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ORBITAL OPERATIONS STUDY

VOLUME I

MISSION ANALYSES

FINAL REPORT

MAY 1972

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Space Division
North American Rockwell

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TECHNICAL REPORT INDEX/ABSTRACT

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VOLUME I - MISSION ANALYSIS

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*VEHICLE INVENTORY, *MISSION MODELS, *INTERFACING ACTIVITIES

ABSTRACT

THIS DOCUMENT IS VOLUME I OF THE FINAL REPORT OF THE ORBITAL OPERATIONS STUDY. A SUMMARY OF THE 25 ELEMENTS IN THE STUDY INVENTORY IS PRESENTED. FOURTEEN INTERFACING ACTIVITIES ARE DEFINED. ELEVEN MISSION MODELS ENCOMPASSING ALL POTENTIAL INTERFACING ELEMENT PAIRS AND INTERFACING ACTIVITIES ARE INCLUDED.

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FOREWORD

This report contains the results of the analyses conducted by the Space Division of North American Rockwell during the Orbital Operations Study, Contract NAS9-12068, and is submitted in accordance with line item 7 of the Data Requirements List (DRL 7).

The data are presented in three volumes and three appendixes for ease of presentation, handling, and readability. The report format is primarily study product oriented. This study product format was selected to provide maximum accessibility of the study results to the potential users. Several of the designated study tasks resulted in analysis data across elements and interfacing activities (summary level); and also analysis data for one specific element and/or interfacing activity (detailed level). Therefore, the final report was structured to present the study task analysis results at a consistent level of detail within each separate volume.

The accompanying figure illustrates the product buildup of the study and the report breakdown. The documents that comprise the reports are described below:

Volume I - MISSION ANALYSES, contains the following data:

- o Generic mission models that identify the potential earth orbit mission events of all the elements considered in the study
- o Potential element pair interactions during on-orbit operations
- o Categorized element pair interactions into unique interfacing activities

Volume II - INTERFACING ACTIVITIES ANALYSIS contains the following data:

- o Cross reference to the mission models presented in Volume I
- o Alternate approaches for the interfacing activities
- o Design concept models that are adequate to implement the approaches
- o Operational procedures to accomplish the approaches
- o Functional requirements to accomplish the approaches
- o Design influences and preferred approach selection by element pairs.

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This volume is subdivided into four books or parts which are:

Part 1. INTRODUCTION AND SUMMARY - Condensed presentation of the significant results of the analyses for all interfacing activities

Part 2. STRUCTURAL AND MECHANICAL ACTIVITY GROUP

- o Mating
- o Orbital Assembly
- o Separation
- o EOS Payload Deployment
- o EOS Payload Retraction and Stowage

Part 3. DATA MANAGEMENT ACTIVITY GROUP

- o Communications
- o Rendezvous
- o Stationkeeping
- o Detached Element Operations

Part 4. SUPPORT OPERATIONS ACTIVITY GROUP

- o Crew Transfer
- o Cargo Transfer
- o Propellant Transfer
- o Attached Element Operations
- o Attached Element Transport

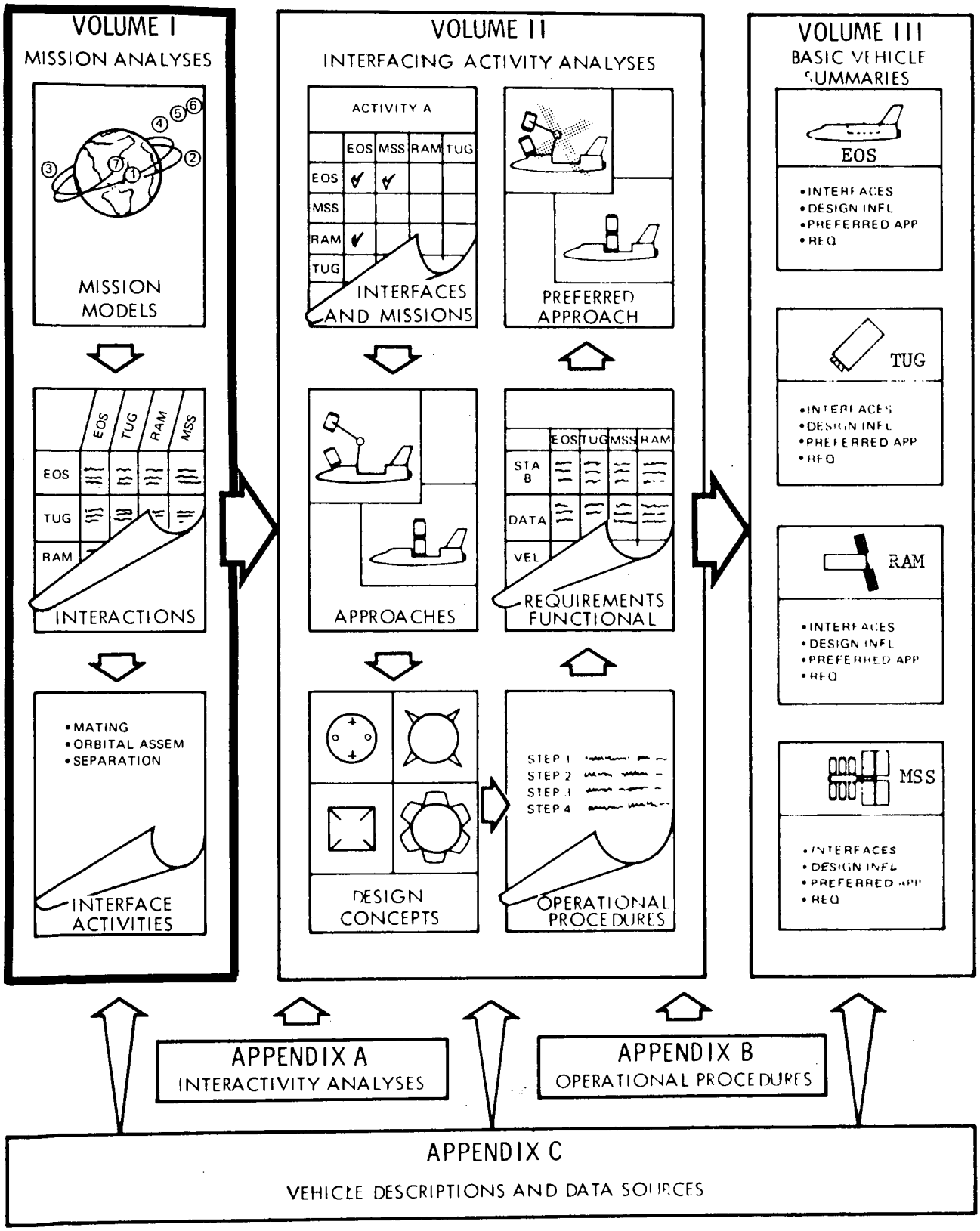
Volume III - BASIC VEHICLE SUMMARIES, contains a condensed summary of the study data pertaining to the following elements:

- o Earth Orbital Shuttle
- o Space Tug
- o Research and Applications Modules
- o Modular Space Station

Appendix A - INTERACTIVITY ANALYSES, contains many of the major trades and analyses conducted in support of the conclusions and recommendations of the study.

Appendix B - OPERATIONAL PROCEDURES, contains the detailed step-by-step sequence of events of each procedure developed during the analysis of an interfacing activity.

Appendix C - VEHICLE DESCRIPTIONS AND DATA SOURCES, presents a synopsis of the characteristics of the program elements that were included in the study (primarily an extraction of the data in Appendix I of the contract statement of work), and a bibliography of the published documentation used as reference material during the course of this study.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ABBREVIATIONS

AM	Amplitude modulation
ATT	Attached
BER	Bit error rate
CCTV	Closed-circuit television
CIS	Cislunar
CLS	Cislunar shuttle
CPS	Chemical propulsion stage
DET	Detached
EO	Earth orbit
EOI	Earth orbit injection
EOS	Earth-to-orbit shuttle
EO SHTL	Earth orbit-to-orbit shuttle
ETR	Eastern Test Range
EVA	Extravehicular activity
FM	Frequency modulation
FSK	Frequency shift keying
GEO	Geosynchronous
GH_z	Giga-Hertz
IVA	Intravehicular activity
Kbps	Kilobits per second
KSC	John F. Kennedy Space Center
LEM	Lunar excursion module
LLT	Lunar landing tug

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ABBREVIATIONS (Continued)

LPS	Lunar program systems
LSB	Lunar surface base
Mbps	Megabits per second
MCC	Mission control center
MH_z	Mega-Hertz
MM	Mission model
MOD	Module
MSFC	Marshall Space Flight Center
MSFN	Manned space flight network
MSS	Modular space station
NONRET	Nonreturnable
OIS	Orbit insertion stage
OLS	Orbiting lunar station
OPD	Orbital propellant depot
OPS	Operations
PCM	Pulse-code modulation
PM	Phase modulation
PRN	Pseudorandom noise
PSK	Phase shift keying
RAM	Research and applications module
RETR	Retrievable
RF	Radio frequency
RNS	Reusable nuclear shuttle
RTN	Returnable
TDA	Tunnel diode amplifier

ABBREVIATIONS (Continued)

TDRS	Tracking and data relay satellite
SLR	Scanning laser radar
S/N	Signal-to-noise ratio
TEI	Transearth injection
TLI	Translunar injection
TPI	Terminal phase final
TWT	Traveling wave tube
TWTA	Traveling wave tube amplifier
UHF	Ultrahigh frequency
VDC	Volts dc
VHF	Very high frequency
WTR	Western Test Range

1.0 INTRODUCTION AND SUMMARY

This volume contains the data developed during the initial phase of the Orbital Operations study and provides the basis for (and, to some extent, the scope of) subsequent phases of the study. In brief, this volume includes the inventory and definition of program elements which were studied, mission models developed which encompass all potential orbital activities and elements, the identification of all potential interfacing activities, the identification of all potential interfacing element pairs, and various summary matrices that show the interrelationship between the program elements, missions, and activities.

The inventory of vehicles (or program elements) to which the mission data are applicable was included in the contract for the Orbital Operations Study. This inventory encompasses all program elements anticipated or under study for potential orbital operations in the late 1970's and 1980 time period. The inventory includes a total of 25 elements that can be grouped into the categories defined and shown pictorially on Figure 1.0-1. A more detailed description of the study program elements is presented in Appendix C of this report. The total list of 25 elements appears on numerous figures throughout the report, including Figure 1.0-4.

The mission model activity was conducted as the initial effort in the Orbital Operations Study. One of the primary purposes of this activity was to identify all element-to-element interfaces that occur in earth orbit involving any reasonable combination of elements in the study inventory. A second and equally important purpose was to identify all interfacing activities that can occur between interfacing elements in earth orbit and to relate these to each element-to-element interface. To accomplish this an extensive literature search was conducted that encompassed the use of approximately 220 documents from various study programs and companies (see Appendix C, Data Sources). Based upon an analysis of these documents, 40 individual missions were derived involving various specific program elements and various program mission operational concepts. These 40 individual missions were integrated and combined into 11 generic mission models which encompass all of the mission events, element-to-element interfaces, and interfacing activities contained in the original 40 missions. Most of the 11 mission models are applicable to multiple mission objectives (e.g., logistics, retrieval, rescue, emplacement, etc.). All of the mission models have multiple program element application, ranging from two to 20 elements.

The titles of the 11 mission models are listed on Figure 1.0-2 and are grouped into five categories according to the primary propulsive vehicle involved. The five categories are earth-to-orbit shuttle (EOS), space-based tug, ground-based tug, orbital insertion stage, and the geosynchronous/cislunar shuttle (CPS and RNS). As the mission model titles indicate, similar mission objectives are accomplished by different mission models. The term "emplacement" is used to signify the delivery of a payload to space (to become a free-

flyer) as opposed to delivery of a payload to another element. The term "retrieval" signifies the picking up of a payload (free-flyer) from space and not from another element. Therefore, "retrieval" is the reverse of "emplacement". The term "logistics" is used to signify the delivery of a payload to another element, picking-up of a payload from another element, or a combination of the two. The term "sortie" applies to a mission (or portion of a mission) in which an experiment payload remains attached to the supporting vehicle (i.e., tug or orbiter) while experiment payload operations are being conducted. The terms "staged" and "non-staged" refer to two-stage and single stage propulsive vehicles, respectively. The term "disposal" refers to the removal of expended elements from earth orbit other than by return to earth in the orbiter cargo bay.

Based upon the extensive mission model activity conducted in this study, a total of 14 interfacing activities have been identified. The 14 activities (listed and defined on Table 1.0-1) include every type of interaction pertinent to this study that can occur between space elements in earth orbit. An attempt was made to derive a list of mutually exclusive activities; however, some overlap was inevitable in order to provide the most useable packaging of data. A large part of the data developed in this Orbital Operations Study (alternate concepts, functional requirements, operational procedures, etc.) is categorized and packaged by related interfacing activity.

To provide additional visibility at the mission model level, Figure 1.0-3 identifies all of the interfacing activities that can occur in each of the 11 mission models documented in Section 2.1 (and listed on Figure 1.0-2). It is noted that all 14 of the interfacing activities occur in mission models MM-2, MM-5, MM-8, MM-10, and MM-11. Each of these mission models encompasses a logistics mission application.

Visibility at the mission model level is presented in Figure 1.0-4 to identify which of the 25 space elements can be involved in each of the mission models. The two mission models that have an application to the greatest number of program elements are MM-2 and MM-5.

The primary method used in reducing the total number of required discrete evaluations/procedures/design evaluations was to group related elements judiciously. The relationships that permitted this grouping were (1) interface activity commonality, (2) multigeneration design concepts, (3) complimentary design concepts, and (4) operations similarity.

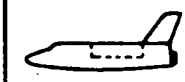
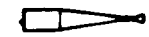
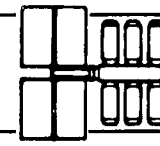
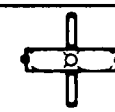
Earth orbital shuttle (EOS) - One element only, referred to throughout this report as EOS, orbiter and shuttle orbiter.	
Interim tug - Various types of nonreusable nonreturnable, and nonreusable returnable kick stages such as Centaur, Agena, Titan Transtage, and Burner II.	
Space tug - Reusable unmanned and manned ground-based tug, and unmanned and manned space-based tug.	
Chemical propulsion stage (CPS) - The orbital insertion stage (mounted on the EOS booster at launch), the earth orbit-to-orbit shuttle, and the cislunar shuttle. The CPS can be modular or nonmodular, and single-stage or two-stage.	
Reusable nuclear shuttle (RNS) - Both the earth orbit-to-orbit shuttle and the cislunar shuttle application. The RNS can be modular or nonmodular and is single-stage only.	
Modular space station (MSS) - The low earth orbital station and the geosynchronous station.	
Research and applications module (RAM) - Both attached and detached RAM's, supported by the EOS and by either of the two MSS's (see above).	
Satellite - Satellites deliverable to orbit by the EOS and those requiring the EOS plus a third stage for delivery. Also included are satellites requiring retrieval and servicing.	
Orbital propellant depot (OPD) - The low earth orbital propellant depot located in an orbit optimized to support the RNS or CPS and the space-based tug.	
Earth orbital resupply module - Cargo and propellant modules for resupply of earth orbiting elements.	
Orbiting lunar station (OLS) - Both the modular and nonmodular configurations (deliverable to lunar orbit by CPS or RNS).	
Lunar surface base (LSB) - The modular base only (deliverable to lunar orbit by CPS or RNS).	
Lunar landing tug (LLT) - Both the unmanned and manned tugs (deliverable to lunar orbit by CPS or RNS).	
Lunar resupply module - Crew, cargo and propellant modules for delivery to lunar orbit by CPS or RNS.	

