraft as well and recommendations should be applicable to them also in these instances.

H.1.1 Contamination Control Requirements

The contamination control requirements specified by NASA for the shuttle bay and identified for the LST and EOS are presented in this subsection.

H.1.1.1 Space Shuttle Contamination Control Requirements

The effluents expected from the Space Shuttle are listed in Table H-3 and their sources noted on Figure H-3. Of particular concern to payloads are contaminants present in the orbiter bay and contaminants introduced by the orbiter into the spacecraft's orbital environment.

The cleanliness requirements for the orbiter bay atmosphere as specified in the Space Shuttle Payload Accommodations document, JSC-07700, dated April 1973 are:

> Payload Bay Atmosphere. The Orbiter payload bay can be atmospheric controlled independent of other parts of the Orbiter structure while on the launch pad. Conditioned air purge will be supplied to the payload bay at the launch pad up to 30 minutes prior to propellant loading. At that time, GN_2 will be supplied up to lift-off. The purge capability is as follows:
>
> a. Flow rate - 0 to 200 lbs/min.
> b. Temperature - adjustable within the range from 45° to 120°F controlled to ±2°F of desired setting.
> c. Class 100,000. See Federal Standard 209A - Clean Room and Work Station Requirements, Controlled Environment.
> d. Air Humidity - 0 to 43 grains/pound of dry air.
> e. GN_2 Humidity - 0 to 1 grain/pound of dry air.
>
> The Orbiter payload bay is vented during the launch and entry phases and operates unpressurized during the orbital phase of the mission. The payload must provide the tankage and gases to accomplish payload bay repressurization if an inert atmosphere is required for entry.

On-orbit effluents are asterisked in Table H-7. Liquid dumping is especially critical to optical experiments and only emergency conditions would precipitate overboard dumping. Water management aboard the orbiter as defined in JSC-00700 is:

- Water Storage - 2 tanks containing 165 lb H_2O each.
- Fuel Cell Water - directed to storage tanks; or if they are full, to water sublimator and thence overboard.
- Emergency Dump - overboard through two heated nozzles
- Humidity Control Waste Water Condensate - three tanks, 100 lb. capacity each

TABLE H-3
SHUTTLE EFFLUENT DESCRIPTION

External Tank System (ETS)

1. LO_2 Tank Vent Media - LO_2, GO_2
2. Intertank Skirt
   GN_2 Pre-flight Purge
   Vent Location TBD
3. ETS/Orbiter Separation Residuals
   LH_2, GH_2, LO_2, GO_2

Solid Rocket Booster (SRB)

4. Typical SRB Exhaust Composition of PBAN Propellant

Al_2O_3 > 1%		FeCl < 1% by Wgt	
CO	N_2	$FeCl_2$	OH
HCl	CO_2	Cl	H
H_2O	H_2	$AlCl_2$	

4a. Motor Emergency Thrust Termination

5. Separation Thrusters - Typically PBAN Type Propellant, Possibly None Required

Orbiter/Payload

6. Pyrotechnic Separation
   Combustion Products?

*7. Reaction Control System (RCS)
   Monopropellant Hydrazine N_2H_4
   Normal Operation Above 70K Feet
   N_2, H_2, NH_3, H_2O (Trace), He (Trace)
   GN_2 Pre-flight Purge of RCS Compartment

*8. Electrical Power System (EPS)
   Battery Vent - GH_2 Normal Ops
   - KOH Failure Mode

*9. Fuel Cells/Supercritical Tankage
   a. GH_2 Purge Media - GH_2, He
   b. GH_2 Relief - GH_2
   c. GO_2 Purge - GO_2, GN_2
   d. GO_2 Relief - GO_2
   e. H_2O Relief - H_2O (System Overpressure)

10. Payload Bay & Midbody Vents (8 Symmetric)
    Media - GN_2 Pre-flight Purge
    - Cabin Atmosphere from Airlock Operation

*11. Environment Control & Life Support System (ECLSS)
    a. N_2 Pressure Relief
    b. Sublimator Dump During System Overpressure
    c. Avionics Bay Pressure Relief
    d. Waste Management Vacuum Vent
    e. Water Dump (Emergency)
    Media - H_2O, O_2, N_2, CO_2, Trace Methane

12. Payload LO_2 Vent - GO_2, LO_2

13. Oxidizer Panel, Orbiter/Payload Launch Umbilical, Payload LO_2 Dump - LO_2, GO_2, N_2

14. Fuel Panel, Orbiter/Payload Launch Umbilical, Payload LH_2 Dump - LH_2, GH_2, He

15. Orbiter LO_2 Dump - LO_2, GO_2, N_2

16. Orbiter LH_2 Dump - LH_2, GH_2, He

17. Main Propulsion System (MPS)
    Normal Exhaust - H_2O, H_2, O_2

*18. Orbital Maneuvering System (OMS)
    Propellants - MMH & N_2O_4
    Normal Exhaust

N_2	1%	H_2	1% by Wgt	
H_2O		O_2	OH	
CO_2		NO	H	
CO		O	He	

    Trace Metals - Fe, Mg, V

*19. Auxiliary Power Unit (APU)
    Monopropellant - N_2H_4
    Normal Exhaust - N_2, H_2, NH_3

20. GH_2 Vent

*21. Orbiter Unpressurized Compartments
    GN_2 Pre-flight Purge - Vent Thru Seals and TBD

*22. Oil from Hydraulic Actuators & Valves

*23. Pressurized Cabin Structure Leakage
    O_2, N_2, H_2O, CO_2

*24. EVA, Portable Life Support System (PLSS)
    H_2O

*25. Orbiter Thermal Protection System (TPS)
    Outgassing - Large Carbon-Silica Molecules and Hydrocarbon Gases

*On-orbit effluent

FIGURE H-3
ORBITER EFFLUENT LOCATION

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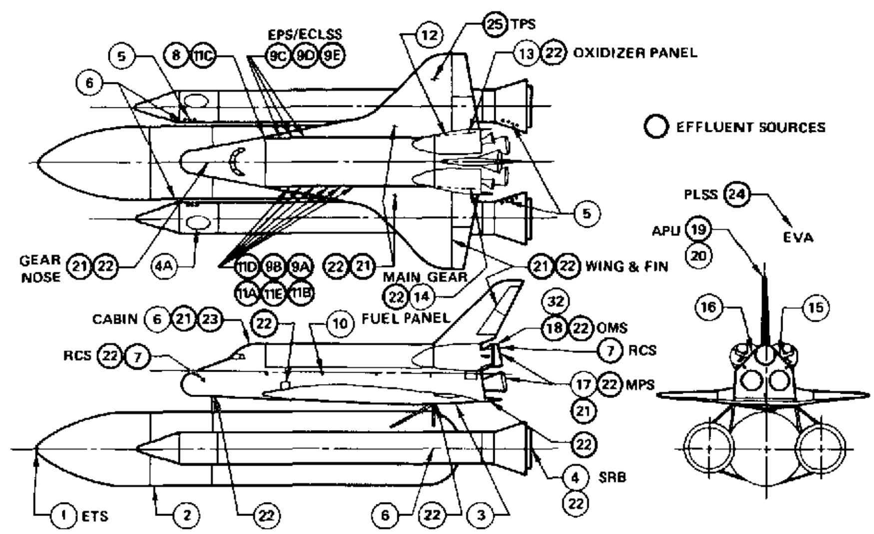


° Waste Management - collects and stores solid and liquid wastes

H.1.1.2 LST Contamination Control Requirements and Solutions

The Large Space Telescope mission objective is to place a large aperture (3 meter) near-diffraction-limited astronomy telescope in earth orbit, thereby permitting observation of celestial objects under conditions free of earth atmosphere obscuring effects. This results in three distinct improvements over ground based telescopes; (1) objects previously too dim may now be seen, (2) light wavelengths previously obscured (principally ultra violet below 300 nanometers) may now be sensed, and (3) optical resolution can be improved to the point where it is limited by design state-of-the-art rather than by environment. Clearly, the introduction of contaminants into the LST environment which encroach upon its sensitivity, spectral bandwidth, or resolution tends to obviate its purpose and usefulness to the scientific community. It is, therefore, important to identify which contaminants are deleterious to mission objectives and what means of their control are available.