Figure 1.0-1. Vehicle Inventory

MISSION MODELS		INTERFACING ELEMENTS	PROPUL. VEHICLE
MM-1	EMPLACEMENT	RAM; SATELLITE; KICKSTAGE; TUG; FIRST MOD OF MSS, OLS, OPD, CLS	EARTH ORBITAL SHUTTLE
MM-2	LOGISTICS/RETRIEVAL	MSS; CLS; OLS; RAM; TUG; SATELLITE; EOS; OPD; CARGO, PROPELLANT, LSB MODS	
MM-3	SORTIE	RAM	
MM-4	RETRIEVAL/EMPLACEMENT	RAM; SATELLITE; CLS; TUG; OPD; EOS; MSS; OLS; OIS	SPACE-BASED TUG
MM-5	LOGISTICS	LLT; RAM; SAT; MSS; CLS; TUG; EOS; OPD; CARGO MODS	
MM-6	DISPOSAL	CLS; OIS; OPD; MSS; OPD	
MM-7	EMPLACEMENT/SORTIE	TUG; SAT; RAM	GROUND-BASED TUG
MM-8	LOGISTICS/RETRIEVAL	TUG; CLS; SAT; MSS; RAM; OPD; EOS; PROPEL, CARGO MODS	
MM-9	DELIVERY	CLS; OLS; OPD; TUG	OIS
MM-10	STAGED LOGISTICS	OPD; EOS; TUG; OIS; RAM; OLS; LSB; MSS; SAT; PROPEL, CARGO MODS	CISLUNAR SHUTTLE
MM-11	NONSTAGED LOGISTICS	OPD; EOS; TUG; OIS; RAM; OLS; LSB; MSS; SAT; PROPEL, CARGO MODS	

Figure 1.0-2. Mission Model Titles

Table 1.0-1. Definition of Interfacing Activities

Activity Title	Activity Definition
Mating	The attachment in earth orbit of any two elements (or modules), including the operations of final closure prior to contact
Orbital Assembly	The joining together of two or more major parts to form a particular configuration of a single operational element in earth orbit, or to facilitate transport to lunar orbit or high-energy earth orbit
Separation	The physical uncoupling of two mated elements, and the subsequent maneuvers required to provide adequate clearance between elements
Cargo Transfer	The transfer of solid and fluid cargo between two elements in orbit
Crew Transfer	The transfer of personnel between two elements in orbit
Propellant Transfer	The transfer of large quantities of liquid hydrogen and liquid oxygen between elements in orbit
EOS Payload Deployment	The removal of a payload from the orbiter cargo bay and readying it for operation or separation
EOS Payload Retraction and Stowage	The insertion of a payload into the orbiter cargo bay subsequent to initial mating of the payload to the orbiter
Communications	The transmission of sound, video, and digital/analog data via space links from element-to-element and from element-to-ground
Rendezvous	The operations required to achieve close proximity of one element to another for purposes of station-keeping and/or mating
Stationkeeping	The maintaining of a predetermined (not necessarily fixed) relative position between two orbiting elements
Attached Element Operations	Support by one element to another attached element while the latter is operating or being serviced, checked out, or stored
Detached Element Operations	The operational support required by a free-flying element from another element and/or ground control
Attached Element Transport	Support by a major propulsive element to an attached payload (element or module) during transport from one orbit to another

MISSION MODEL	INTERFACING ACTIVITY													
	MATING	ORBITAL ASSEMBLY	SEPARATION	CARGO TRANSFER	CREW TRANSFER	PROPELLANT TRANSFER	EOS PAYLOAD DEPLOYMENT	EOS PAYLOAD RETRACTION	COMMUNICATIONS	RENDEZVOUS	STATIONKEEPING	ATTACHED ELEM. OPERATIONS	DETACHED ELEM. OPERATIONS	ATTACHED ELEM. TRANSPORT
MM-1 EOS EMPLACEMENT	X	X	✓	✓	✓	X	✓	X	✓	X	✓	X	✓	✓
MM-2 EOS LOGISTICS/RETRIEVAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-3 EOS SORTIE	X	X	X	✓	✓	X	✓	✓	✓	X	X	✓	X	✓
MM-4 SPACE-BASED TUG RETRIEVAL/EMPLACEMENT	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-5 SPACE-BASED TUG LOGISTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-6 SPACE-BASED TUG DISPOSAL	✓	X	✓	✓	✓	✓	X	X	✓	✓	X	✓	✓	✓
MM-7 GROUND-BASED TUG EMPLACEMENT/SORTIE	✓	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓
MM-8 GROUND-BASED TUG LOGISTICS/RETRIEVAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-9 OIS DELIVERY	✓	✓	✓	X	X	X	X	X	✓	✓	X	X	X	✓
MM-10 STAGED GEO/CISLUNAR SHUTTLE LOGISTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-11 NON-STAGED GEO/CISLUNAR SHUTTLE LOGISTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 1.0-3. Mission Model Interfacing Activity Summary

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MISSION MODEL	PROGRAM ELEMENT INVENTORY																							
	EOS	TUG				RAM				SATELLITE			EO RESUP MODS	MSS		CPS			RNS	LUNAR PROGRAM SYSTEMS					OPD
		NON RET	RTN	GND BASED	SPACE BASED	ATT. EOS	DET. EOS	ATT. MSS	DET. MSS	EOS DELIV	EOS + 3RD ST	RETR RESUP		LOW EO	GEO SYNCH	OIS	EO SHTL	CLS		OLS	TUG UNMAN	TUG MAN	RESUP MOD	LSB	
MM-1 EOS EMPLACEMENT	✓	✓			✓		✓		✓	✓	✓			✓	✓		✓	✓	✓	✓					✓
MM-2 EOS LOGISTICS / RETRIEVAL	✓		✓	✓	✓		✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-3 EOS SORTIE	✓					✓																		
MM-4 SPACE BASED TUG RETRIEV/EMPLACEMENT	✓				✓				✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓			✓
MM-5 SPACE BASED TUG LOGISTICS	✓			✓	✓			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MM-6 SPACE BASED TUG DISPOSAL					✓									✓		✓	✓	✓	✓						✓
MM-7 GND BASED TUG EMPLACEMENT/SORTIE	✓		✓	✓					✓		✓				✓										
MM-8 GND BASED TUG LOGISTICS / RETRIEVAL	✓			✓	✓			✓	✓			✓	✓		✓		✓	✓	✓		✓	✓	✓		✓
MM-9 ORBITAL INSERTION STAGE DELIVERY					✓											✓	✓	✓	✓	✓					✓
MM-10 STAGED GEO/CISLUNAR SHUTTLE LOGISTICS	✓			✓	✓			✓	✓			✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
MM-11 NON-STAGED GEO/CIS-LUNAR SHUTTLE LOGIST.	✓			✓	✓			✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 1.0-4. Mission Model--Program Element Summary

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2.0 MISSION MODELS

This section presents the mission model related data for each of the 11 mission models and is subdivided into these 11 groups for convenience to the user. Each data group is comprised of a description (including application) of the mission, a mission model table (sequence of events and related interface data), a pictorial representation of the mission, and a matrix identifying the interfacing activities applicable to each mission event. The text describing each mission refers to mission event numbers that conform to those used on the mission model sequence of events table. The descriptive text also identifies all of the types of specific missions and all of the space elements to which each mission model is applicable.

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2.1. MM-1 EOS EMPLACEMENT MISSION

A pictorial representation of the mission and the mission model sequence of events for MM-1 are presented on Figure 2.1-1 and Table 2.1-1, respectively. The interfacing activities identified for each mission event on Table 2.1-1 are presented in matrix form on Figure 2.1-2. This mission is applicable to a wide variety of individual missions where the EOS orbiter is used to emplace a free-flying payload in earth orbit. Emplacement signifies delivery of a free-flying payload to a point in space (earth orbit) and does not include direct delivery of a payload to another element in space. The payloads to which this mission model is applicable include satellites, RAM's, initial modules of the CPS, RNS, MSS, OLS, and OPD, and a nonreturnable tug (kickstage) with an attached payload.

The mission starts with earth launch, followed by separation of the orbiter from the booster, orbiter orbit insertion, payload deployment and separation from the orbiter, and subsequent stationkeeping for visual and RF checkout of the payload by the orbiter. Subsequently, the orbiter returns to earth. In the vent the deployed payload consists of a nonreturnable tug (third stage) with an attached payload, the tug engine is ignited (Event 11) to perform an orbit transfer maneuver in order to transport the tug payload to high-energy orbit. The tug then is separated from the payload (Event 12), followed by initiation of payload operations (Event 13).

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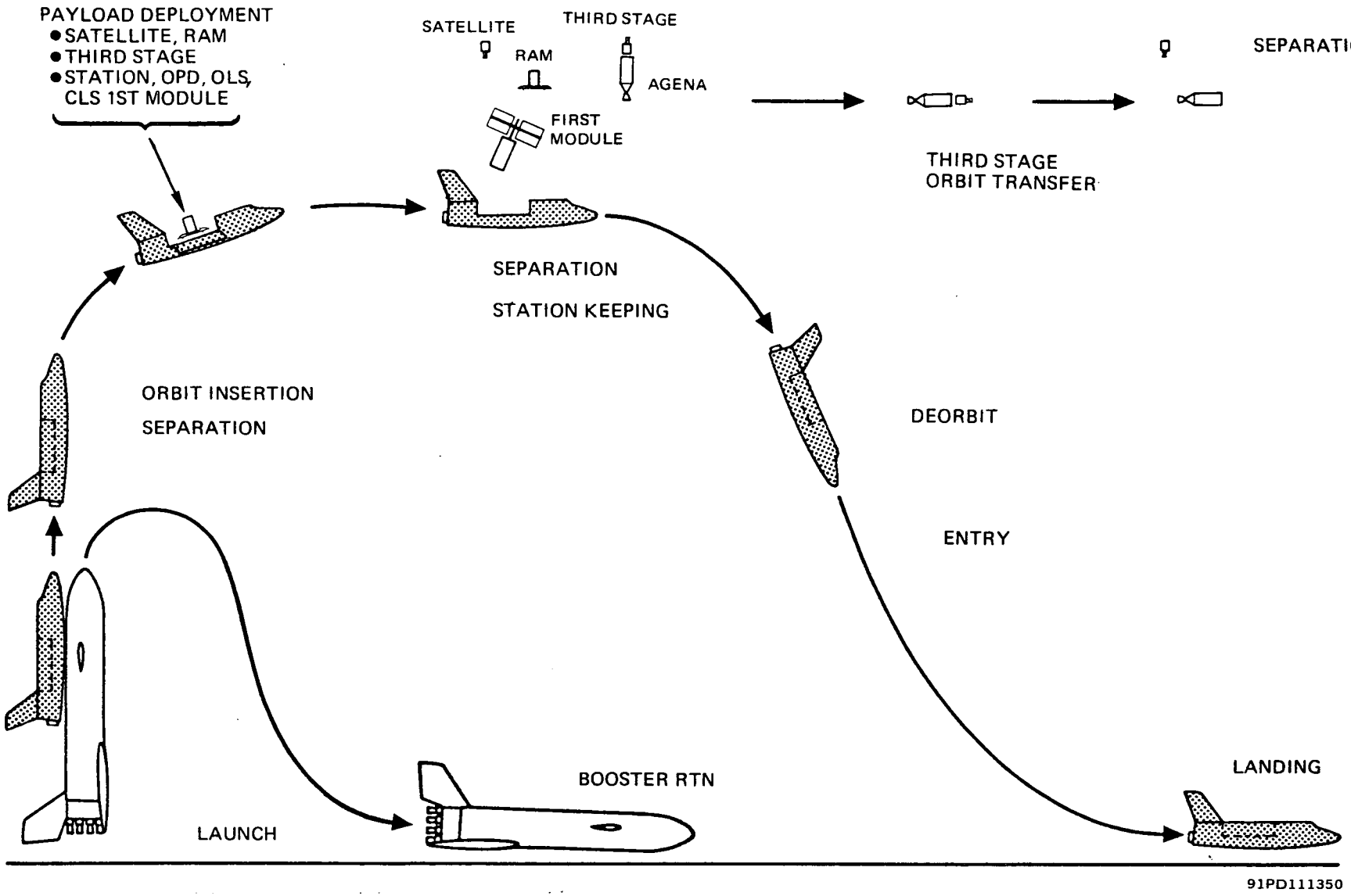

Figure 2.1-1. MM-1 EOS Emplacement Mission

Table 2.1-1
MM-1 EOS Emplacement Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from EOS and return to earth	EOS - Booster EOS - MSFN; Booster - MSFN	Communications	
4. Transport payload by EOS	EOS - Payload	Attached Element Transport	RAM; Satellite; Kickstage; Tug; 1st Module of MSS, OLS, OPD, CLS
5. Conduct phasing/orbit transfer maneuvers	EOS - TDRS, MSFN	Communications Attached Element Transport	Same as Step 4
6. Deploy payload	EOS - Payload	EOS Payload Deployment Crew Transfer, Cargo Transfer	Same as Step 4
7. Separate payload	EOS - Payload	Separation	Same as Step 4
8. Initiate "payload" on-orbit operations and/or station-keeping	EOS - Payload EOS - TDRS, MSFN Payload - TDRS, MSFN	Communications Stationkeeping Detached Element Operations	Same as Step 4
9. Perform deorbit maneuvers	EOS - TDRS, MSFN	Communications	
10. Perform descent, entry and landing maneuvers	EOS - MSFN	Communications	
11. Kickstage perform phasing/orbit transfer maneuvers	Kickstage - TDRS, MSFN	Communications Attached Element Transport	Kickstage
12. Separate kickstage from payload	Kickstage - Payload Kickstage - TDRS, MSFN Payload - TDRS, MSFN	Separation Communications	Kickstage; RAM; Satellite
13. Initiate on-station operations	Payload - TDRS, MSFN	Communications	RAM; Satellite
End of mission	Direct EOS Emplacement Mission - Delete Steps 11, 12, and 13		

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
2	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X	X	✓
5	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
6	X	X	X	✓	✓	X	✓	X	X	X	X	X	X	X
7	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X	✓	X	✓	X	✓	X
9	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
10	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
11	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
12	X	X	✓	X	X	X	X	X	✓	X	X	X	X	X
13	X	X	X	X	X	X	X	X	✓	X	X	X	X	X

Figure 2.1-2. Interfacing Activities Versus Mission Events for MM-1 EOS Emplacement Mission

2.2. MM-2 EOS LOGISTICS/RETRIEVAL MISSION

A pictorial representation of the mission and the mission sequence of events for MM-2 are presented on Figure 2.2-1 and Table 2.2-1, respectively. The interfacing activities identified for each mission event on Table 2.2-1 are presented in matrix form on Figure 2.2-2. This mission is applicable to EOS delivery of various payloads from earth to other major elements in earth orbit, retrieval of free-flying elements in orbit for return to earth, and rescue of personnel from a disabled orbiting element. The payloads that can be delivered by the orbiter to another element (or picked up from another element) are listed opposite Event 4 on Table 2.2-1 and include the crew, cargo, and propellant; OPD, MSS, RNS, CPS, OLS, LSB, and RAM modules; the tug; and satellites. The elements to which the payload may be delivered include the low earth orbital MSS, OPD, space-based tug, RNS, and CPS. The elements which may be retrieved from earth orbit include a free-flying RAM, free-flying satellite, and a tug. Crew may be rescued from a low earth orbital MSS, tug, RNS, CPS, or another EOS orbiter.

The logistics mission starts with earth launch and eventual mating of the orbiter with another element (Event 8). Payload is transferred (both delivered and picked up) followed by return of payload to earth in the orbiter cargo bay. In the case of the retrieval mission, the element to which the orbiter is mated (Event 7), is retracted into the cargo bay and returned to earth. For the crew rescue case, Event 9 includes crew transfer followed by return of rescued crew to earth.

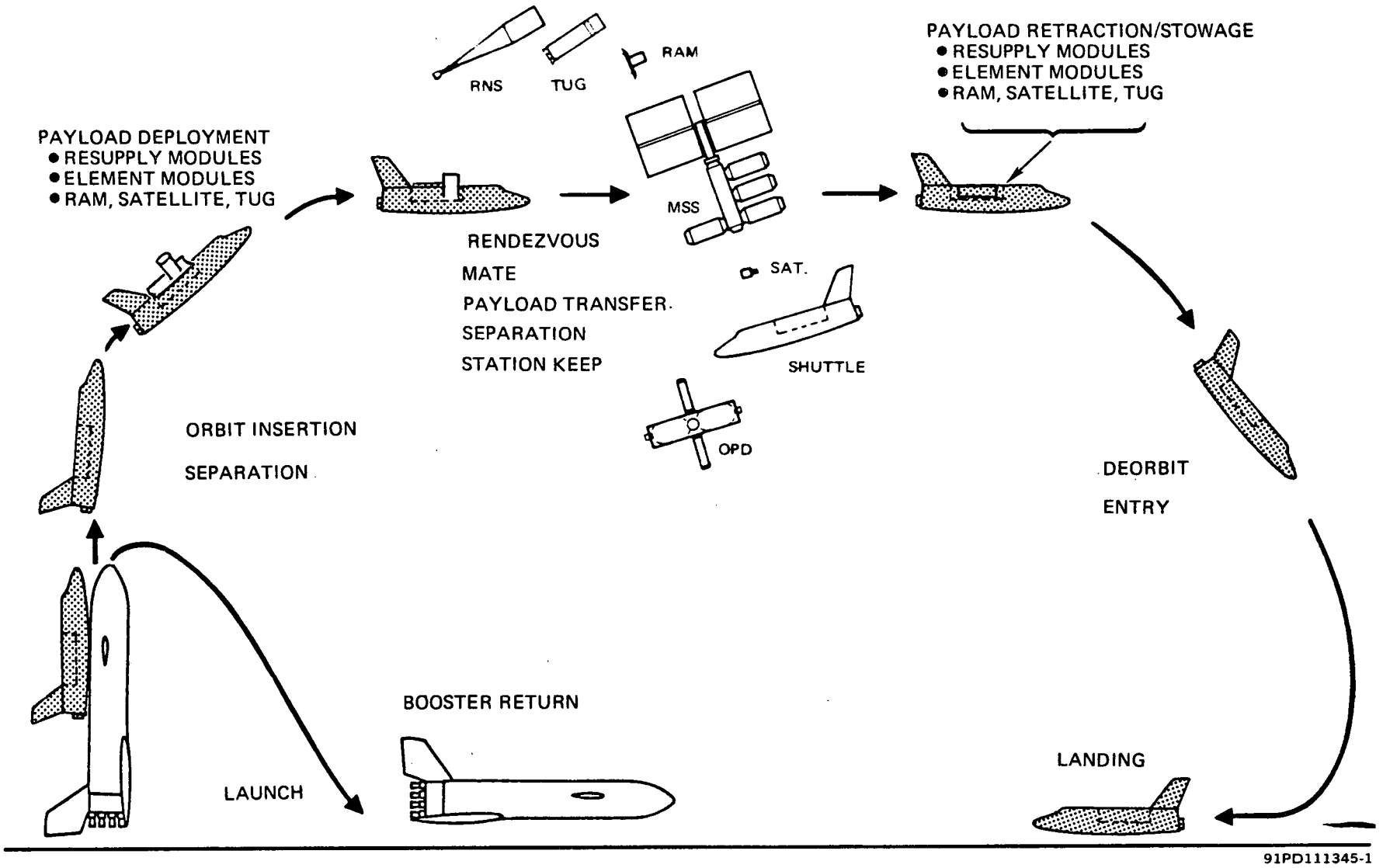

Figure 2.2-1. MM-2 EOS Logistics/Retrieval Mission

Table 2.2-1.

MM-2 EOS Logistics/Retrieval Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from EOS and return to earth	EOS - Booster EOS - MSFN; Booster - MSFN	Communications	
4. Transport payload by EOS	EOS - Payload	Attached Element Transport	Crew, Cargo, Propellant, OPD, MSS, CLS, OLS, LSB, RAM Modules; Tug; Satellite
5. Conduct phasing/orbit transfer maneuvers	EOS - TDRS, MSFN	Communications Attached Element Transport	
6. Rendezvous with orbital element	EOS - Orbital Element EOS - TDRS, MSFN Orbital Element - TDRS, MSFN	Communications Rendezvous Attached Element Transport	MSS, OPD, Tug, Satellite, CLS, RAM, EOS
7. Deploy payload	EOS - Payload	EOS Payload Deployment	Same as Step 4
8. Mate with orbital element	EOS - Orbital Element	Mating, Communications	Same as Step 6
9. Transfer payload	EOS - Orbital Element-Payload	Orbital Assembly; Cargo, Crew, Propellant Transfer; Communications; Attached Element Operations	Same as Step 4
10. Separate from orbital element and/or payload	EOS - Orbital Element-Payload	Stationkeeping Detached Element Operations Separation	Crew, Cargo, Propellant, MSS, OLS, LSB, CLS, OPD, RAM Modules; Tug; Satellite; MSS; OPD; CLS
11. Retract and stow payload in EOS	Payload - EOS	EOS Payload Retraction and Stowage, Communications, Attached Element Transport	Same as Step 10
12. Perform deorbit maneuvers	EOS - TDRS, MSFN	Communications	
13. Perform descent, entry and landing maneuvers	EOS - MSFN	Communications	
End of mission	Retrieval Mission - Delete Steps 7, 9, and 10 Retrieval/Servicing/Replacement - Delete Step 7		

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
2	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X	X	✓
5	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
6	X	X	X	X	X	X	X	X	✓	✓	X	X	X	✓
7	X	X	X	X	X	X	✓	X	X	X	X	X	X	X
8	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
9	X	✓	X	✓	✓	✓	X	X	✓	X	X	✓	X	X
10	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
11	X	X	X	X	X	X	X	✓	✓	X	X	X	X	✓
12	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
13	X	X	X	X	X	X	X	X	✓	X	X	X	X	X

Figure 2.2-2. Interfacing Activities Versus Mission Events for MM-2 EOS Logistics/Retrieval Mission

2.3 MM-3 EOS SORTIE MISSION

Figure 2.3-1 presents a pictorial representation of the mission, and Table 2.3-1 presents the mission sequence of events for MM-3. The interfacing activities identified for each mission event on Table 2.3-1 are presented in matrix form on Figure 2.3-2. This sortie mission model encompasses all individual missions where the EOS orbiter delivers an experiments payload (i.e., RAM, experiments module) to earth orbit, subsequent to which the payload remains attached to the orbiter. Following the orbital operations period, during which experiments are conducted, the payload is retracted into the cargo bay and returned to earth.

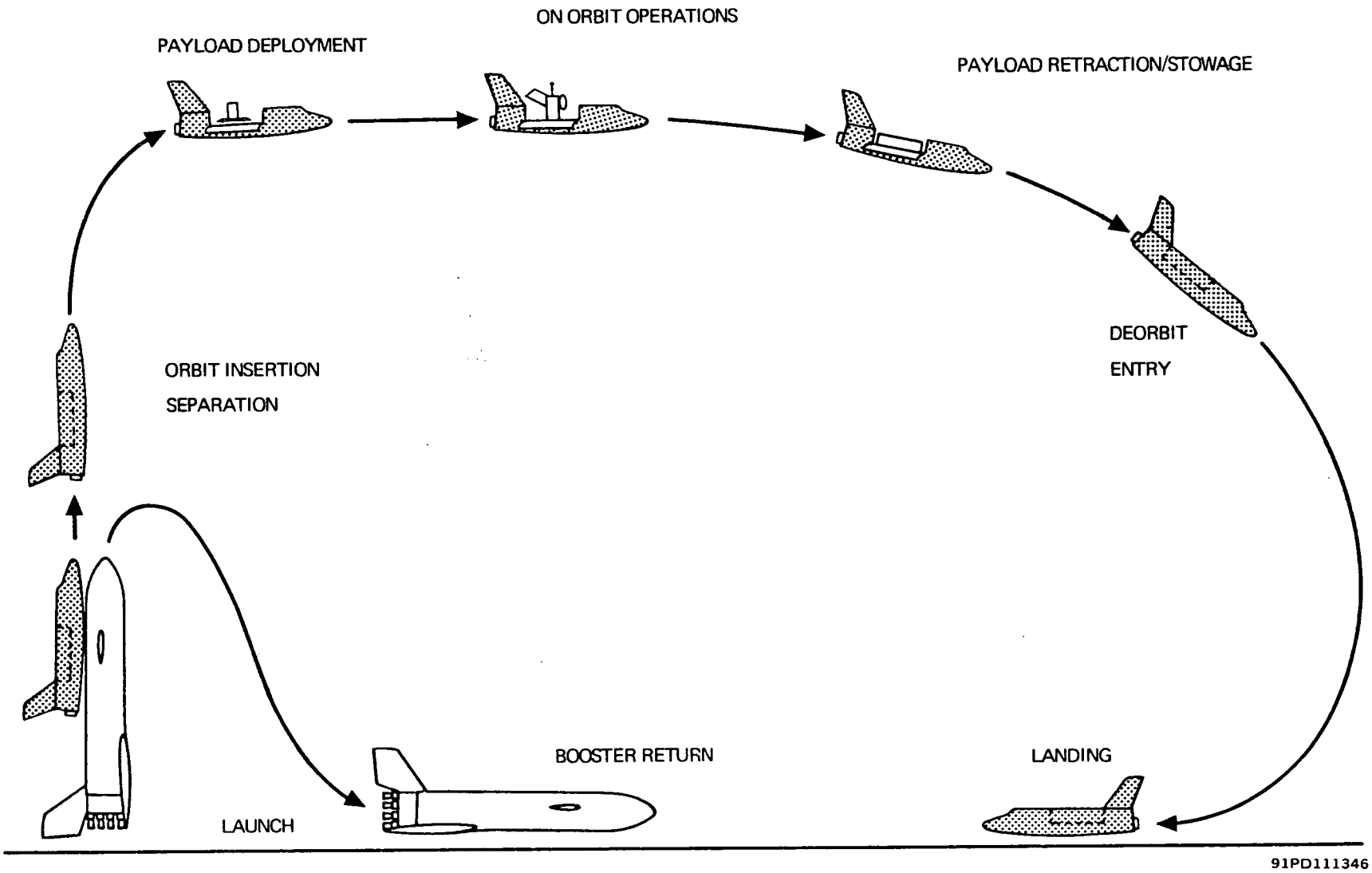

Figure 2.3-1. MM-3 EOS Sortie Mission

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Table 2.3-1.
MM-3 EOS Sortie Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from EOS and return to earth	EOS - Booster EOS - MSFN; Booster - MSFN	Communications	
4. Transport payload by EOS	EOS - Payload	Attached Element Transport	RAM
5. Conduct phasing/orbit transfer maneuvers	EOS - MSFN, TDRS	Communications Attached Element Transport	
6. Deploy payload	EOS - Payload	EOS Payload Deployment	Same as Step 4
7. Conduct on-orbit operations	EOS - Payload	Cargo Transfer Crew Transfer Attached Element Operations	Same as Step 4
8. Retract and stow payload in EOS	Payload - EOS	EOS Payload Retraction and Stowage	Same as Step 4
9. Perform deorbit maneuvers	EOS - TDRS, MSFN	Communications	
10. Perform descent, entry and landing maneuvers	EOS - MSFN	Communications	
End of mission			

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
2	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X	X	✓
5	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
6	X	X	X	X	X	X	✓	X	X	X	X	X	X	X
7	X	X	X	✓	✓	X	X	X	X	X	X	✓	X	X
8	X	X	X	X	X	X	X	✓	X	X	X	X	X	X
9	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
10	X	X	X	X	X	X	X	X	✓	X	X	X	X	X

Figure 2.3-2. Interfacing Activities Versus Mission Events for MM-3 EOS Sortie Mission

2.4. MM-4 SPACE-BASED TUG RETRIEVAL/EMPLACEMENT MISSION

A pictorial representation of the mission and the mission sequence of events for MM-4 are presented on Figure 2.4-1 and Table 2.4-1, respectively. The interfacing activities identified for each mission event on Table 2.4-1 are presented in matrix form on Figure 2.4-2. This mission is applicable to a variety of mission objectives. These objectives would include retrieval by a space-based tug of a free-flying element and subsequent transport to another major element for servicing or refueling followed by emplacement of the free-flying element, tug retrieval of a free-flying payload in earth orbit and delivery to the EOS orbiter for return to earth in the cargo bay, and picking up a payload from a major element followed by tug emplacement of the free-flying payload in another orbit.

The free-flying payloads that may be retrieved for subsequent servicing to another major element include RAM's and satellites. Servicing may take place at an EOS orbiter, OPD, or MSS. Elements that may be retrieved for refueling include the RNS, CPS, and another space-based tug. Refueling may take place at the OPD or EOS orbiter tanker. The space-based tug may pick up a satellite, RAM, or an initial module from the EOS orbiter followed by emplacement in another orbit. The tug also may pick up a single-module CPS, RNS, OLS, or large initial OPD module from an OIS and subsequently emplace the payload in another orbit. The tug may be space-based at the OPD, low earth orbital MSS, or the geosynchronous MSS.

A typical retrieval/emplacement mission starts with the tug separating from the MSS, flying to a free-flying RAM, and transporting the RAM to the MSS for servicing. Subsequently, the tug emplaces the RAM in space and then returns to the MSS where it is based. Events 4, 5, 6, and 7 do not apply for the emplacement of a payload picked up from another element. Events 12, 13, and 14 do not apply for delivery of a free-flying payload to the orbiter for earth return.

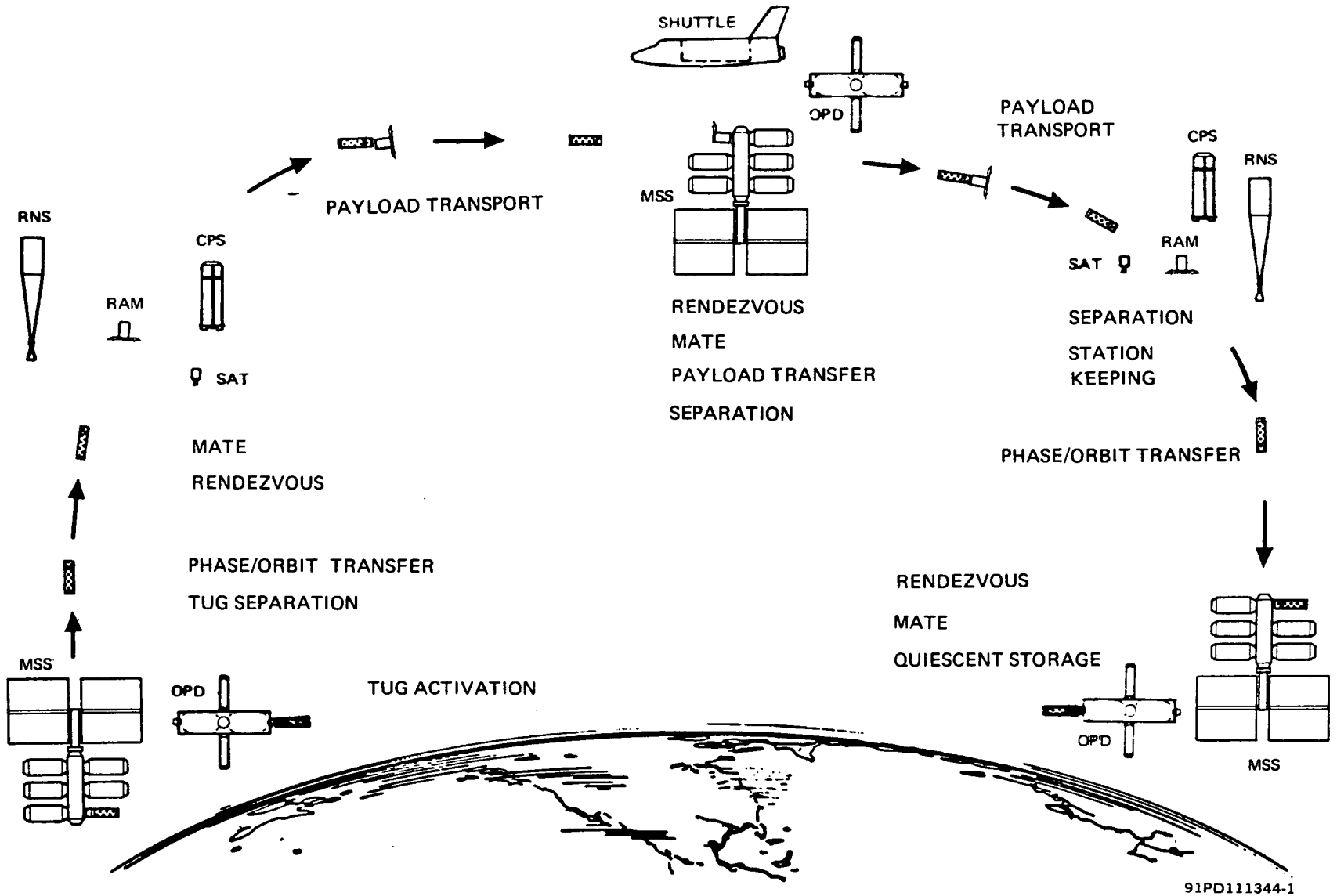

Figure 2.4-1. MM-4 Space-Based Tug Retrieval/Emplacement Mission

Table 2.4-1.
MM-4 Space-Based Tug Retrieval/Emplacement Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Activate tug at orbital base	Tug - Orbital Base Tug - TDRS, MSFN	Cargo, Crew, Propellant Transfer Communications Attached Element Operations	MSS, OPD
2. Separate from base	Tug - Orbital Base	Separation	Same as Step 1
3. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
4. Rendezvous with payload	Tug - Payload Tug - TDRS, MSFN Payload - TDRS, MSFN	Communications Rendezvous	RAM, Satellite, CLS, Tug
5. Mate with payload	Tug - Payload	Mating, Communications	Same as Step 4
6. Transport payload	Tug - Payload	Attached Element Transport	Same as Step 4
7. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
8. Rendezvous with orbital elements	Tug - Orbital Element Tug - TDRS, MSFN Orbital Element - TDRS, MSFN	Communications, Rendezvous, Attached Element Transport	MSS, OPD, EOS, OIS
9. Mate with orbital element	Tug - Orbital Element	Mating, Communications, Attached Element Transport	Same as Step 8
10. Transport payload	Payload - Orbital Element	Cargo, Crew, Propellant Transfer EOS Payload Deployment EOS Payload Retraction and Stowage, Attached Element Operations	EOS, MSS, OPD, CLS, Satellite, RAM, Tug
11. Separate from orbital element	Tug - Orbital Element	Separation, Stationkeeping, Detached Element Operations	Same as Step 8
12. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
13. Separate from payload	Tug - Orbital Element	Separation	RAM, Satellite, CLS
14. Initiate payload on-station operations	Payload - Orbital Element - TDRS, MSFN	Commun., Stationkeeping Detached Element Operations	RAM, Satellite, MSS, Tug
15. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
16. Rendezvous with orbital base	Tug - Orbital Base Tug - TDRS, MSFN Orbital Base - TDRS, MSFN	Communications, Rendezvous	Same as Step 1
17. Mate with orbital base	Tug - Orbital Base	Mating, Communications	Same as Step 1
18. Initiate quiescent storage End of mission	Tug - Orbital Base	Attached Element Operations	Same as Step 1

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1				✓	✓	✓			✓			✓		
2			✓											
3									✓					
4									✓	✓				
5	✓								✓					
6														✓
7									✓					✓
8									✓	✓				✓
9									✓					✓
10				✓	✓	✓	✓	✓				✓		
11			✓								✓		✓	
12									✓					✓
13			✓											
14									✓		✓		✓	
15									✓					
16									✓	✓				
17	✓								✓					
18												✓		

Figure 2.4-2. Interfacing Activities Versus Mission Events for MM-4 Space-Based Tug Retrieval/Emplacement Mission

2.5. MM-5 SPACE-BASED TUG LOGISTICS MISSION

A pictorial representation of the mission and the mission sequence of events for MM-5 are presented on Figure 2.5-1 and Table 2.5-1, respectively. The interfacing activities identified for each mission event on Table 2.5-1 are presented in matrix form on Figure 2.5-2. This mission is applicable to the delivery by a space-based tug of a payload from one major space element to another. It also is applicable to the fueling of a non-free-flying lunar tug or a lunar propellant module in earth orbit using the space-based tug as the transport vehicle. The payloads that can be transported from one element to another include RAM's, satellites, element modules, and resupply modules. The elements from which and to which the payloads may be delivered include the MSS, RNS, CPS, tug, EOS orbiter, and the OPD. The space-based tug can be based at the OPD, MSS, CPS, or RNS.