Table H-4 lists the various LST mission requirements.

TABLE H-4

LARGE SPACE TELESCOPE MISSION REQUIREMENTS

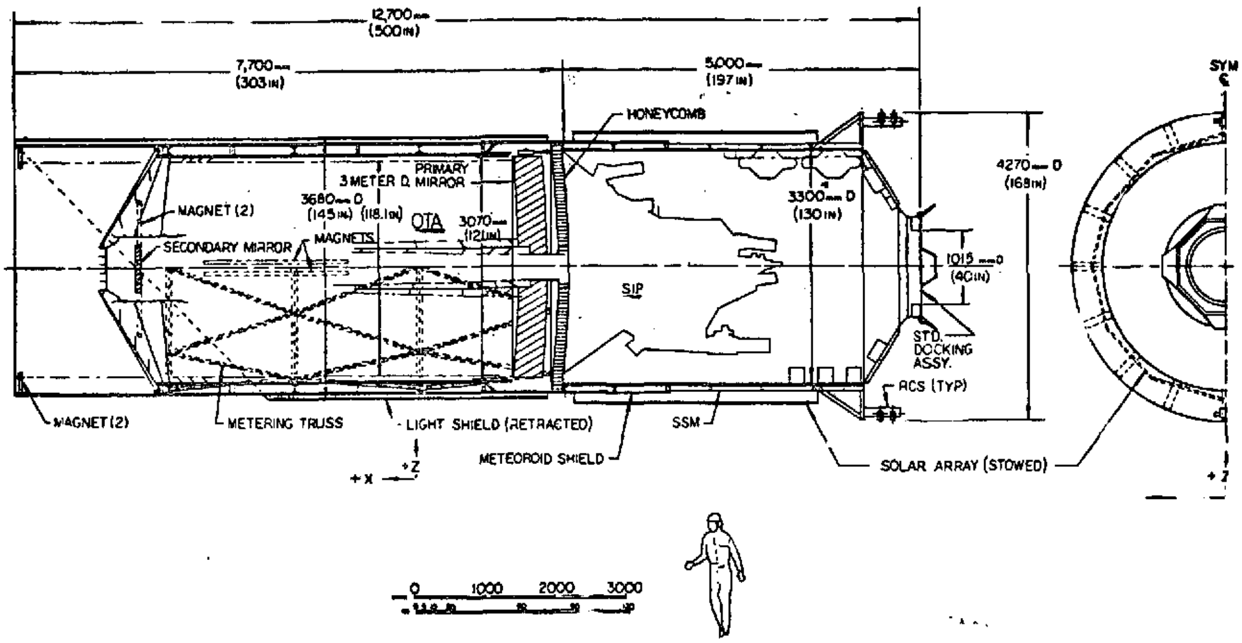
Characteristic	Value
Orbit Altitude (nmi)	330
Orbit Inclination (deg)	28.5
Mission Duration (yrs)	15
Spectral Range (nm)	110-5000
Spatial Resolution (arc-sec at 500 nm)	0.04
Wave Front Error (rms at 633 nm)	0.05λ

The LST, shown in Figure H-4, is composed of three major elements: the Optical Telescope Assembly (OTA), the Scientific Instumentation Package (SIP), and the Support Systems Module (SSM).

The OTA major elements include a 3-meter Ritchey-Chretien Cassegrain two-mirror system supported by a low coefficient of expansion carbon-epoxy truss structure. The optical mirrors and structure are enclosed in an aluminum cylinder which provides thermal, light, and micrometeoroid shielding. A sliding sun shade is extended after LST delivery on orbit to reduce entry of stray radiation. An aperture door at the OTA forward end prevents inadvertent viewing of the sun, moon, or earth from damaging the OTA or SIP. This door can also serve to prevent optics contamination during LST delivery, maintenance, and retrieval. The door is designed to withstand an internal pressure differential of 0.1 psig. The OTA aft end is closed off by the SSM pressure bulkhead. This bulkhead contains a normally open door in the optical path which is shut during orbital maintenance operations when the SSM is pressurized to a shirtsleeve environment.

The primary mirror is a monolithic casting of CerVit glass having an aluminum reflective surface overcoated with soft MgF_2. The MgF_2 surface is not considered cleanable because it is soft, being deposited on the aluminum at room temperature instead of the usual 250°C so that the aluminum will not lose its reflectivity.

FIGURE H-4
LST REFERENCE DESIGN LONGITUDINAL CROSS SECTION



The Scientific Instrument Package is located aft of the pressure bulkhead in the optical path. It is a system which can select, analyze, and process incident radiation energy. Energy reaching the focal plane may be selectively imaged on a variety of detectors and spectrographs. Processed data is then transmitted to ground receivers. Although final selection of SIP instruments has not yet been made, Table H-5 presents typical candidates identified in Reference H1. Arrangement of these sensors is shown in Figure H-5. The instruments are of modular design which will enable their being serviced in orbit or replaced with other experiments during the course of the program.