A typical logistics mission starts with the tug separating from the MSS, flying to the orbiter, picking up a lunar resupply module, transporting the module to the RNS, separating from the module, and returning to the MSS. For the fueling of a lunar tug, the space-based tug flies to the RNS (or CPS), picks up the lunar tug (Event 6), and transports the lunar tug to the OPD where propellant transfer (Event 11) takes place followed by separation from the OPD with the lunar tug still attached to the space-based tug. Subsequently, Events 8 through 11 are repeated for return (by the space-based tug) of the fueled lunar tug to the RNS from which it came. Following this procedure, Events 12 through 16 take place and end with the return of the space-based tug to the MSS or OPD.

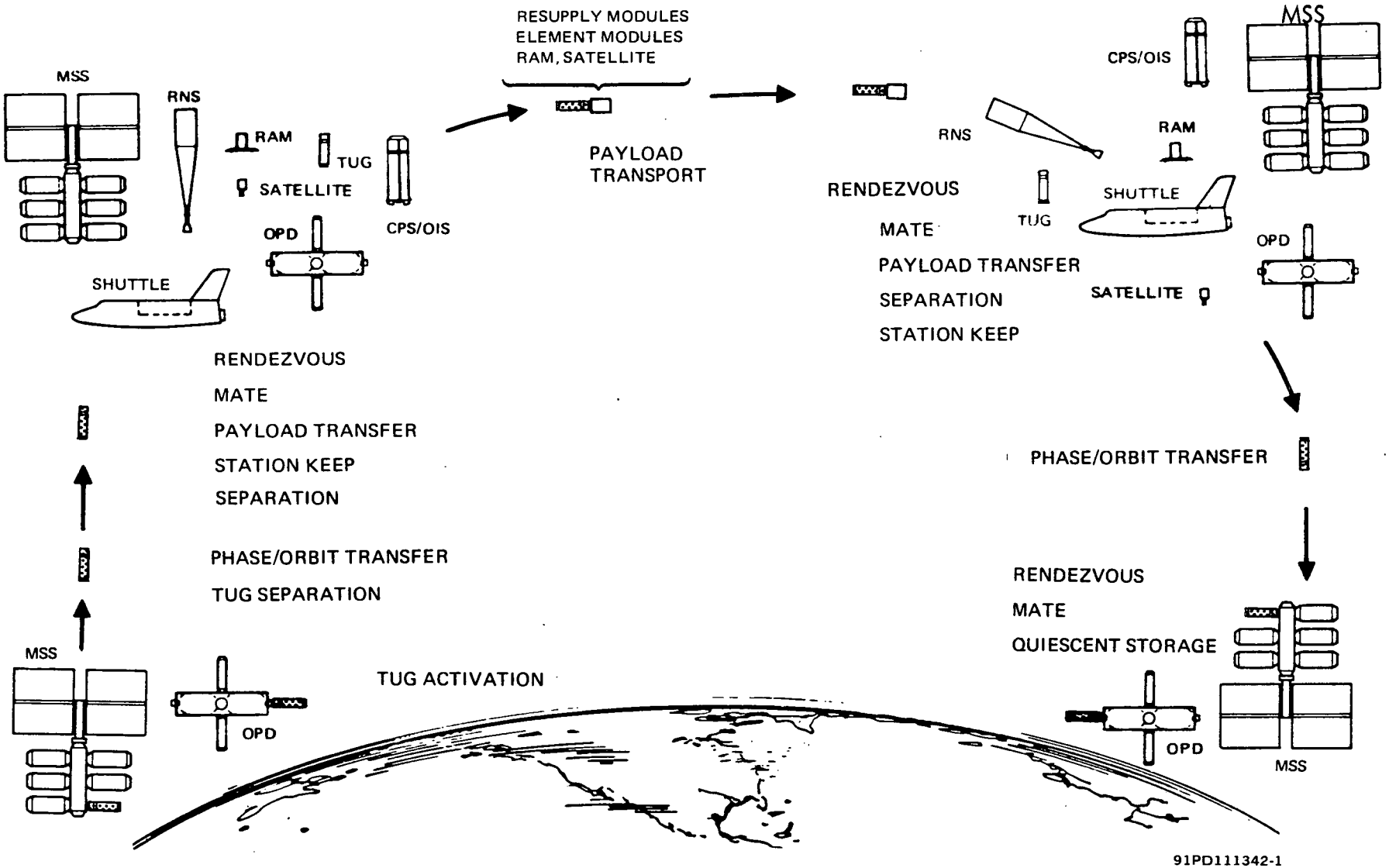

Figure 2.5-1. MM-5 Space-Based Tug Logistics Mission

Table 2.5-1.
MM-5 Space-Based Tug Logistics Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Activate tug at orbital base	Base - Tug; Base - TDRS, MSFN	Cargo, Crew, Propellant Transfer; Commun.; Attach. Element Ops.	Station, OPD, CLS
2. Separate from base	Tug - Base	Separation	Same as Step 1
3. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
4. Rendezvous with orbital element	Tug - Orbit Element - TDRS, MSFN	Communications, Rendezvous	EOS, Station, OPD, CLS, OLS, Satellite, RAM, Tug, OIS
5. Mate with orbital element	Tug - Orbital Element	Mating, Communications	Same as Step 4
6. Transfer payload	Tug - Orbital Element - Payload	Cargo, Crew, Propellant Transfer; EOS P/L Deployment; Retraction & Stowage; Attach. Element Ops.	Crew, Cargo, Propellant, OLS, LSB, CLS, Station Modules; RAM; Satellite; Tug
7. Separate from orbital element	Tug - Payload - Orbital Element	Separation, Stationkeeping Detached Element Operations	Same as Step 4
8. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
9. Rendezvous with orbital element	Tug - Orbital Element - TDRS, MSFN	Orbital Assembly, Communications, Rendezvous, Attached Element Transport	Same as Step 4
10. Mate with orbital element	Tug - Orbital Element	Mating, Communications Stationkeeping	Same as Step 4
11. Transfer payload	Tug - Orbital Element - Payload	Cargo, Crew, Propellant Transfer; EOS Payload Deployment EOS Payload Retraction & Stowage	Same as Step 6

Table 2.5-1.

MM-5 Space-Based Tug Logistics Mission (Continued)

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
12. Separate from orbital element	Tug - Orbital Element	Separation, Stationkeeping Detached Element Operations	Same as Step 4
13. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
14. Rendezvous with orbital base	Tug - Orbital Base	Communications, Rendezvous	Same as Step 1
15. Mate with orbital base	Tug - Orbital Base	Mating, Communications	Same as Step 1
16. Initiate quiescent storage	Tug - Orbital Base	Attached Element Operations	
End of mission			

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	✓	✓	✓	X	X	✓	X	X	✓	X	X
2	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
5	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
6	X	X	X	✓	✓	✓	✓	✓	X	X	X	✓	X	X
7	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
8	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
9	X	✓	X	X	X	X	X	X	✓	✓	X	X	X	✓
10	✓	X	X	X	X	X	X	X	✓	X	✓	X	X	X
11	X	X	X	✓	✓	✓	✓	✓	X	X	X	X	X	X
12	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
13	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
14	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
15	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
16	X	X	X	X	X	X	X	X	X	X	X	✓	X	X

Figure 2.5-2. Interfacing Activities Versus Mission Events for MM-5 Space-Based Tug Logistics Mission

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2.6. MM-6 SPACE-BASED TUG DISPOSAL MISSION

A pictorial representation of the mission and the mission sequence of events for MM-6 are presented on Figure 2.6-1 and Table 2.6-1, respectively. The interfacing activities identified for each mission event on Table 2.6-1 are presented in matrix form on Figure 2.6-2. It is assumed for this study that all elements that are expended in earth orbit and can be returned to earth in the cargo bay of the EOS orbiter will be disposed of in this manner. Hence, this disposal mission is applicable only for disposal of large expended elements by placing the element in an earth-impact trajectory. The elements that may be disposed of by this mission include the single-module RNS, CPS, and OIS, and the larger OPD modules. The tug may be based at the MSS, OPD, RNS, or CPS.

Typically, the space-based tug separates from the MSS, flies to the expended CPS, mates with the CPS, performs an orbit transfer maneuver to attain the desired orbit for deorbit, performs a retrograde burn for deorbit, separates from the CPS, performs a posigrade burn to prevent tug entry into the earth's atmosphere, and returns to the MSS. Following separation, the CPS enters the earth's atmosphere, is partially burned up, and ultimately impacts the earth.

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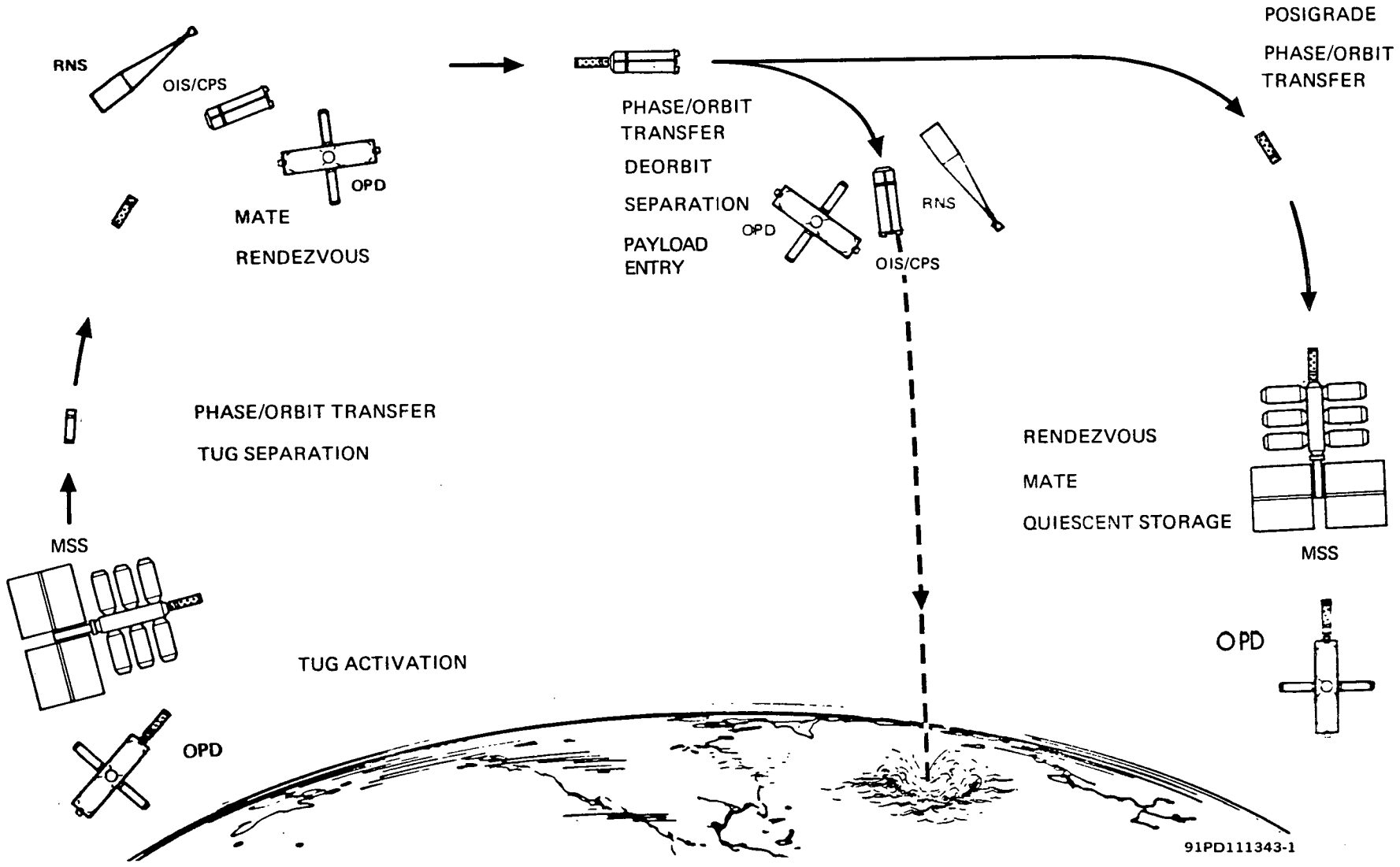

Figure 2.6-1. MM-6 Space-Based Tug Disposal Mission

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Table 2.6-1.
MM-6 Space-Based Tug Disposal Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Activate tug at orbital base	Orbital Base - Tug Tug - TDRS, MSFN Orbital Base - TDRS, MSFN	Cargo, Crew, Propellant Transfer Communications Attached Element Operations	MSS, OPD, CLS
2. Separate from orbital base	Tug - Orbital Base	Separation	Same as Step 1
3. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
4. Rendezvous with expended element	Tug - Expended Element, Tug - TDRS, MSFN Expended Element - TDRS, MSFN	Communications, Rendezvous Detached Element Operations	OIS, CPS, RNS, OPD
5. Mate with expended element	Tug - Expended Element	Mating, Communications	Same as Step 4
6. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
7. Perform deorbit maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
8. Separate payload	Tug - Payload	Separation	Same as Step 4
9. Payload descent and entry	Payload - MSFN	Communications	
10. Perform posigrade maneuvers	Tug - TDRS, MSFN	Communications	
11. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
12. Rendezvous with orbital base	Tug - Orbital Base, Tug - TDRS, MSFN Orbital Base - TDRS, MSFN	Communications Rendezvous	Same as Step 1
13. Mate with orbital base	Tug - Orbital Base	Mating, Communications	Same as Step 1
14. Initiate quiescent storage	Tug - Orbital Base	Attached Element Operations	Same as Step 1
End of mission			

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	✓	✓	✓	X	X	✓	X	X	✓	X	X
2	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	✓	✓	X	X	✓	X
5	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
6	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
7	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
8	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
9	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
10	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
11	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
12	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
13	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
14	X	X	X	X	X	X	X	X	X	X	X	✓	X	X

Figure 2.6-2. Interfacing Activities Versus Mission Events for MM-6 Space-Based Tug Disposal Mission

2.7. MM-7 GROUND-BASED TUG EMPLACEMENT/SORTIE MISSION

A pictorial representation of the mission and the mission sequence of events for MM-7 are presented on Figure 2.7-1 and Table 2.7-1, respectively. The interfacing activities identified for each mission event on Table 2.7-1 are presented in matrix form on Figure 2.7-2. This mission is applicable to ground-based tug emplacement of a free-flying element in a high-energy orbit and to a sortie mission where the tug payload (an experiment payload) remains attached to the tug in a high-energy orbit. The payloads that may be emplaced in a high-energy orbit by the ground-based tug include satellites and free-flying RAM's.