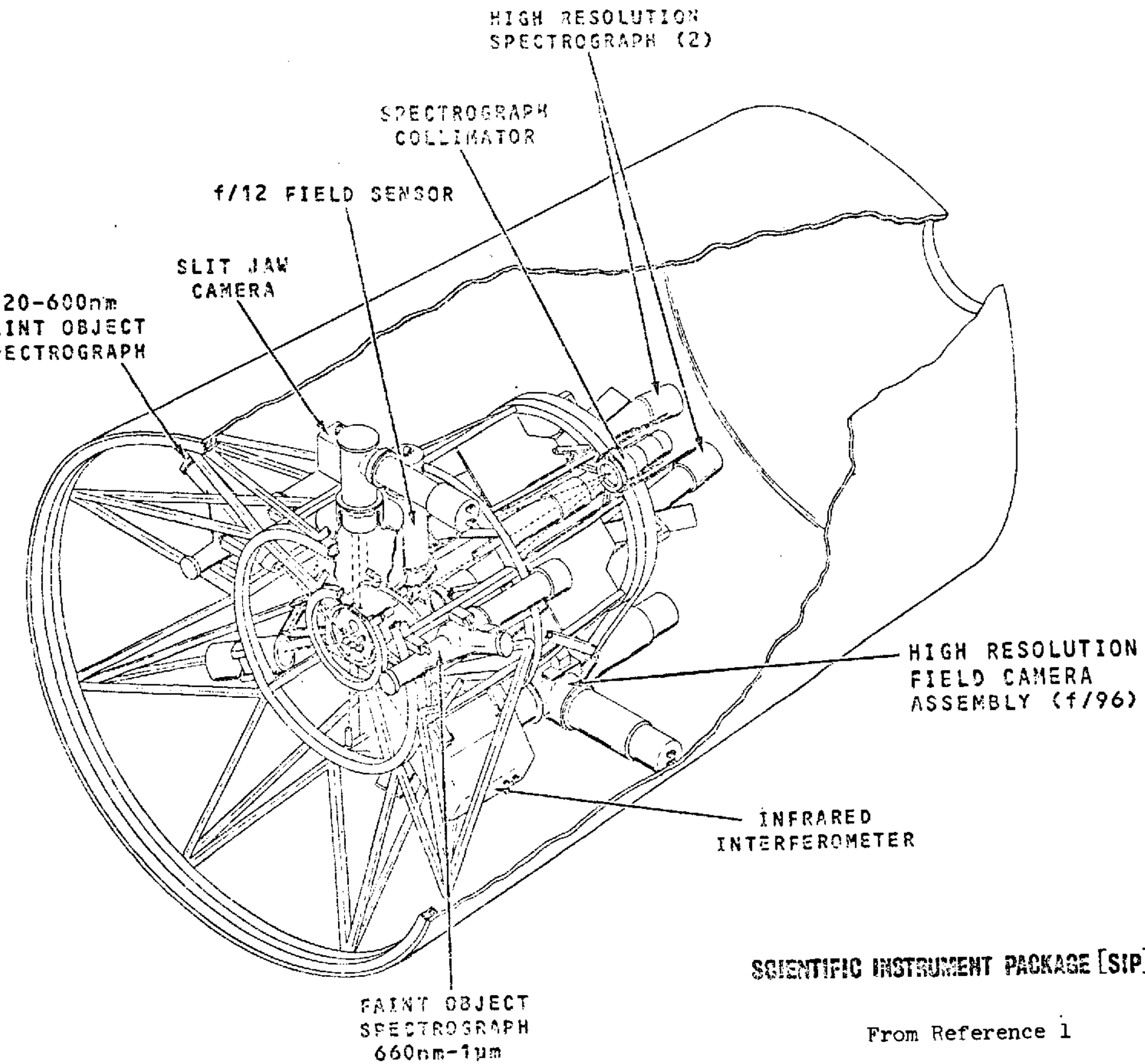
The observed radiation follows the path from primary to secondary mirror, thence to a folding mirror assembly at the focal plane located in the SIP, thence to the individual instruments. The optical paths of the instruments are sealed, providing inherent contamination insusceptibility except for the entrance window. If orbital maintenance involves instrument disassembly, this feature will be nullified and an increased probability of contamination will occur.

TABLE H-5
SIP INSTRUMENTS & PERFORMANCE SUMMARY

INSTRUMENT	SPECTRAL RANGE (NANOMETERS) λ_1-λ_2	LIMITING RESOLUTION (n rad)	SPECTRAL RESOLUTION $\lambda_1/\Delta\lambda$	LIMITING MAGNITUDE MV (S/N=2)
High Resolution Field Camera f/96	115-1100	160	-	32.5
Wide Field Camera f/12	160-700	840	-	30.5
High Spectral Resolution Spectrograph I	115-180	-	4.5×10^4	17.2
High Spectral Resolution Spectrograph II	180-350	-	3×10^4	19.7
Faint Object Spectrograph I	115-160 160-220	- -	1.25×10^3 1.75×10^3	21 22.5
Faint Object Spectrograph II	220-350 350-660	- -	1.23×10^3 0.75×10^3	25 25
Faint Object Spectrograph III	660-1000	-	1.5×10^3	22
Mid-IR Interferometer	1000-5000	-	-	13

FIGURE H-5

SIP CONFIGURATION



SCIENTIFIC INSTRUMENT PACKAGE [SIP]

From Reference 1

The System Support Module shown in Figure H-6 structurally interfaces with the OTA and contains the LST attitude control equipment, electrical power and distribution subsystem, communications and data handling subsystem, thermal control equipment, contamination control equipment, launch vehicle structural interface, and docking structure. An entry door on the SSM aft end permits personnel egress for LST servicing while on orbit. With the pressure bulkhead door closed and the aft door connected to the Shuttle, possibly via a Sortie Lab, the SSM can be pressurized to a 14.7 psia shirtsleeve environment.

The electrical power system uses two deployable aluminum honeycomb solar arrays of 2 x 6 cm, 10-ohm-cm cells having a 12 mil coverslide. The RCS is a cold gas GN_2 system used for docking and emergency control. If the delivery vehicle is a Titan, the RCS would also provide attitude control during orbit adjust stage (OAS) operation, separation, sun orientation, and control moment gyro (CMG) spin-up. CMG's are normally used for LST fine pointing and maneuvering and are desaturated magnetically. Therefore, during normal LST operation there is no RCS activity.

The cleanliness requirements of the LST vary throughout the literature and Table H-6 presents a summary of the ranges encountered. Where conflicting requirements are shown, Reference H1 was considered to govern.

An attempt was made to identify the LST contaminant-sensitive areas and their degradation modes, References H4 through H6. Table 3-7 summarizes the evaluation results.

Contamination of the primary and secondary mirror system is especially critical in the form of a non-particulate (film) surface deposit. When a film depth of 1/4 the wavelength of incident radiation is deposited on a mirror, the radiation reflected from the film top and bottom surfaces is 180° out of phase and will be dimmed or even extinguished. Oil molecules produce a large monolayer thickness such that relatively few layers can result in a film depth of 1/4 wavelength, especially in ultraviolet spectrum. Oil characteristically exhibit low vapor pressure and would produce a very persistent film at LST operating temperatures. While ultraviolet irradiation of organic films can cause polymerization, thereby producing an even more opaque and persistent film, the UV

FIGURE H-6

SUPPORT SYSTEMS MODULE (SSM) REFERENCE DESIGN

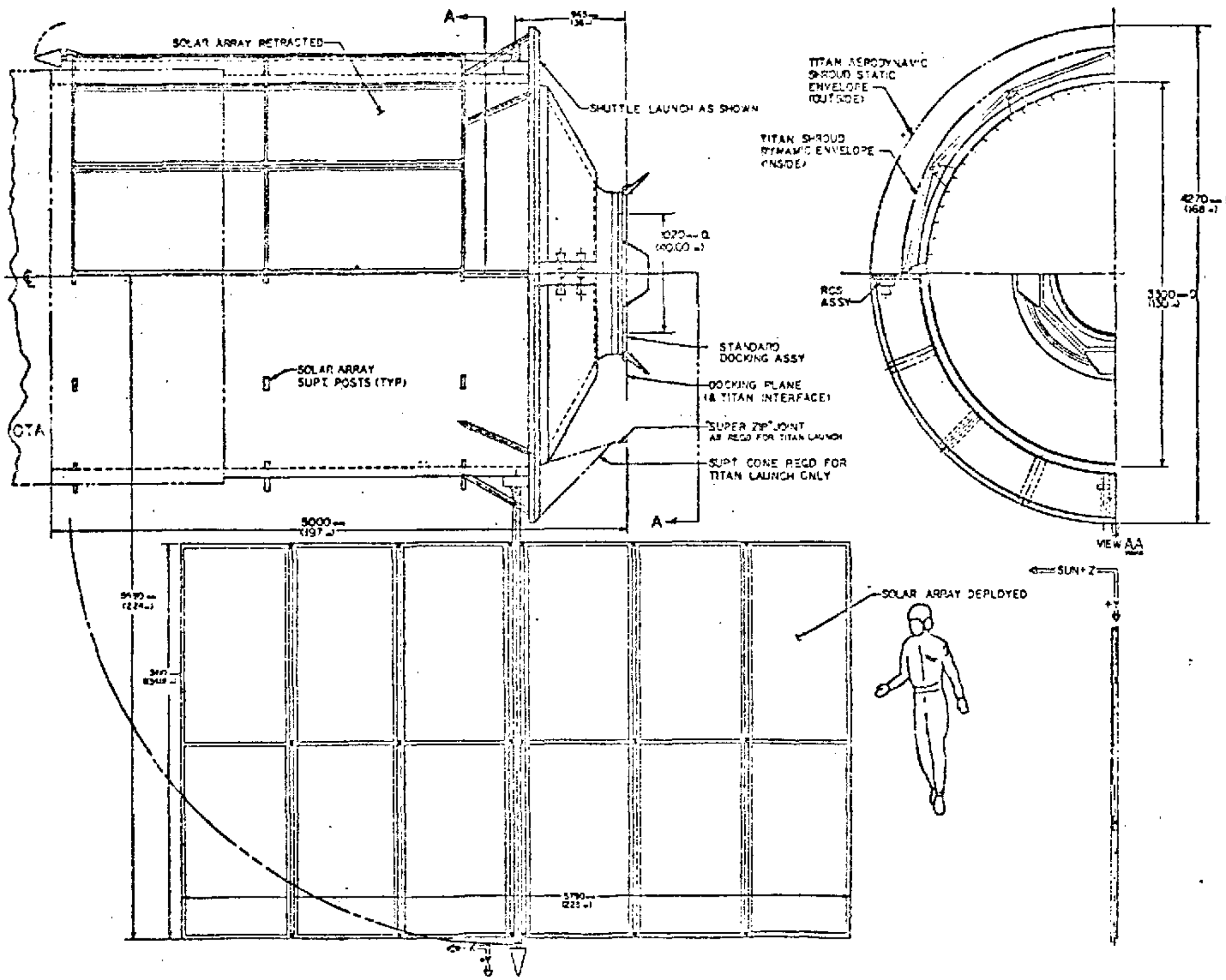


TABLE H-6

LST CLEANLINESS REQUIREMENTS SUMMARY

Contaminant	Acceptable or Design Level	Location	Ref.
Particulate	10,000 Class	SIP	H1
	100,000 Class	SSM	H1
Relative Humidity	30% 50% Max	SIP	H2 H3
Hydrocarbon Trace (Methane Standard)	1 ppm 15 ppm	 SIP	H3 H1
Ammonia	2.8 ppm	SIP	H1
Low Vapor Pressure ($\geq 10^{-2}$ mmHg) Non-Particulate	10 ppm	SIP	H1
Hard-to-Oxidize High Vapor Pressure Non-Particulates	15 ppm	SIP	H1

intensity to be observed by the LST is not expected to result in this problem. Surface films also create a double reflection of incident light which in an aggravated form produces image "ghosts" and fuzziness. This degrades the resolution power of the telescope.

Thus, film surface deposits on the primary and secondary mirror system tend to negate the three prime advantages which the LST has over earth based telescopes, i.e., superior resolution, bandwidth, and brightness sensitivity.

Particulate surface deposits on the primary and secondary mirrors are undesirable but not as critical as film contamination. Particles of dust or ice act as scatterers which increase the diffuse background light and decrease the image intensity. The resut is a decreased ability of the telescope to sense faint objects but little effect on bandwidth or resolution.

Molecular clouds in the LST vicinity will be created by the orbiter and LST RCS thrusters, venting, and outgassing. Depending on the cloud constituents,

TABLE H-7

LST CONTAMINATION CRITICAL ELEMENTS

ELEMENT	CONTAMINANT & DEGRADATION EFFECT			
	NON-PARTICULATE FILM DEPOSIT (E.G., SILICONE OIL, NH_3)	PARTICULATE DEPOSIT (E.G., DUST, WATER DROPS)	MOLECULAR CLOUD (E.G., GN_2, RCS PLUME)	PARTICULATE CLOUD (E.G., WATER DROPLETS, ICE)
Primary & Secondary Mirrors	• Reduces spectral bandwidth transmission, particularly in UV range. Worst at 1/4 λ. • Reduces reflectance and therefore ability to sense faint objects. • Produces ghosts about the image and therefore degrades resolution.	• Scatters incident radiation decreasing sensitivity and increasing background level (reduces signal-to-noise ratio).	• Decreases incident radiation filters out certain frequencies, decreases signal-to-noise.	• Scatters light, decreases signal-to-noise, creates false objects. Most scattering produced by .2 to 100 μ particles.
Focal Plane Folding Mirror	• Same as above	• Same as above	• Not applicable	• Not applicable
Field Camera Window	• Reduces spectral bandwidth • Reduces brightness sensitivity	• Same as above	• Not applicable	• Not applicable
Spectrograph Window	• Reduces spectral bandwidth		• Not applicable	• Not applicable
Star Tracker	• Decreases sensitivity, increases system jitter	• Decreases sensitivity, increases system jitter	• High voltage arcing if critical pressure is exceeded.	• False star lock-on, increases system jitter
Sun Sensor	• Relatively insensitive	• Relatively insensitive	• Relatively insensitive	• Relatively insensitive
Solar Arrays	• Virtually immune, operates at red end of spectrum where transmission & scattering losses are least. • High operating temp (150 °F) tends to vaporize films and water. • Corrosive films could attack cells at edges where not protected by cover slide.		• Insensitive to levels encountered in orbit	• Insensitive to levels encountered in orbit
Thermal Control Surfaces	• Can alter α/ε. Degradation tends to increase both α and ε toward unity.		• Not a problem	• Not a problem

certain light wavelengths will be scattered or absorbed. Once the orbiter has left the vicinity, the generation of molecular cloud matter is essentially limited to LST outgassing and its RCS GN_2. The former will be largely complete in 48 hours and, under normal conditions, LST RCS thrusting will not be used. The low effluent rate, residual earth atmosphere sweeping effect, and inherent small scattering cross section of molecules makes the molecular cloud effects of little concern to LST operation.

Particulate clouds, typically composed of ice and dust, can pose serious problems as light scatters, particularly when viewing faint objects. Water particles causing this phenomena are usually in the .2 to 100 μ range. The Skylab waste tank vent system underwent extensive tests and design changes to assure that no droplets over 6μ in size and preferably only H_2O vapor below the triple point would be vented.

There is no water generation or venting from the LST; therefore, once the orbiter departs the LST vicinity, the possibility of generating these contaminants is eliminated. Any cloud of ice or other particles left by the orbiter with the LST will be swept clear by the residual atmosphere in a matter of hours - or at most, days.

In examining the next major element in the optical path after the primary and secondary mirrors, attention is brought to the focal plane folding mirror (FPFM). This element directs focused radiation to the various SIP instruments. Deposit contaminants have similar effects on the FPFM as on the primary and secondary mirrors. Molecular or particulate clouds are not expected to be present at any significant concentration in this area.