The ground-based tug, with attached payload, is launched from earth in the cargo bay of the EOS orbiter. Following orbit insertion and payload deployment, the tug with attached payload is separated from the EOS orbiter. After stationkeeping for visual and RF checkout, the tug engine is ignited for transfer of tug and payload to a high-energy orbit (such as geosynchronous orbit). If the payload is to be emplaced, separation then occurs (Event 11), and the tug returns to the orbiter for return to earth. If the payload is an experiments' payload, separation from the payload may not occur, and Event 11 would not apply.

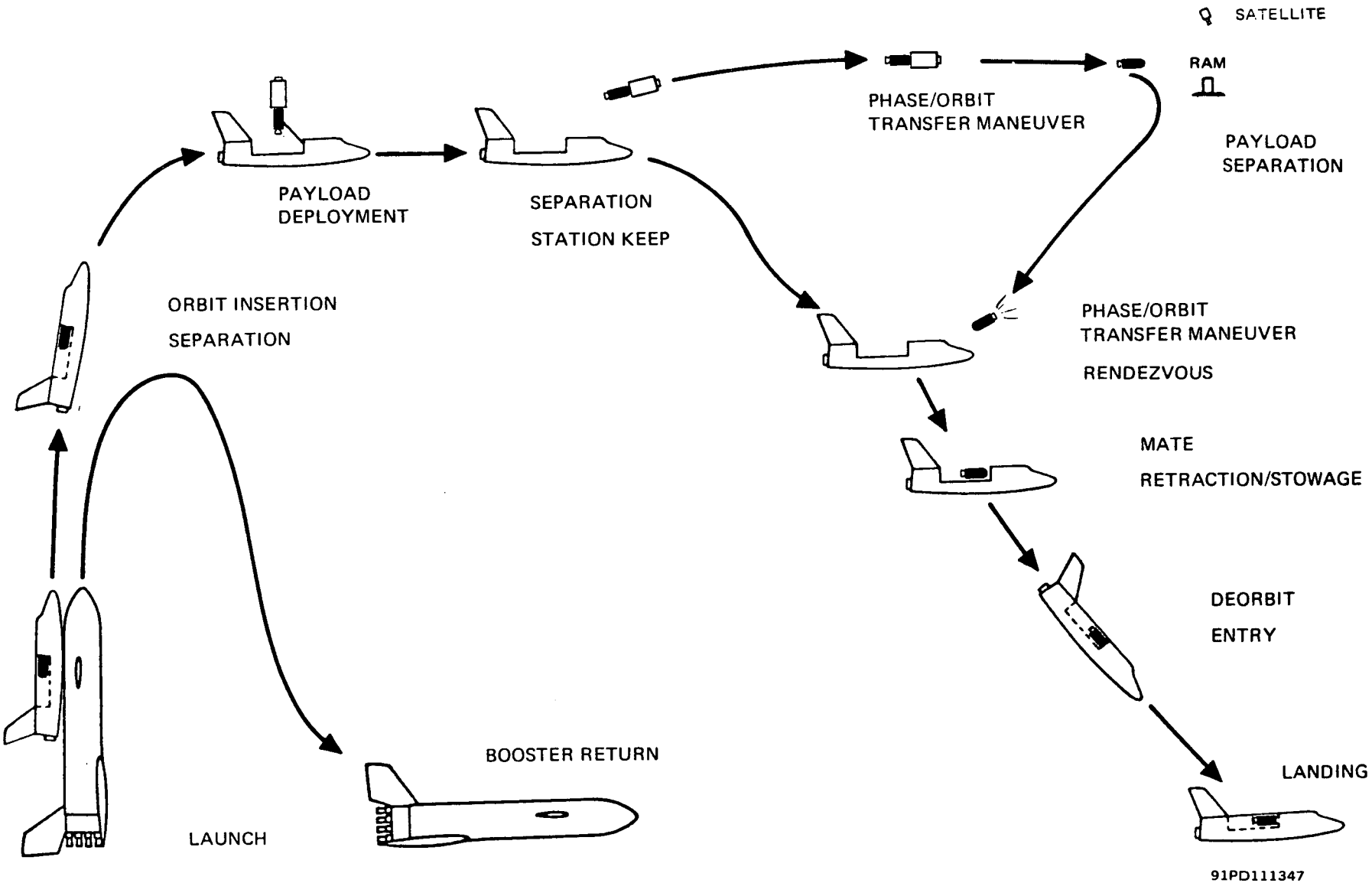

Figure 2.7-1. MM-7 Ground-Based Tug Emplacement/Sortie Mission

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Table 2.7-1.
MM-7 Ground-Based Tug Emplacement/Sortie Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from EOS and return to earth	Booster - EOS Booster - MSFN EOS - MSFN	Communications	
4. Transport payload by EOS	EOS - Payload	Communications Attached Element Transport	Tug, Satellite, RAM
5. EOS conduct phasing/orbit transfer maneuvers	EOS - TDRS, MSFN	Communications Attached Element Transport	
6. EOS deploy payload	EOS - Payload	EOS Payload Deployment	Same as Step 4
7. Separate tug and payload from EOS	EOS - Payload	Separation, Stationkeeping Detached Element Operations	Same as Step 4
8. Initiate tug orbital operations	Tug - EOS Tug - TDRS, MSFN	Communications Attached Element Operations	Same as Step 4
9. Perform tug phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
10. Initiate payload orbital operations	Tug - Payload Tug - TDRS, MSFN Payload - TDRS, MSFN Tug - EOS; Payload - EOS	Communications Attached Element Operations Crew Transfer Cargo Transfer	Same as Step 4
11. Separate payload from tug	Tug - Payload	Separation, Stationkeeping Detached Element Operations	Satellite, Geo Station Module
12. Perform tug phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
13. Rendezvous with EOS	Tug - EOS; Tug - TDRS, MSFN EOS - TDRS, MSFN	Communications Rendezvous	
14. Mate with EOS	Tug - EOS	Mating, Communications	EOS
15. Retract and stow tug with/without payload	Tug - EOS	EOS Payload Retraction and Stowage	EOS; Satellite
16. EOS perform deorbit maneuvers	EOS - TDRS, MSFN	Communications	
17. EOS perform descent, entry and landing maneuvers	EOS - MSFN	Communications	
End of mission	Sortie Mission - Delete Step 11		

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
2	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
5	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
6	X	X	X	X	X	X	✓	X	X	X	X	X	X	X
7	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
8	X	X	X	X	X	X	X	X	✓	X	X	✓	X	X
9	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
10	X	X	X	✓	✓	X	X	X	✓	X	X	✓	X	X
11	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
12	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
13	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
14	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
15	X	X	X	X	X	X	X	✓	X	X	X	X	X	X
16	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
17	X	X	X	X	X	X	X	X	✓	X	X	X	X	X

Figure 2.7-2. Interfacing Activities Versus Mission Events for MM-7 Ground-Based Tug Emplacement/Sortie Mission

2.8 MM-8 GROUND-BASED TUG LOGISTICS/RETRIEVAL MISSION

A pictorial representation of the mission and the mission sequence of events for MM-8 are presented on Figure 2.8-1 and Table 2.8-1, respectively. The interfacing activities identified for each mission event on Table 2.8-1 are presented in matrix form on Figure 2.8-2. This mission is applicable to delivery by the ground-based tug of a payload to another element in a high-energy orbit, geosynchronous MSS buildup, retrieval by the tug of a free-flying payload in a high-energy orbit, rescue of crew from a manned element in a high-energy orbit, and use of the ground-based tug as a tanker for refueling other elements. The payloads that may be delivered to another element include resupply modules and RAM's. Free-flying elements that may be retrieved in this mission include satellites and detached RAM's. In the tug-tanker application, the tug can transfer propellant to the OPD, RNS, CPS, or a space-based tug.

In the logistics mission application, the ground-based tug is launched from earth (in the EOS orbiter cargo bay) with an attached payload. The tug and attached payload are deployed and separated from the orbiter in low earth orbit. The tug performs an orbit transfer maneuver, transports the payload to a high-energy orbit, transfers the payload to another space element, picks up a down payload, and returns to the EOS orbiter for subsequent return to earth. In the retrieval mission application, the tug may or may not have an attached payload when it is launched from earth in the orbiter cargo bay. If a payload is attached, the tug delivers this payload to an element in a high-energy orbit prior to retrieving another free-flying element from space. The ground-based tug transports the free-flying element to the EOS orbiter for return of the tug and attached element to earth. In the station buildup mission application, the tug delivers a geosynchronous MSS module to the portion of the MSS that has been previously delivered to geosynchronous orbit. In this case the tug probably returns to the orbiter without a down payload, but (depending upon payload weights) the potential exists in this mission for tug retrieval of a free-flying payload subsequent to delivery of the MSS module. Possibly a more viable application of this mission (than geosynchronous MSS module delivery), due to potential weight limitations, is the tug rescue of personnel from the geosynchronous MSS and delivery of these personnel to the EOS orbiter for return to earth. For tug-tanker application, the tug has no payload other than propellant for transfer to another element. Upon separation from the EOS orbiter, the tug-tanker flies to and mates with the element requiring refueling. Direct propellant transfer occurs (Event 11) followed by return of the tug to the orbiter for return to earth.

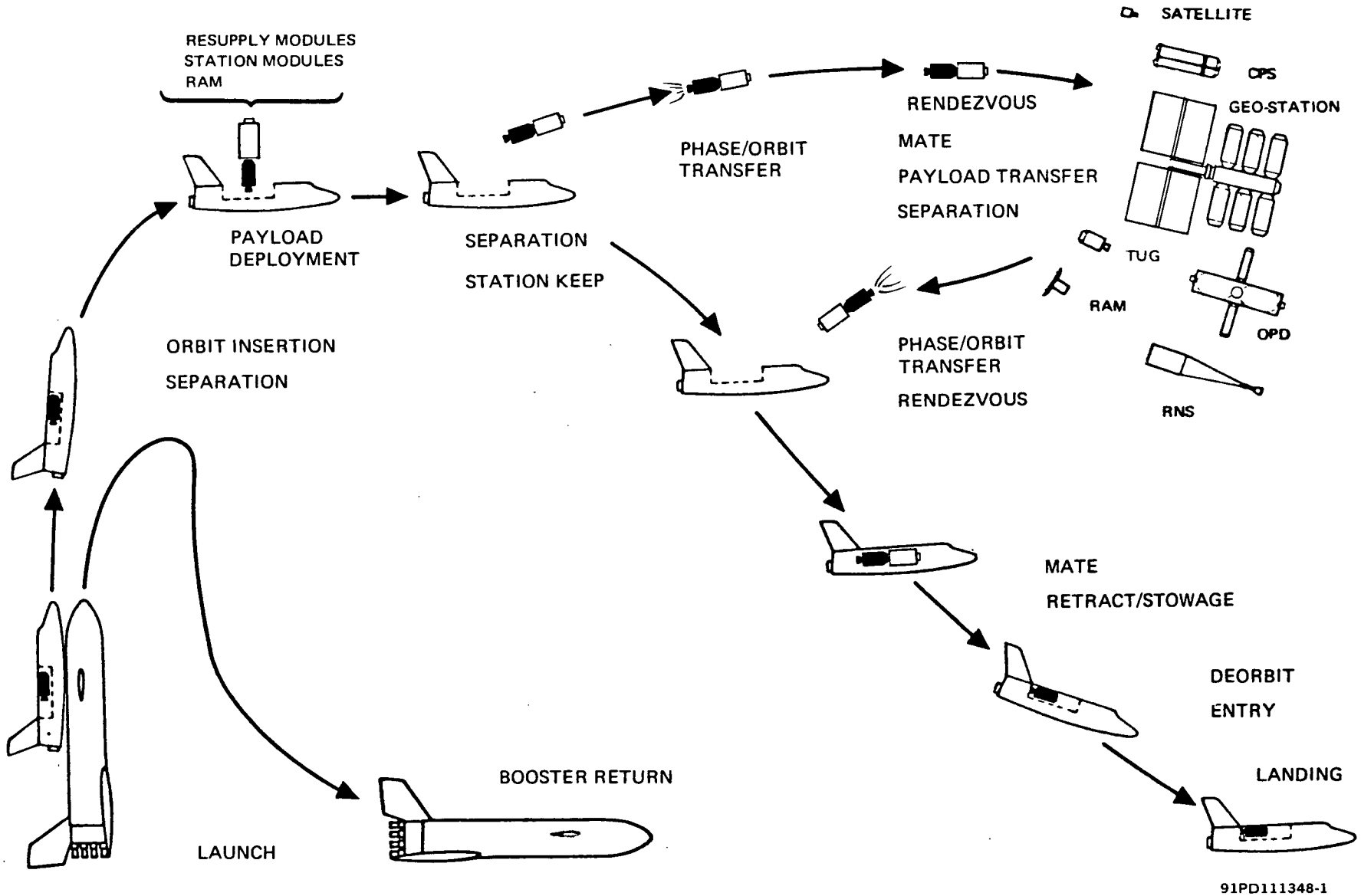

Figure 2.8-1. MM-8 Ground-Based Tug Logistics/Retrieval Mission

Table 2.8-1.

MM-8 Ground-Based Tug Logistics/Retrieval Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from EOS and return to earth	EOS - Booster; EOS - MSFN Booster - MSFN	Communications	
4. Transport payload by EOS	EOS - Payload	Attached Element Transport	Tug, Satellite, Geo Station Module, RAM, Resupply Module
5. EOS conduct phasing/orbit transfer maneuvers	EOS - TDRS, MSFN	Communications Attached Element Transport	Same as Step 4
6. EOS deploy payload	EOS - Payload	EOS Payload Deployment	Same as Step 4
7. Separate tug and payload from EOS	EOS - Payload	Separation, Stationkeeping Detached Element Operations	Same as Step 4
8. Perform tug phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications Attached Element Transport	
9. Rendezvous with orbital element	Tug - Orbital Element Tug - TDRS, MSFN Orbital Element - TDRS, MSFN	Communications, Rendezvous Attached Element Transport	Geo Station; CLS; OPD; Tug; Satellite; RAM
10. Mate with orbital element	Tug - Orbital Element	Mating, Communications	Same as Step 9
11. Transfer payload	Tug - Orbital Element	Orbital Assy; Cargo, Crew, Propellant Transfer Attached Element Operations	RAM; Satellite; Crew, Cargo, Propellant, Geo Station Modules
12. Separate from orbital element	Tug - Orbital Element	Separation, Stationkeeping Detached Element Operations	Same as Step 9
13. Perform phasing/orbit transfer maneuvers	Tug - TDRS, MSFN	Communications	
14. Rendezvous with EOS	Tug - EOS Tug - TDRS, MSFN EOS - TDRS, MSFN	Communications Rendezvous	EOS

Table 2.8-1.
MM-8 Ground-Based Tug Logistics Retrieval Mission (Cont'd)

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Element
15. Mate with EOS	Tug - EOS	Mating Communications	EOS
16. EOS retract and stow tug and payload	EOS - Tug EOS - Payload	EOS Payload Retraction and Stowage	Satellite; RAM; Crew, Cargo, Propellant Modules
17. EOS perform deorbit maneuvers	EOS - TDRS, MSFN	Communications	
18. Perform descent, entry and landing maneuvers	EOS - MSFN	Communications	
End of mission	Retrieval Mission - Delete Step 12		

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1									✓					
2									✓					
3									✓					
4														✓
5									✓					✓
6							✓							
7			✓								✓		✓	
8									✓					✓
9									✓	✓				✓
10	✓								✓					
11		✓		✓	✓	✓						✓		
12			✓								✓		✓	
13									✓					
14									✓	✓				
15	✓								✓					
16								✓						
17									✓					
18									✓					

Figure 2.8-2. Interfacing Activities Versus Mission Events for MM-8 Ground-Based Tug Logistics/Retrieval Mission

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2.9 MM-9 ORBITAL INSERTION STAGE DELIVERY MISSION

A pictorial representation of the mission and the mission sequence of events for MM-9 are presented on Figure 2.9-1 and Table 2.9-1, respectively. The interfacing activities identified for each mission event on Table 2.9-1 are presented in matrix form on Figure 2.9-2. It is assumed for this study that all elements in the study inventory that can be delivered to earth orbit in an EOS cargo bay will be delivered in this manner. This mission is applicable to delivery of large elements to earth orbit, including the single-module CPS, RNS, and OLS as well as large modules of the OPD. The payload delivery may consist of emplacement of the payload in earth orbit or transfer of the payload to another element in orbit. The elements to which the payload may be delivered include the CPS, RNS, OPD, and space-based tug. The single-module OIS used for delivery ultimately may be converted into a CPS (orbit-to-orbit shuttle or cislunar shuttle) or expended.