A discussion with Kollsman personnel indicated that the scientific instruments of the SIP have closed optical paths which are not exposed to the environment. The contamination critical surface therefore is the instrument window. Again, the principle contaminant of concern is a film deposit on the window which can result in blocking shorter wavelength radiation and in reducing total bandwidth transmitted energy. Particulate deposits result in scattering with ensuing decreased brightness sensitivity and signal-to-noise ratio. Molecular or particulate clouds in the SIP are not expected to be present in significant concentrations to effect instrument operation.

Star trackers are sensitive to contamination which decreases target brightness or signal-to-noise ratio. This results in increased system jitter caused by electronic processing of the incoming signal. Film and particulate deposits are therefore of concern. Although molecular clouds are of little concern in the star tracker line of sight, they may be very significant is present in the electronics section. Some electronics designs are open to the environment to take advantage of in-vaccuo operation. If a residual atmosphere such as might be caused by outgassing is above a critical level, high voltage arcing could occur and damage the sensor. External particulate clouds scattering decreases the signal-to-noise ratio and increases system jitter. Exceptionally bright particles could cause false lock-on of the system.

A sun sensor for the LST has such an intense target that contamination does little to affect sensor performance, and the required contamination control techniques would be nominal.

Solar arrays operate at the red end of the visible spectrum where film and particulate surface deposit effects are minimal. Analyses performed for Skylab showed that retro rocket exhaust deposition has little effect on array performance. Typical array surface temperatures in daytime range from 130°F to 170°F and readily drive off moisture and other films. Each solar cell is protected by a coverslide; however, the cell edges are exposed to the environment. Conceivably, water/contaminant mixtures could chemically attack these areas; however, subsequent to the orbiter departure there should be no reason for such mixtures to persist.

Thermal control surfaces of the LST include high performance insulation (HPI), paints and coatings. The 24-layer aluminimized mylar HPI is located beneath the micrometeoroid shield and external to the SSM pressure shell, and thus is protected from orbiter RCS thruster impingement. Moisture is detrimental to HPI and could be a problem during pre- and post-launch periods. The specified Shuttle bay air and GN_2 humidity levels and temperature ranges result in dewpoints below expected LST surface temperatures which tends to alleviate moisture problems.

Reference 1 proposes that the exterior of the LST be painted with a white zinc orthotitanate (Zn_2TiO_4) paint of low absorptivity to emissivity ratio (α/ε = .12/.92 = .13) to minimize solar heating. Film and particulate deposits tend to degrade both α and ε optical properties toward 1.0 with the resultant effect of increasing the ratio and solar heating. Orbiter RCS exhaust is probably the major contaminant contributor in this regard. Inhibiting orbiter RCS thruster operation, reduction of thruster size, and keeping the LST outside a 10° half-angle cone about the thrust axes are potential methods of reducing or eliminating this contamination problem.

A review of the LST mission profile was made to identify during which period major contamination can occur. Table H-8 lists the critical contamination hazards by mission phase and summarizes candidate control measures suggested in References H1, H3 and H7. The basic contamination control approach is to make the LST self-sufficient in a hostile environment. The techniques of Reference H1 appear practical, effective, and impose reasonable requirements on the orbiter. Orbital maintenance of the LST is considered to pose the most critical phase of contamination control. Figures H-7 and H-8 taken from Reference H1 depict the orbiter and LST contamination control system, respectively, proposed for use during manned servicing of the LST.

H.1.1.3 EOS Contamination Control Requirements & Solutions

The Earth Observatory Satellite mission objective is to provide a space platform for test of experimental sensors and spacecraft subsystems. Sensor development will be directed toward environmental research, locating and mapping earth resources, environmental management, and meteorology. The EOS will be placed in a sun synchronous orbit such as at 99° inclination and 530 n.mi. altitude.

Early definition of EOS as given in Reference H8 identified an EOS A&B spacecraft generation for the 1976 timeframe. Sensors for this configuration were essentially state-of-the-art and the 2600 pound spacecraft could be delivered by a Delta launch vehicle. The next EOS generation (C&D) would incorporate more advanced sensors, would weigh about 3800 pounds, and would be operational in the 1980's timeframe, compatible with the Space Shuttle. A more recent EOS configuration, shown in Figure H-9, incorporates on-orbit servicing capability, advanced sensors, and weighs about 10,000 pounds.

TABLE H-8

LST CONTAMINATION HAZARDS AND CANDIDATE METHODS OF CONTROL

MISSION PHASE	CRITICAL CONTAMINANT	CONTAMINANT CAUSE	CRITICAL SPACECRAFT ELEMENTS	CANDIDATE CONTAMINATION CONTROL METHODS
Pre Launch (After Leaving Clean Room)	Film Deposits Particulate Deposits	Atmosphere, surrounding LST structure & equipment, orbiter bay environment	Primary & secondary mirrors, SIP mirrors & instruments, star trackers, thermal insulation, solar arrays	Closed OTA aperture doors with GSE supplied 10,000 class dry GN_2 purge introduced via SIP area. LST interior pressure maintained at .01 to .1 psi above ambient. Entire LST is enclosed in a clean bag to reduce purge gas requirement. Removable covers placed on star trackers.
Launch	Same as above	Particle migration accentuated by acoustics & vibration. Launch pad atmosphere at liftoff.	Same as above	Same as above except: Orbiter supplies GN_2 purge
Ascent	Same as above	Particle migration accentuated by acoustics & vibration. Orbiter bay & LST outgassing.	Same as above	Same as above. Outgassing can be significantly reduced by proper design and manufacturing practices in material selection, cleaning, and bake-out.
LST Deployment	Film Deposits Particulate Deposits	• Orbiter bay & LST outgassing • Orbiter TPS outgassing • RCS plume, orbiter venting, fuel cell water dump	Same as above	Same as above except LST supplies GN_2 purge from time of orbiter/LST disconnect until orbiter is in stand-off escort. Clean bag removed and remains in orbiter bay. Fuel cell water dump and other vents inhibited during LST deployment. LST to stay outside 10° of orbiter RCS thrust axes. Use of 25 lbf orbiter thrusters mitigates RCS contaminants.
LST Operation	Film Deposits Particulate Deposits Molecular Clouds Particulate Clouds	• LST outgassing • LST GN_2 RCS operation • Orbiter residual clouds	Same as above	LST purge terminated, aperture doors opened, star tracker covers removed, inhibit orbiter dump & vent. Residual molecular clouds will disperse and be swept clear of LST in minutes by earth's atmosphere. Particulate clouds will require longer, ~6 minutes for 1μ particles and ~5 hours for 50μ particles. Orbital regression and atmosphere rotation prevents particle buildup on successive orbits. LST outgassing essentially complete after first 48 hours in orbit. Molecular clouds caused by subsequent outgassing have little scattering or absorption effects on light due to low column densities and small scattering cross section of molecules. Particulate & film deposits are essentially line-of-sight dependent. LST aperture orientation away from orbiter should suffice to prevent optics contamination by orbiter RCS.

TABLE H-8 (CONTINUED)

LST CONTAMINATION HAZARDS AND CANDIDATE METHODS OF CONTROL

MISSION PHASE	CRITICAL CONTAMINANT	CONTAMINANT CAUSE	CRITICAL SPACECRAFT ELEMENTS	CANDIDATE CONTAMINATION CONTROL METHODS
LST Maintenance	Film Deposits Particulate Deposits	SSM atmosphere, personnel, surrounding LST equipment & structure	Same as above	Aperture doors closed and oriented away from orbiter; closed pressure bulkhead door; SSM egress door connected to special orbiter clean area; 100,000 class clean air provided by orbiter, filtered to 10,000 clean by LST HEPA filters for SIP area, SSM pressurized to 14.7 psia, trace contaminants controlled by orbiter EC/LSS; personnel in clean room attire.
Reentry	Film Deposits Particulate Deposits	Atmosphere, orbiter bay environment, surrounding LST equipment & structure	Same as above	Aperture, pressure bulkhead & SSM doors closed; GN_2 purge supplied by orbiter; LST interior pressure maintained between .01 to .1 psi above ambient; LST placed in clean bag if practical; star trackers covered.
Post-Landing	Film Deposits Particulate Deposits	Same as above	Same as above	Same as for pre-launch.

FIGURE H-7

CONTAMINATION CONTROL SYSTEM FOR CLASS 350/3500 (10,000/100,000) LST

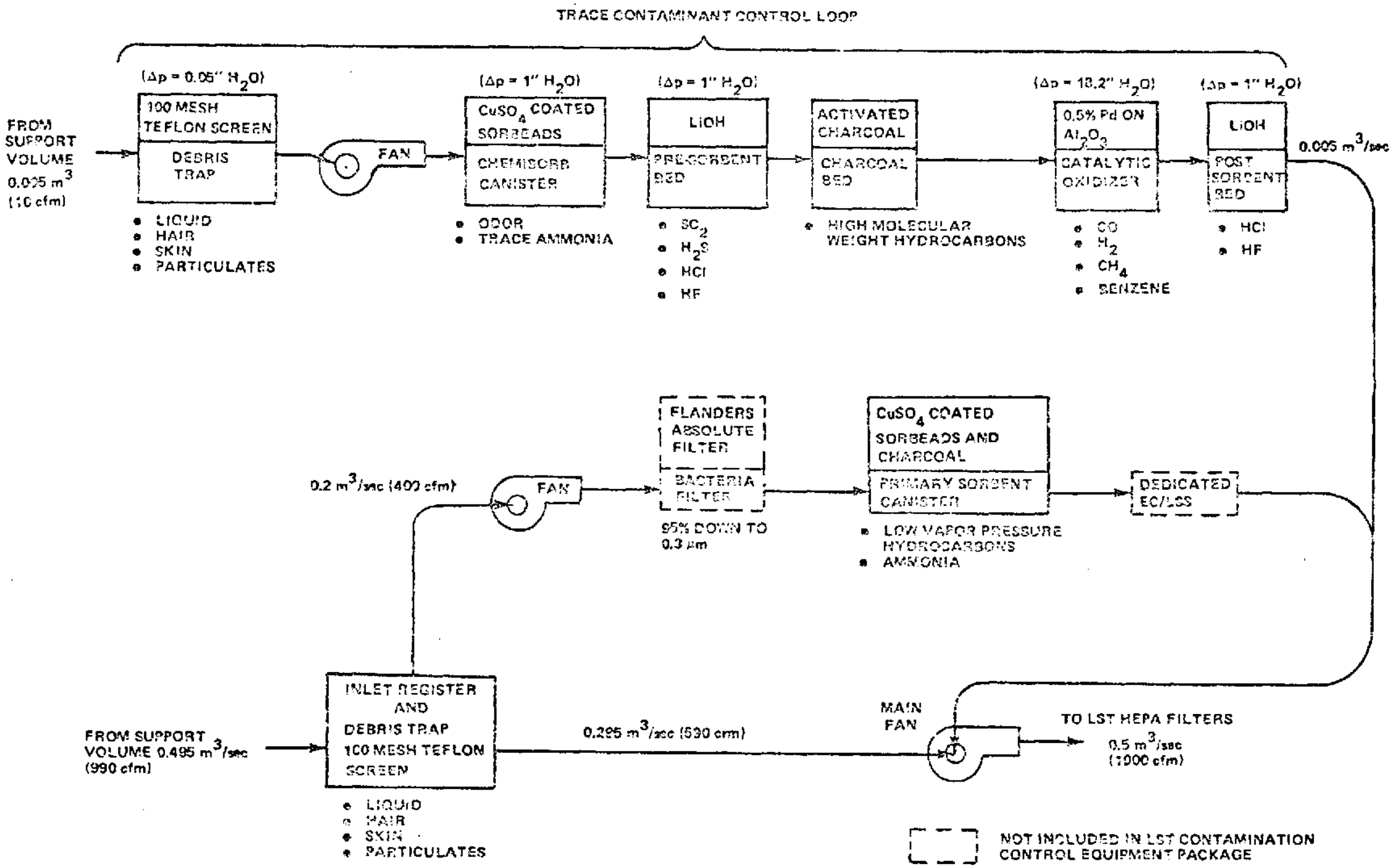
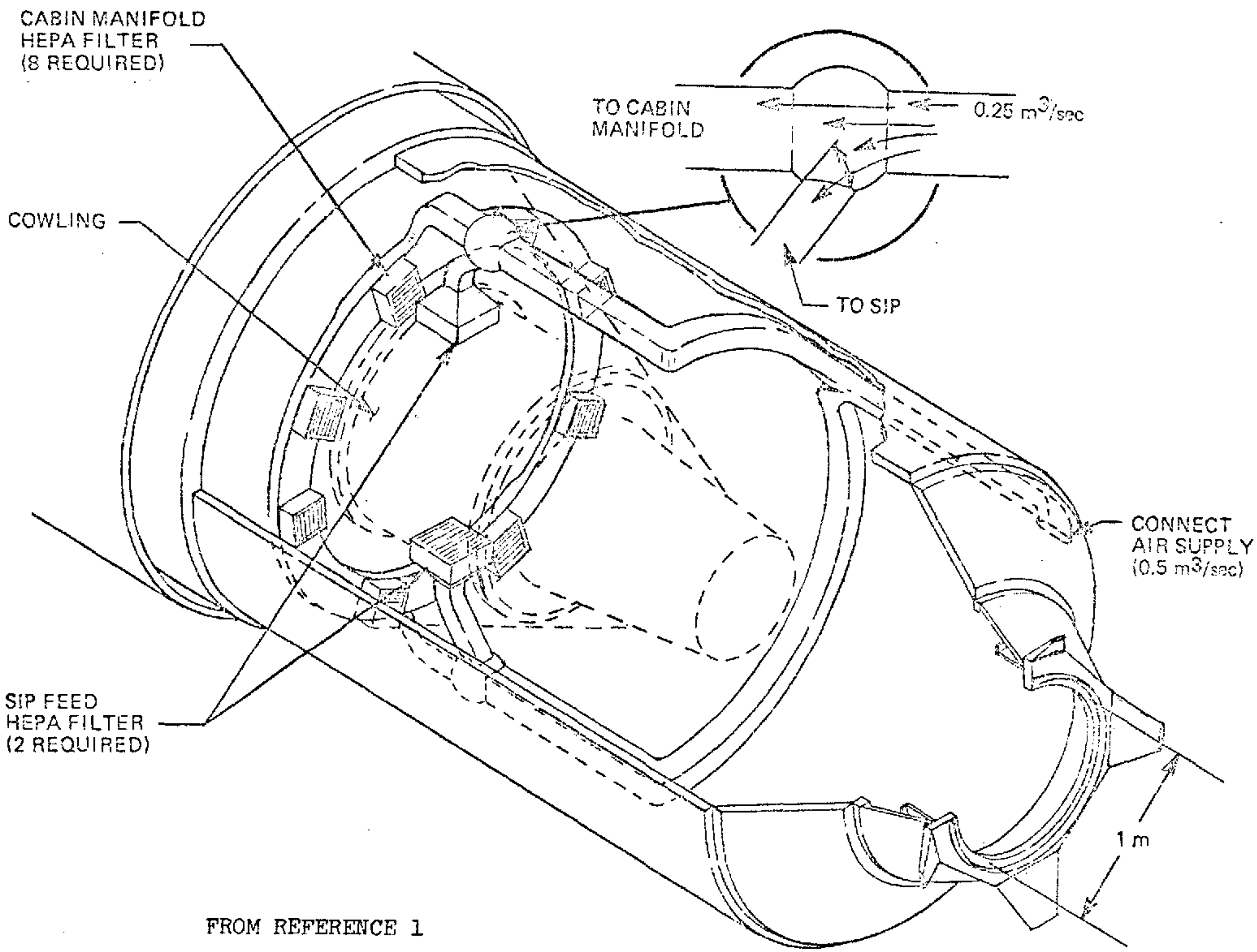