The mission starts with launch from earth with the OIS mounted as a second stage on the EOS booster. The OIS replaces the EOS orbiter in this application. The payload is attached to the OIS and is inserted into earth orbit by the OIS. The OIS payload may be emplaced in orbit (in which case, Events 6 and 7 do not apply), or the payload may be transferred to another element (Event 7). The element to which the payload is transferred may subsequently deliver the payload to another orbit or may perform assembly operations in near earth orbit. For example, a space-based tug may receive large OPD modules from the OIS and transfer these modules to smaller OPD modules (which have been brought to orbit in the EOS orbiter cargo bay) for assembly in earth orbit. Following OIS separation from its payload (Event 8), the OIS either may be placed in a quiescent mode (Event 9) for subsequent conversion to a CPS (delete Event 10) or may be disposed of. The OIS may be capable of performing the deorbit maneuver for disposal (Event 10), or a space-based tug may be used to deorbit the OIS (see mission model MM-6).

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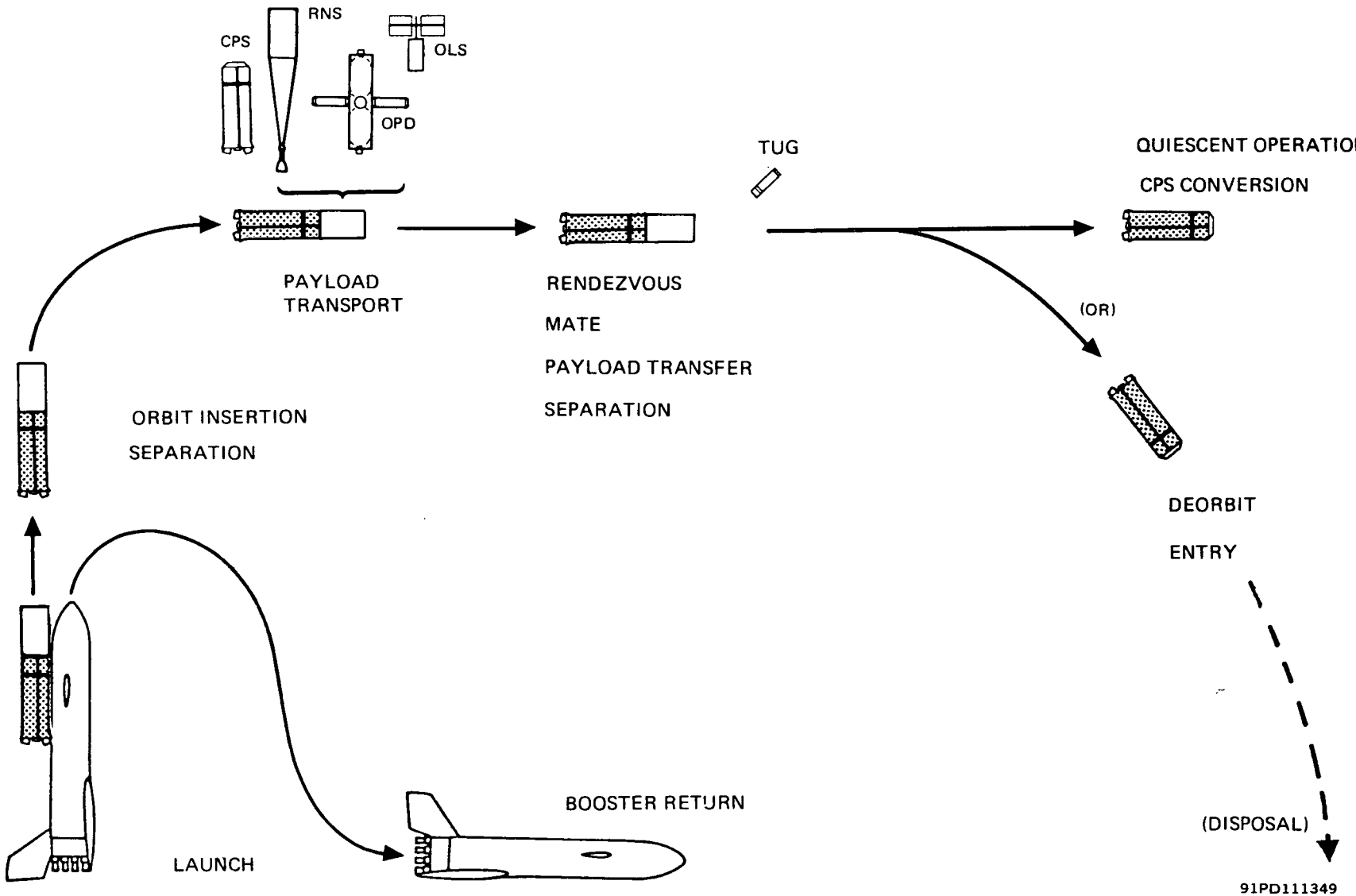

Figure 2.9-1. MM-9 Orbital Insertion Stage Delivery Mission

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Table 2.9-1.
MM-9 Orbital Insertion Stage Delivery Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Element
1. Launch	Shuttle - KSC, WTR	Communications	
2. Complete booster thrust	Shuttle - MSFN	Communications	
3. Separate booster from OIS and return to earth	OIS - Booster OIS - MSFN Booster - MSFN	Communications	
4. Perform orbit insertion/ stabilization maneuvers	OIS - TDRS, MSFN	Communications Attached Element Transport	
5. Activate payload (NOTE 1)	Payload - TDRS, MSFN	Communications	CPS; RNS; OLS OPD
6. Rendezvous with orbital element	OIS - TDRS, MSFN OIS - Orbital Element Orbital Element - TDRS, MSFN	Communications Rendezvous	OPD, Tug; CLS
7. Mate payload with orbital element	OIS - Orbital Element OIS - Payload Payload - Orbital Element	Mating, Orbital Assembly Communications	Combinations of Steps 5 & 6
8. Separate from payload	OIS - Payload OIS - Orbital Element	Separation	Same as Step 5
9. Initiate quiescent operations (NOTE 2)	OIS - TDRS, MSFN OIS - Orbital Element	Communications	Same as Step 5
10. Perform deorbit and entry maneuvers (NOTE 3)	OIS - TDRS, MSFN	Communications	
End of mission	Emplacement Mission - Delete Steps 6 and 7		

NOTES:
1. Applicable for OIS emplacement of payload
2. Applicable to OIS to be (a) deorbited by a tug, or (b) conversion to a CPS
3. Applicable to nonreusable OLS with self-contained deorbit capability

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
2	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
3	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
4	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
5	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
6	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
7	✓	✓	X	X	X	X	X	X	✓	X	X	X	X	X
8	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
9	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
10	X	X	X	X	X	X	X	X	✓	X	X	X	X	X

Figure 2.9-2. Interfacing Activities Versus Mission Events for MM-9 Orbital Insertion Stage Delivery Mission

2.10 MM-10 STAGED GEOSYNCHRONOUS/CISLUNAR SHUTTLE LOGISTICS MISSION

A pictorial representation of the mission and the mission sequence of events for MM-10 are presented on Figure 2.10-1 and Table 2.10-1, respectively. The interfacing activities identified for each mission event on Table 2.10-1 are presented in matrix form on Figure 2.10-2. This mission is applicable to the use of a two-staged CPS for delivery of payloads to (and return of payloads from) a high-energy earth orbit (such as geosynchronous) or to lunar orbit. It also is applicable to personnel rescue and emplacement and/or retrieval of free-flying payloads from these orbits. For flights to high-energy earth orbits, the active propulsive vehicle may be a two-stage space-based tug. The precise order in which some of the events occur and the need for transport assembly support from an additional vehicle(s) (see Events 20 through 24) are a function of the performance characteristics of the individual stages, the payload weight, and the selected orbital mechanics mission concept. This mission model includes all of the mission events that can occur and involve interfacing activities between interfacing elements. (It should be noted that only those events that occur in earth orbit are subject to evaluation in this Orbital Operations Study.) The payloads that may be delivered to another space element in this mission include MSS modules, resupply modules, RAM's, OLS and LSB modules, and tugs. The elements that may be emplaced or retrieved include satellites and detached RAM's.

In the mission sequence presented in Table 2.10-1, the two-staged CPS (or tug) is activated in parking orbit, flies to the propellant supply system (tug-tanker, EOS orbiter tanker, or OPD) for refueling, and flies to the logistics supply system (space-based tug or EOS orbiter) to pick up a payload. The first stage then performs an orbit transfer maneuver to place the two stages and the payload into a translunar trajectory (or transgeosynchronous trajectory). Staging occurs (Event 11) followed by a first-stage retrograde burn (Event 12) to prevent the first stage from leaving low earth orbit. The second stage and attached payload continue to lunar orbit (or geosynchronous orbit) where the payload is delivered to a lunar element, a down payload is picked up, and the CPS (second stage) returns the payload to low earth orbit (Event 15). Rendezvous and mating then occur between the second stage of the CPS and the return logistics system (Events 16 and 17). After payload transfer and separation, the second stage of the CPS is picked up by a space-based tug (Event 21) for subsequent assembly operations. Meanwhile, a tug will rendezvous and mate with the first stage of the CPS (Events 22 and 23) for subsequent assembly operations. Finally, the first and second stages of the CPS are brought together and mated (Event 23) followed by quiescent operations.

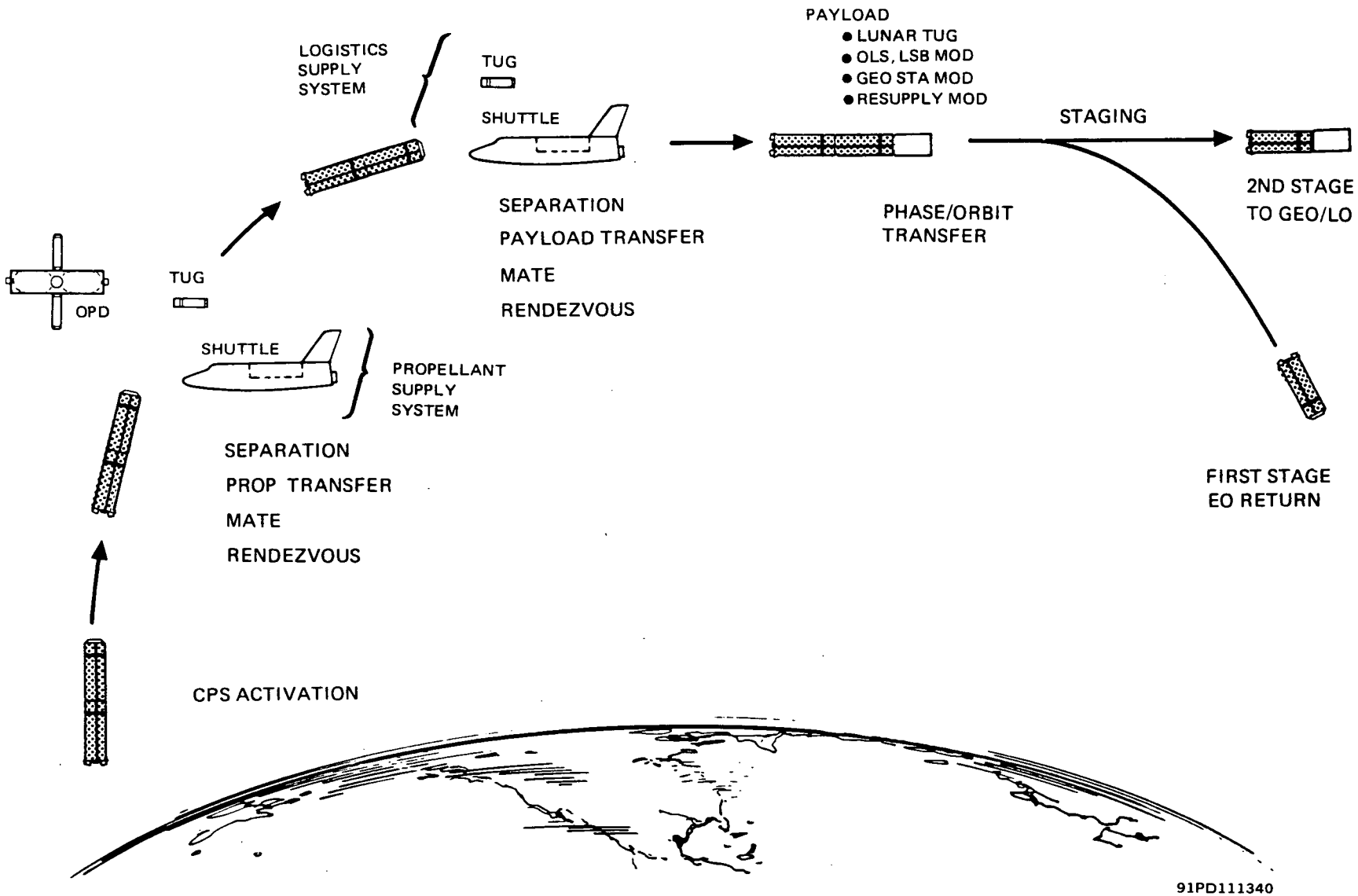

Figure 2.10-1. MM-10 Staged Geosynchronous/Cislunar Shuttle Logistics Mission

(Sheet 1 of 2)

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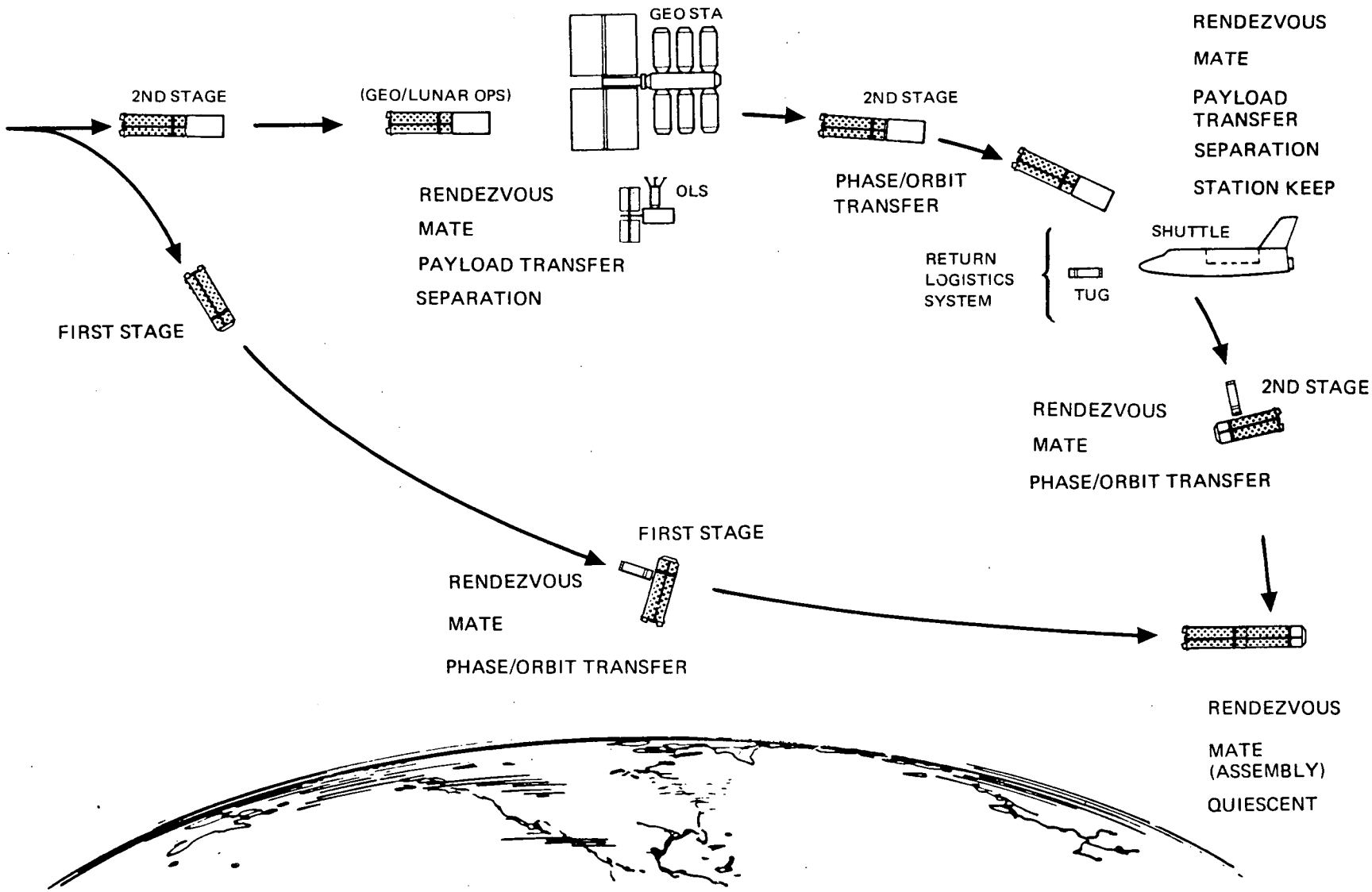

Figure 2.10-1. MM-10 Staged Geosynchronous/Cislunar Shuttle Logistics Mission (Sheet 2 of 2)