FIGURE H-8

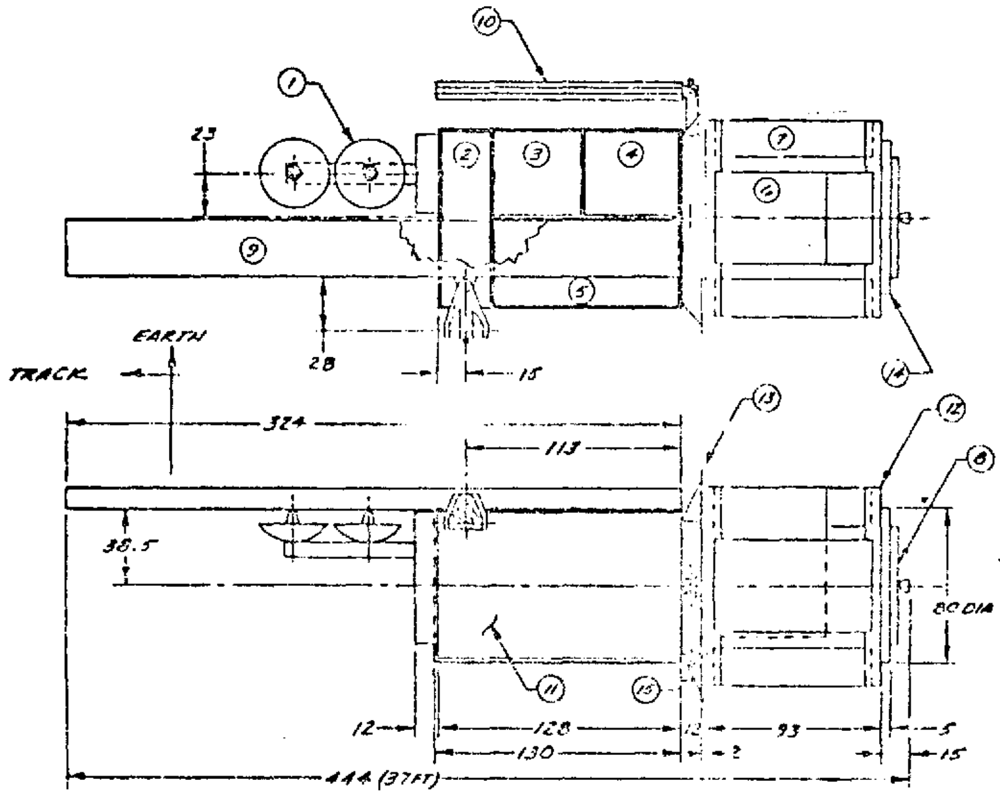
CLASS 350/3500 (10,000/100,000) LST CONTAMINATION CONTROL SYSTEM LAYOUT (HYBRID VERSION)

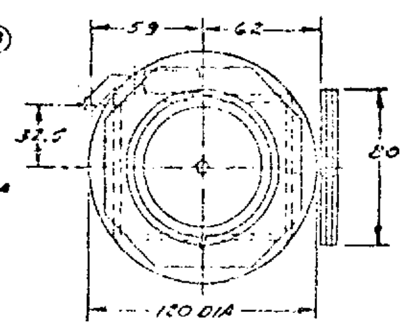


FROM REFERENCE 1

FIGURE H-9

TERRESTRIAL EARTH-ORBITING SATELLITE NO. 6B





1. K-BAND ANTENNA & ELECTRONICS
2. RADAR ELECTRONICS/ACTUATOR
3. METRIC CAMERA
4. POINTING IMAGER
5. THERMATIC MAPPER
6. METEOROLOGY
7. SUBSYSTEMS (3)
8. ORBIT ADJUST ENGINE/ACS THRUSTERS
9. RADAR ANTENNA
10. SOLAR ARRAY
11. FWD INSTR. SECT.
12. AFT INSTR SECT.
13. INSTR. SECT ADAPTER & P/L RETENTION INTERFACE & ASSEMBLY
14. DOCKING RING
15. SAMS/EOS CONNECTOR

FROM REFERENCE 9

For purposes of this contamination evaluation the specific EOS configuration definition is not essential and a reasonable assessment of contaminant seriousness and control may be made by examining typical sensors and spacecraft elements. Table H-9 lists typical experiments as proposed in Reference H8. It will be noted that the Sea Surface Temperature Imaging Radiometer (SSTIR) operates in the near ultra-violet spectrum and therefore is critical to film deposits on its optics, particularly the primary mirror. A hydrocarbon film only a few monolayers thick will decrease and possibly shut out UV radiation from the instrument. Since the SSTIR is also cooled, water vapor or droplets in the vicinity could coat the unit as a film or particulate deposit. At a 90°K detector temperature, H_2O deposition does not require an initiating nucleus. The subsequent sublimation rate of H_2O is very low and a coating of frost might persist on the SSTIR for the mission duration. Such a coating, depending on its thickness and location, could cause light scattering and bandwidth degradation.

The thematic mapper, while not operating in the UV regime, has stringent resolution requirements and is also cooled. Film deposits on the instrument primary mirror would degrade resolution. Frost films could destroy the unit's energy sensing ability.

The EOS spacecraft utilizes certain control instruments which are themselves sensitive to particulate and film contaminants. When the thematic mapper is employed, precise station keeping and orientation is required to permit retracing ground paths, to limit sweep distortion, and to permit precision attitude determination. The attitude determination system would use star sensor(s), horizon sensors and sun sensors. The effect of contamination on star sensors and sun sensors was shown in Table H-7. The horizon sensor makes use of the 14-16 μm CO_2 absorption band in the IR spectrum. Film deposits on the sensor's optics would not likely affect light transmission at this wavelength.

EOS contamination control measures will be most effective if treated from both a design and operational aspect. As with the LST, the most positive approach to EOS contamination control is to make the spacecraft essentially immune to a hostile environment.