Table 2.10-1.
MM-10 Staged Geo/Cislunar Shuttle Logistics Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Element
1. Activate orbital shuttle	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Operations	
2. Rendezvous with propellant supply system (NOTE 1)	Orbital Shuttle - Propellant Supply Sys; Orbital Shuttle - TDRS, MSFN; Propellant Supply Sys - TDRS, MSFN	Communications, Rendezvous Detached Element Operations	OPD, EOS, Tug
3. Mate with propellant supply system	Orbital Shuttle - Propellant Supply System	Mating	OPD; EOS; Tug; Propellant Module
4. Transfer payload	Orbital Shuttle - Payload	Propellant Transfer	Same as Step 3
5. Separate from propellant supply system	Orbital Shuttle - Propeliant Supply System	Separation	Same as Step 3
6. Rendezvous with logistics system	Orbital Shuttle - Logistics System; Orbital Shuttle - TDRS, MSFN Logistics System - TDRS, MSFN	Communications, Rendezvous Detached Element Operations	Tug, EOS, OIS
7. Mate with logistics system	Orbital Shuttle - Logistics System	Mating Communications	Same as Step 6
8. Transfer payload	Orbiter Shuttle - Payload	Cargo, Crew Transfer; EOS Payload Deployment	Tug; Crew, Cargo, Propellant, RAM, OLS, LSB, Station Modules, Satellite
9. Separation from logistics system	Orbital Shuttle - Logistics Sys.	Separation, Stationkeeping Detached Element Operations	Same as Step 6
10. Perform phasing/orbit transfer/ TLI maneuvers	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Transport	
11. Separate first stage of shuttle	First Stage - TDRS, MSFN	Separation, Communications	
12. Perform first stage earth orbit return maneuvers	First Stage - TDRS, MSFN	Communications	
13. Initiate first stage station-keeping operations	First Stage - TDRS, MSFN	Communications, Station-keeping, Detached Element Operations	

Table 2.10-1.
MM-10 Staged Geo/Cislunar Shuttle Logistics Mission (Continued)

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
14. Conduct geo/lunar orbit operations with second stage	Orbital Shuttle - TDRS, MSFN	Orbital Assembly Communications Attached Element Transport	
15. Perform phasing/orbit transfer/ TEI/EOI maneuver	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Transport	
16. Rendezvous second stage shuttle with logistics system	Orbital Shuttle - Logistics Sys; Orbital Shuttle - TDRS, MSFN Logistics Sys - TDRS, MSFN	Communications, Rendezvous Detached Element Operations Attached Element Transport	EOS, Tug
17. Mate with logistics system	Orbital Shuttle - Logistics System	Mating, Communications	Same as Step 16
18. Transfer payload	Logistics System - Payload	Cargo, Crew Transfer ; EOS Payload Retraction and Stowage	Tug; EOS; Crew, Cargo Propellant Modules
19. Separate from logistics system	Orbital Shuttle - Logistics Sys	Separation, Stationkeeping	Same as Step 16
20. Rendezvous second stage with assembly tug	Second Stage - Assembly Tug - TDRS, MSFN	Communications, Rendezvous Detached Element Operations	Same as Step 16
21. Mate with assembly tug	Second Stage - Assembly Tug	Mating, Communications	Same as Step 16
22. Rendezvous with first stage	First Stage - Assembly Tug - TDRS, MSFN	Communications, Rendezvous Detached Element Operations Attached Element Transport	Same as Step 16
23. Mate with first stage	Orbital Shuttle - Assembly Tug	Mating, Communications	Same as Step 16
24. Separate orbital shuttle from assembly tug	Orbital Shuttle - Assembly Tug	Separation	Same as Step 16
25. Initiate quiescent orbital shuttle operations	Orbital Shuttle - Assembly Tug - TDRS, MSFN	Communications Attached Element Operations	Same as Step 16
End of mission			

NOTE 1: Reference to OPD assumes quiescent CLS operations in vicinity of OPD, or transport of CLS by tug (or EOS) to OPD

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1									✓			✓		
2									✓	✓			✓	
3	✓													
4						✓								
5			✓											
6									✓	✓			✓	
7	✓								✓					
8				✓	✓		✓							
9			✓								✓		✓	
10									✓					✓
11			✓						✓					
12									✓					
13									✓		✓		✓	
14		✓							✓					✓
15									✓					✓

Figure 2.10-2. Interfacing Activities Versus Mission Events for MM-10 Staged Geo/Cislunar Shuttle Logistics Mission (Sheet 1 of 2)

Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
16	X	X	X	X	X	X	X	X	✓	✓	X	X		✓
17	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
18	X	X	X	✓	✓	X	X	✓	X	X	X	X	X	X
19	X	X	✓	X	X	X	X	X	X	X	✓	X	X	X
20	X	X	X	X	X	X	X	X	✓	✓	X	X	✓	X
21	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X
22	X	X	X	X	X	X	X	X	✓	✓	X	X	✓	✓
23	X	X	X	X	X	X	X	X	✓	X	X	X	X	X
24	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
25	X	X	X	X	X	X	X	X	✓	X	X	✓	X	X

Figure 2.10-2. Interfacing Activities Versus Mission Events for MM-10 Staged Geo/Cislunar Shuttle Logistics Mission (Sheet 2 of 2)

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2.11 MM-11 NONSTAGED GEOSYNCHRONOUS/CISLUNAR SHUTTLE LOGISTICS MISSION

A pictorial representation of the mission and the mission sequence of events for MM-11 are presented on Figure 2.11-1 and Table 2.11-1, respectively. The interfacing activities identified for each mission event on Table 2.11-1 are presented in matrix form on Figure 2.11-2. This mission is applicable to the use of a single-stage CPS or RNS for flights to high-energy earth orbits and to lunar orbit. It also is applicable to the use of a single-stage tug for flights to high-energy earth orbits with modest payloads. This mission is similar to MM-10 with the exclusion of those mission events that are peculiar to a two-stage propulsive vehicle. The mission objectives and elements discussed relative to MM-10 are equally applicable to MM-11.

In the mission sequence presented in Table 2.11-1, the RNS or CPS are first refueled (Event 4) by a tanker or OPD. The RNS then picks up a payload (Event 8), performs orbit transfer (Event 10), and transports the payload to lunar orbit (or geosynchronous orbit). The RNS picks up a down-payload (cargo, rescued personnel, or retrieved RAM/satellite) and returns to low earth orbit where it delivers the payload to a tug or EOS orbiter (Event 15). The RNS then separates from the payload and is placed in a quiescent mode.

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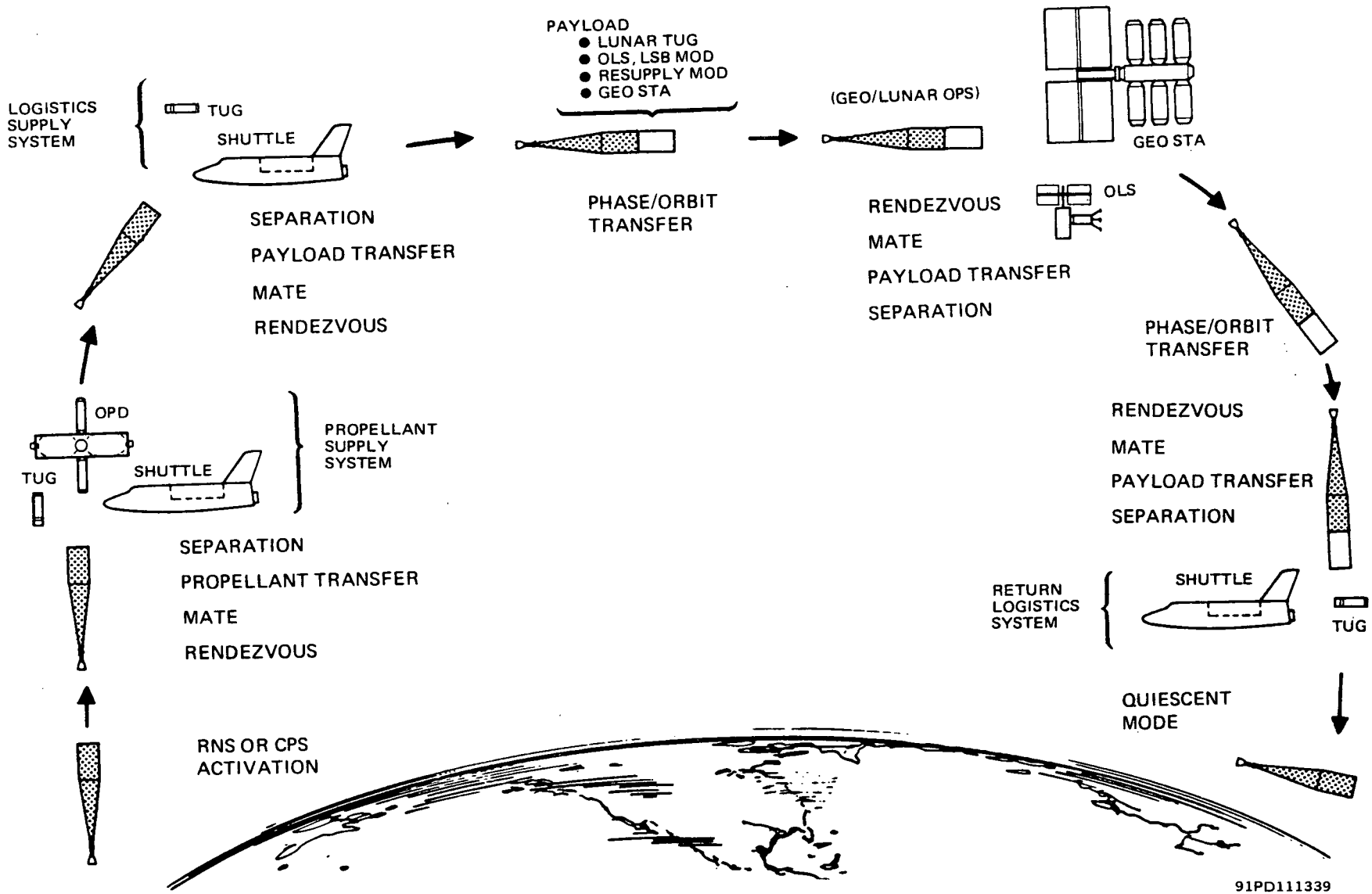

Figure 2.11-1. MM-11 Nonstaged Geosynchronous/Cislunar Logistics Mission

Table 2.11-1.
MM-11 Non-Staged Geo/Cislunar Shuttle Logistics Mission

Mission Event	Major Interfaces	Interfacing Activity	Potential Interfacing Elements
1. Activate orbital shuttle	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Operations	
2. Rendezvous with propellant supply system (NOTE 1)	Orbital Shuttle - TDRS, MSFN Orbital Shuttle - Prop Supply Sys; Prop Supply Sys - TDRS, MSFN	Communications, Rendezvous	OPS; EOS; Tug
3. Mate with propellant supply system	Orbital Shuttle - Propellant Supply System	Mating	OPD; Tug; Propellant Module; EOS
4. Transfer payload	Orbital Shuttle - Payload	Propellant Transfer	Same as Step 3
5. Separate from propellant supply system	Orbital Shuttle - Propellant Supply System	Separation	Same as Step 3
6. Rendezvous with logistics system	Orbital Shuttle - Logistics System Orbital Shuttle - TDRS, MSFN Logistics Sys - TDRS, MSFN	Communications Rendezvous	EOS; Tug, OIS
7. Mate with logistics system	Orbital Shuttle - Logistics System	Mating	Same as Step 6
8. Transfer payload	Orbital Shuttle - Payload	Cargo, Crew Transfer; EOS Payload Deployment	Tug; Crew, Cargo, Propellant, Station, OLS, LSB, RAM Modules; Satellites
9. Separate from logistics system	Orbital Shuttle - Logistics System	Separation, Stationkeeping Detached Element Operations	Same as Step 6
10. Perform phasing/orbit transfer/ TLI maneuvers	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Transport	
11. Conduct geo/lunar orbit operations	Orbital Shuttle - MSFN	Orbital Assembly Communications Attached Element Transport	
12. Perform phasing/orbit transfer/TEI/EOI maneuvers	Orbital Shuttle - TDRS, MSFN	Communications Attached Element Transport	
13. Rendezvous with logistics system	Orbital Shuttle - Logistics System Orbital Shuttle - TDRS, MSFN Logistics Sys - TDRS, MSFN	Communications, Rendezvous Attached Element Transport	Same as Step 2

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Table 2.11-1.

MM-11 Non-Staged Geo/Cislunar Shuttle Logistics Mission (Continued)

Mission Event	Major Interface	Interfacing Activity	Potential Interfacing Element
14. Mate with logistics system	Orbital Shuttle - Logistics Sys	Mating	Same as Step 2
15. Transfer payload	Logistics System - Payload	Cargo, Crew Transfer; EOS Payload Retraction and Stowage	Crew, Cargo, Propellant, OLS Modules; Tug; EOS; OPD
16. Separate from logistics system	Orbital Shuttle - Logistics Sys	Separation, Stationkeeping Detached Element Operations	Same as Step 2
17. Initiate orbital shuttle quiescent operations	Orbital Shuttle - Logistics Sys Orbital Shuttle - TDRS, MSFN	Communications Attached Element Operations	Same as Step 2
End of mission			

NOTE 1: Reference to OPD assumes quiescent CLS operations in vicinity of OPD, or transport of CLS by tug (or EOS) to OPD

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Mission Event Number	Interfacing Activity													
	Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propellant Transfer	EOS Payload Deployment	EOS Payload Retraction	Communications	Rendezvous	Station Keeping	Attached Element Ops	Detached Element Ops	Attached Element Transport
1	X	X	X	X	X	X	X	X	✓	X	X		X	X
2	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
3	✓	X	X	X	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	✓	X	X	X	X	X	X	X	X
5	X	X	✓	X	X	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	✓	✓	X	X	X	X
7	✓	X	X	X	X	X	X	X	X	X	X	X	X	X
8	X	X	X	✓	✓	X	✓	X	X	X	X	X	X	X
9	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
10	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
11	X	✓	X	X	X	X	X	X	✓	X	X	X	X	✓
12	X	X	X	X	X	X	X	X	✓	X	X	X	X	✓
13	X	X	X	X	X	X	X	X	✓	✓	X	X	X	✓
14	✓	X	X	X	X	X	X	X	X	X	X	X	X	X
15	X	X	X	✓	✓	X	X	✓	X	X	X	X	X	X
16	X	X	✓	X	X	X	X	X	X	X	✓	X	✓	X
17	X	X	X	X	X	X	X	X	✓	X	X	✓	X	X

Figure 2.11-2. Interfacing Activities Versus Mission Events for MM-11 Nonstaged Geosynchronous/Cislunar Shuttle Logistics Mission

3.0 ELEMENT-TO-ELEMENT INTERFACES

This section presents data that identify the following:

1. Every potential element-to-element interface that can occur in earth orbit and involving pairs of elements in the study vehicle inventory.

2. Every interfacing activity that can occur at each of these element-to-element interfaces.

3. Every mission model within which each element-to-element interface occurs.

All of these data were derived from the mission model data presented in Section 2.0. The methodical in-depth approach used in the mission model activity assured that the data in this section are complete and that no significant interface occurring in earth orbit has been overlooked.

The matrix presented on Figure 3.0-1 includes all 25 study elements on both the ordinate and the abscissa. There are a total of 325 matrix intersections on the figure chart. Of this total, 117 of the intersections have been identified as potential element-to-element interfaces in earth orbit and are shown as noncross-hatched blocks. The numbers appearing in these blocks are for reference purposes and are used in Table 3.0-1 for identification. Each potential element-to-element interface (noncross-hatched block) is so identified if one or more of the 14 interfacing activities occur between the two elements. To avoid redundant data presentation on Figure 3.0-1, the lower half of the chart is left blank. As a result, in order to determine all element interfaces involving a particular element, it is necessary to read down a column (to the bottom of the column) and then read across to the right. For example, the elements that interface with the "RAM-Detached MSS" are identified on the chart as element interfaces numbers 9, 78, 99, 178, 179, 181 and 183.

As might be expected, the EOS (earth orbital shuttle orbiter) interfaces with more elements than any other one element, with the space-based tug running a close second. This is a reflection of the importance of these two propulsive vehicles as workhorses of the earth orbital space program. In contrast, three of the elements in the inventory interface with one other element only. These elements are the "RAM-Attached EOS," "RAM-Detached EOS," and the "EOS Delivered Satellite," each of which interfaces with the EOS only (element interfaces numbers 6, 7, and 10, respectively). The interface between two EOS's (element interface number 1) occurs only in the event of the rescue of crew from one EOS by another EOS. This also is true in the case of the interface between two ground-based tugs (interface number 73). The RNS-to-RNS interface (number 298) exists because of the possibility of there being a modular RNS requiring the mating of modules in earth orbit.