TABLE H-9

TERRESTRIAL EARTH ORBITING SATELLITE NO. 6B

INSTRUMENT	SPECTRAL RANGE (μm)	RESOLUTION μ rad	DETECTOR COOLER TEMP (°K)	REMARKS
Sea Surface Temperature Imaging Radiometer	10.5-11.5 8.85-9.35 6.5-7.0 3.6-4.1 0.2-4.0	250	90	Primary mirror dia. = 8.8 cm. UV range sensitive to film deposits. Cooler sensitive to frost and other surface deposits.
Oceanic Scanning Spectrophotometer	0.4-0.7 $\Delta\lambda$=.015		None	Primary mirror dia. = 7.6 cm.
Thematic Mapper	0.5-0.6 0.6-0.7 0.7-0.8 0.8-1.1 1.55-1.75 2.08-2.35 10.4-12.6	33 33 33 33 33 33 100	None None None None 120 120 90	Primary mirror dia. = 40.6 cm. Resolution sensitive to film deposits. Cooler sensitive to surface deposits.
Passive Multichannel Microwave Radiometer	6.01 cm 2.81 cm 1.67 cm 1.40 cm .81 cm		None	
Upper Atmosphere Sounder	9.4-10 14.0-16.3 14.5-16.7 20-40		Cooling Req'd Temp?	
Atmospheric Pollution	2-20	.001-350 ppm		Senses CO, CO_2, SO_2, NO, N_2O, NO_2, NH_3, CH_4
Horizon Sensor	14-16		N/A	Uses CO_2 absorption band to discern horizon
Star Sensors			N/A	Used for precise attitude determination
Autocollimator			N/A	Used if star sensors are remote from reference block
Sun Sensor			N/A	Used for initial orientation capture and solar array pointing

It is therefore proposed that protective covers be provided for critical elements; namely, the various experiment sensor optical viewports, star trackers, and detector coolers. These covers would be remotely commandable to the open position after EOS deployment from the orbiter and to the closed position prior to orbiter approach and docking during revisits. The covers should be able to control particulate contamination to 10,000 class cleanliness, and keep non-particulates below 10 ppm and 15 ppm for low and high vapor pressure materials, respectively. A dry GN_2 blanket purge may be necessary to achieve these levels during pre- and post-launch periods. When closed, radiation cooler covers would be designed to preclude moisture condensation on the cooler in orbit.

Maintenance of the EOS on orbit as treated in Reference H9 is automated and does not involve shirtsleeve personnel access. The controlled shirtsleeve environment necessitated for the LST is therefore not required, rather concern is focused on the orbiter external environment during service operations.

It is assumed that entire instrument modules would be exchanged rather than sub-elements which would involve exposing the internal light path of the sensor. During the exchange process, temporary lens caps would maintain viewport cleanliness until the module was installed. At that time they would be removed and the contamination control covers closed. Clearly, orbiter effluents are highly significant during the EOS service periods. Dumping and venting should be inhibited at this time. Pressure relief vents should be designed to be directed away from the payload bay and service area. Orbiter RCS firing, particularly the pitch engines, might best be inhibited during critical periods of equipment exposure. Once contamination covers are closed, this restriction will not be necessary.

If RCS inhibit during spacecraft servicing is unacceptable, consideration should be given to the use of smaller (e.g., 25 lbf) pitch engines and/or opening orbiter attitude deadband limits. Reference H10 indicates that the smaller engines require, and therefore emit, orders of magnitude less propellant mass than the baseline 950 lbf thrusters. In addition, an increase in pulse width is more tolerable for the small thruster. This has the advantage of shifting most of the thruster duty cycle to the steady state rather than the transient operating regime. It is well known that most of the objectionable RCS contaminants of unburned propellants, droplets, and catalyst fines are produced during the start and stop transient periods. The smaller plume of the smaller engines would also increase the payload servicing envelope within which RCS exhaust impingement is insignificant.

During orbiter-to-payload docking and undocking operations, it may not be possible to inhibit RCS thruster operation. Assuming the orbiter approaches the EOS from its SAMS/EOS connector side, see Figure H-9, the spacecraft critical view ports, solar array, and antennas are essentially out of thruster line of sight. With closed EOS contamination control covers, RCS plume impingement on the spacecraft should not be a serious problem.

During orbiter descent with the EOS, ambient atmosphere would be bled via particulate filters into the volume enclosed by the contamination control covers. If it is determined that non-particulate contamination will be a problem during descent, localized GN_2 purging could offer an alternate repressurization approach.

H.1.2 Conclusions

Both the LST and EOS contain scientific and spacecraft instruments which necessitate meticulous design, fabrication and handling to maintain a high degree of cleanliness. The cleanliness levels specified or implied for each program are significantly more stringent than will be provided in the shuttle orbiter bay. During deployment or maintenance operation, a less predictable and perhaps uncontrollable environment will be encountered. It therefore appears unreasonable to impress more stringent particulate cleanliness requirements on the orbiter bay than the presently specified 100,000 class level. Rather, it is proposed that the spacecraft contain provisions to assure that cleanliness levels are maintained in an unclean environment. This may take the form of protective covers, purges, and operational methods. These are considered to be practical approaches since highly controlled particulate and non-particulate levels are needed for only certain sensor optics, and generally involve small areas of the payload. Such protective measures would also serve the payload during pre-launch and post-launch periods while it is neither in the orbiter payload bay nor in a cleanroom.

It is desirable to keep the rest of the spacecraft as clean as practical. This will decrease the likelihood of contaminant secondary emissions in orbit when spacecraft instruments are in operation and exposed. Proper ground handling procedures and the protection afforded by the orbiter bay should be effective in such gross contamination control prior to spacecraft deployment. After the payload leaves the orbiter bay, the orbiter becomes the largest contributor to the degree of contamination deposited in the payload. The policy of inhibiting orbiter venting and dumping in the deployed payload vicinity, and minimizing or ceasing RCS operation during critical spacecraft maintenance periods should be pursued.

A summary of suggested shuttle contamination control requirements consistent with the above philosophy is contained in Table H-2.

It is to be understood that the contamination control techniques proposed are for unmanned, automated spacecraft which operate free of the orbiter. Once the orbiter withdraws from the spacecraft vicinity, the contamination which may have been left by this vehicle will dissipate and become inconsequential. Presuming intended performance of payload on-board contamination control devices and procedures, orbiter effluent control may therefore be relaxed compared to that necessary for palletized or sortie lab type operations.

H.2 REFERENCES

H1. LST Phase A Final Report, NASA TMX-64726, 12/15/72

H2. LST Preliminary Study, Volume I, Executive Summary 2/72

H3. Sortie Lab Study Task 4.1.4 - Service Mission Definition, MSFC 8/21/72

H4. Optical Contamination of Spacecraft, R. J. Nauman, S&E-SSL-P, NASA/MSFC

H5. Optical Contamination Effects Due to Outgassed Products from Thermal Control Surfaces, J. J. Trenkle, S&E-SSL-TR, NASA/MSFC

H6. Discussions with personnel from ITT, Kollsman, Honeywell, Brown-Teledyne

H7. Shuttle Orbital Applications and Requirements (SOAR) Final Report - Phase II, MDC G4473, April 1973.

H8. Earth Observatory Satellite (EOS) Definition Phase Report, Volume I, August 1971, GSFC

H9. Shuttle/Typical Payload Interface Study, Final Report SD 72-SA-0194, Rockwell International, 30 October 1972

H10. Space Shuttle System Payload Accommodations, JSC 07700, Volume XIV

H11. Discussions with personnel at NASA/MSFC and NASA/GSFC familiar with Skylab, ATM, OAO, LST and EOS Programs.