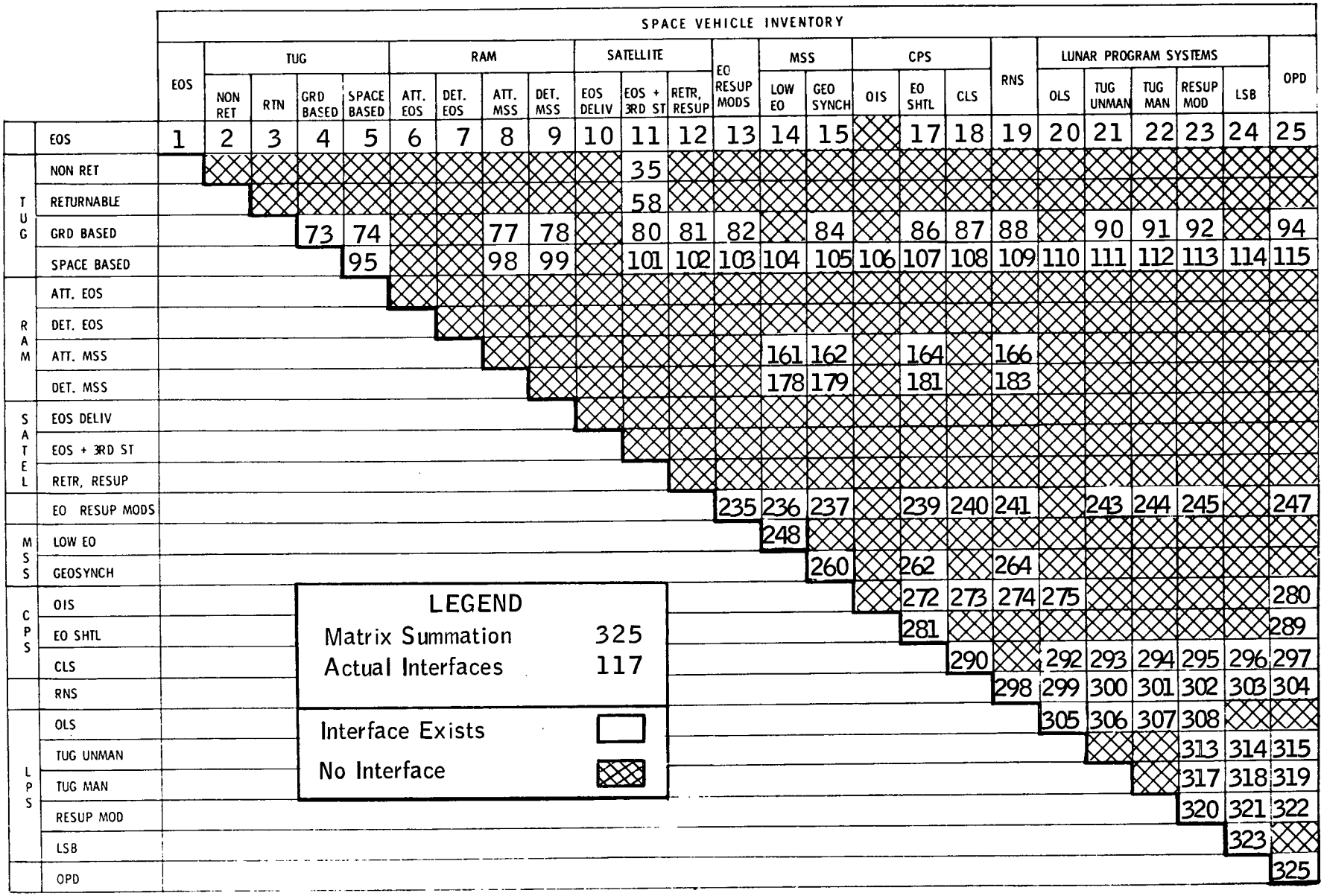

Figure 3.0-1. Element-to-Element Interfaces

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The same situation exists for two of the CPS elements (interface numbers 281 and 290) as well as for the MSS configurations (numbers 248 and 260), the OLS (number 305), the OPD (number 325), and the LSB (number 323). A more detailed discussion of element-to-element interfaces is presented in each of the interfacing activity sections of this report (Volume II).

An interface summary chart (Table 3.0-1) cross-references all of the interfacing activities and mission models to element interfaces. For example, Table 3.0-1 shows that element interface number 1 (EOS-to-EOS, as defined on Figure 3.0-1) involves 9 of the 14 interfacing activities (see Table 1.0-1). Also, mission model MM-2 is the only mission in which the EOS-to-EOS interface occurs. More typically a given element interface occurs in several of the mission models. Obviously, this table does not show which interfacing activities occur in which mission models for a given element interface, except where only one mission model applies (as is the case with element interface number 1). This detailed visibility is available, however, in each of the interfacing activity sections (Volume II) and is presented in element-to-element matrix form.

Table 3.0-1. Interface Summary Chart

Element Interface*		Interfacing Activity**													Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
1	EOS-EOS	✓		✓	✓	✓				✓	✓	✓	✓	✓			✓									
2	EOS-NON RET TUG			✓				✓		✓		✓	✓	✓	✓	✓										
3	EOS-RTN TUG	✓		✓				✓	✓	✓	✓	✓		✓	✓	✓	✓					✓				
4	EOS-GB TUG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓		✓	✓
5	EOS-SB TUG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓
6	EOS-ARAM, EOS				✓	✓		✓	✓	✓			✓		✓			✓								
7	EOS-DRAM, EOS	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									
8	EOS-ARAM, MSS	✓	✓	✓				✓	✓						✓		✓			✓			✓		✓	✓
9	EOS-DRAM, MSS	✓	✓	✓				✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓		✓	✓
10	EOS-SAT, EOS DEL			✓				✓		✓		✓	✓	✓	✓	✓	✓									
11	EOS-SAT, 3RD ST			✓				✓		✓		✓	✓	✓	✓	✓			✓			✓				
12	EOS-SAT, RETR	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓			
13	EOS-EO RESUP MODS	✓	✓	✓	✓	✓		✓	✓				✓		✓		✓			✓			✓		✓	✓
14	EOS-LOW EO MSS	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**													Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
15	EOS-GEO MSS	✓	✓	✓	✓	✓		✓	✓	✓					✓	✓	✓		✓	✓		✓	✓		✓	✓
17	EOS-CPS, EO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓
18	EOS-CPS, CLS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓
19	EOS-RNS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓
20	EOS-OLS	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓	✓
21	EOS-UNMAN LLT	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓			✓		✓	✓
22	EOS-MAN LLT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓
23	EOS-LUN RESUP MOD	✓	✓	✓			✓	✓	✓				✓		✓		✓			✓					✓	✓
24	EOS-LSB	✓	✓	✓				✓	✓				✓		✓	✓	✓			✓					✓	✓
25	EOS-OPD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓	✓
35	NON RET TUG-SAT, 3RD ST														✓	✓										

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
58	RTN TUG - SAT, 3RD ST												✓		✓							✓				
73	GB TUG-GB TUG	✓	✓	✓	✓	✓				✓	✓	✓		✓	✓								✓			
74	GB TUG-SB TUG	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓					✓			✓			
77	GB TUG-ARAM, MSS	✓		✓						✓					✓							✓	✓			
78	GB TUG-DRAM, MSS	✓		✓						✓		✓	✓	✓	✓							✓	✓			
80	GB TUG-SAT, 3RD ST			✓									✓		✓							✓				
81	GB TUG-SAT, RETR	✓		✓	✓					✓	✓	✓	✓	✓	✓							✓	✓			
82	GB TUG-EO RESUP MOD	✓		✓	✓	✓							✓		✓							✓	✓			
84	GB TUG-GEO MSS	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓							✓	✓			

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity **													Mission Model ***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
86	GB TUG-CPS, EO	✓	✓	✓			✓			✓	✓	✓		✓								✓	✓		✓	✓
87	GB TUG-CPS, CLS	✓	✓	✓			✓			✓	✓	✓		✓								✓	✓		✓	✓
88	GB TUG-RNS	✓	✓	✓			✓			✓	✓	✓		✓								✓	✓			✓
90	GB TUG-UNMAN LLT	✓		✓			✓			✓	✓			✓								✓	✓			
91	GB TUG-MAN LLT	✓		✓			✓			✓	✓	✓		✓								✓	✓			
92	GB TUG-LUN RESUP MOD	✓	✓	✓			✓															✓	✓			
94	GB TUG-OPD	✓	✓	✓			✓			✓	✓		✓									✓	✓			
95	SB TUG-SB TUG	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓					✓	✓
98	SB TUG-ARAM, MSS	✓	✓	✓						✓					✓		✓			✓					✓	✓
99	SB TUG-DRAM, MSS	✓	✓	✓						✓	✓	✓	✓	✓	✓		✓		✓	✓					✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis./Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
101	SB TUG-SAT, 3RD ST	✓		✓									✓		✓		✓		✓	✓					✓	✓
102	SB TUG-SAT, RETR	✓		✓	✓					✓	✓	✓	✓	✓	✓		✓		✓	✓					✓	✓
103	SB TUG-EO RESUP MOD	✓	✓	✓	✓	✓	✓						✓		✓		✓			✓			✓		✓	✓
104	SB TUG-LOW EO MSS	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓		✓		✓	✓	✓					
105	SB TUG-GEO MSS	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓				✓	✓	✓					✓
106	SB TUG-OIS	✓		✓						✓	✓	✓		✓	✓				✓	✓	✓			✓		
107	SB TUG-CPS, EO	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓	✓				✓	✓
108	SB TUG-CPS, CLS	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓	✓				✓	✓
109	SB TUG-RNS	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓	✓				✓	✓
110	SB TUG-OLS	✓	✓	✓	✓	✓				✓	✓	✓		✓	✓		✓		✓	✓					✓	✓
111	SB TUG-UNMAN LLT	✓	✓	✓			✓			✓	✓			✓	✓		✓		✓	✓					✓	✓
112	SB TUG-MAN LLT	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓	✓		✓		✓	✓					✓	✓
113	SB TUG-LUN RESUP MOD	✓	✓	✓			✓								✓		✓		✓	✓					✓	✓
114	SB TUG-LSB	✓	✓	✓											✓		✓		✓	✓					✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
115	SB TUG-OPD	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓	✓			✓	✓	✓
161	ARAM,MSS-LOW EO MSS	✓	✓	✓	✓	✓							✓				✓		✓	✓			✓			
162	ARAM,MSS-GEO MSS	✓	✓	✓	✓	✓							✓				✓		✓	✓		✓	✓		✓	✓
164	ARAM,MSS-CPS, EO	✓	✓	✓						✓					✓		✓		✓	✓			✓		✓	✓
166	ARAM,MSS-RNS	✓	✓	✓						✓					✓		✓		✓	✓			✓		✓	✓
178	DRAM,MSS-LOW EO MSS	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓			
179	DRAM,MSS-GEO MSS	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓			✓		✓	✓		✓	✓		✓	✓
181	DRAM,MSS-CPS, EO	✓	✓	✓						✓					✓		✓		✓	✓					✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis./Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
183	DRAM,MSS-RNS	✓	✓	✓						✓					✓		✓		✓	✓					✓	✓
235	EO RESUP MOD-EO RESUP MOD	✓		✓													✓		✓	✓			✓			
236	EO RESUP MOD-LOW EO MSS	✓	✓	✓	✓	✓							✓				✓		✓	✓			✓			
237	EO RESUP MOD-GEO MSS	✓	✓	✓	✓	✓							✓				✓		✓	✓			✓		✓	✓
239	EO RESUP MOD-CPS, EO	✓	✓	✓			✓								✓		✓		✓	✓			✓		✓	✓
240	EO RESUP MOD-CPS, CLS	✓		✓			✓										✓		✓	✓			✓		✓	✓
241	EO RESUP MOD-RNS	✓	✓	✓			✓								✓		✓		✓	✓			✓		✓	✓
243	EO RESUP MOD-UNMAN LLT	✓		✓	✓		✓										✓		✓	✓			✓			
244	EO RESUP MOD-MAN LLT	✓		✓	✓	✓	✓										✓		✓	✓			✓			
245	EO RESUP MOD-LUN RESUP MOD	✓		✓			✓										✓		✓	✓			✓			

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model ***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
247	EO RESUP MOD-OPD	✓		✓			✓						✓				✓		✓	✓			✓		✓	✓
248	LOW EO MSS-LOW EO MSS	✓	✓	✓	✓	✓										✓	✓		✓	✓	✓		✓			
260	GEO MSS-GEO MSS	✓	✓	✓	✓	✓										✓	✓		✓	✓		✓	✓		✓	✓
262	GEO MSS-CPS, EO	✓	✓	✓						✓	✓	✓	✓	✓	✓		✓		✓	✓			✓	✓	✓	✓
264	GEO MSS-RNS	✓	✓	✓						✓	✓	✓	✓	✓	✓		✓		✓	✓			✓		✓	✓
272	OLS-CPS, EO			✓						✓					✓									✓		
273	OIS-CPS, CLS			✓						✓					✓									✓		
274	OIS-RNS			✓						✓					✓									✓		
275	OIS-OLS			✓						✓					✓									✓		
280	OIS-OPD			✓						✓					✓									✓		

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
281	CPS,EO-CPS, EO	✓	✓	✓						✓	✓	✓					✓		✓	✓	✓		✓	✓	✓	
289	CPS, EO-OPD	✓		✓			✓			✓	✓	✓	✓				✓		✓	✓			✓	✓	✓	✓
290	CPS, CLS-CPS, CLS	✓	✓	✓						✓	✓	✓		✓			✓		✓	✓	✓		✓	✓	✓	
292	CPS, CLS-OLS	✓	✓	✓						✓							✓		✓	✓					✓	✓
293	CPS, CLS-UNMAN LLT	✓	✓	✓						✓	✓			✓			✓		✓	✓					✓	✓
294	CPS, CLS-MAN LLT	✓	✓	✓						✓	✓	✓		✓			✓		✓	✓			✓		✓	✓
295	CPS, CLS-LUN RESUP MOD	✓	✓	✓													✓		✓	✓					✓	✓
296	CPS, CLS-LSB	✓	✓	✓													✓		✓	✓					✓	✓
297	CPS, CLS-OPD	✓		✓			✓			✓	✓	✓	✓	✓					✓	✓			✓		✓	✓
298	RNS-RNS	✓	✓	✓													✓		✓	✓	✓		✓	✓		✓
299	RNS-OLS	✓	✓	✓						✓							✓		✓	✓					✓	✓
300	RNS-UNMAN LLT	✓	✓	✓						✓	✓			✓			✓		✓	✓			✓		✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
301	RNS-MAN LLT	✓	✓	✓						✓	✓	✓		✓			✓		✓	✓			✓		✓	✓
302	RNS-LUN RESUP MOD	✓	✓	✓													✓		✓	✓			✓		✓	✓
303	RNS-LSB	✓	✓	✓													✓		✓	✓			✓		✓	✓
304	RNS-OPD	✓		✓			✓			✓	✓	✓	✓	✓					✓	✓			✓			✓
305	OLS-OLS	✓	✓	✓	✓	✓											✓		✓	✓			✓	✓	✓	✓
306	OLS-UNMAN LLT	✓	✓	✓						✓							✓		✓	✓			✓	✓	✓	✓
307	OLS-MAN LLT	✓	✓	✓	✓	✓				✓							✓		✓	✓			✓	✓	✓	✓
308	OLS-LUN RESUP MOD	✓	✓	✓	✓	✓											✓		✓	✓		✓	✓	✓	✓	✓
313	UNMAN LLT-LUN RSP MOD	✓	✓	✓													✓		✓	✓		✓	✓	✓	✓	✓
314	UNMAN LLT-LSB	✓	✓	✓													✓		✓	✓			✓	✓	✓	✓
315	UNMAN LLT-OPD	✓		✓			✓			✓							✓		✓	✓			✓		✓	✓
317	MAN LLT-LUN RESUP MOD	✓	✓	✓													✓		✓	✓		✓	✓	✓	✓	✓

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Table 3.0-1. Interface Summary Chart (Cont.)

Element Interface*		Interfacing Activity**														Mission Model***										
		Mating	Orbital Assy	Separation	Cargo Transfer	Crew Transfer	Propel. Transfer	EOS Payload Deployment	EOS Payload Retr. & Stowage	Communications	Rendezvous	Stationkeeping	Attached Elem. Operations	Detached Elem. Operations	Attached Elem. Transport	EOS Emplacement	EOS Logis/Retriev.	EOS Sortie	SB Tug Retr/Emplace.	SB Tug Logistics	SB Tug Disposal	Grd-Based Tug Emplace/Sortie	Grd-Based Tug Logis/Retriev.	OIS Delivery	CLS Staged Logistics	CLS Nonstaged Logistics
No.	Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11
318	MAN LLT-LSB	✓	✓	✓													✓		✓	✓			✓	✓	✓	✓
319	MAN LLT-OPD	✓		✓			✓			✓							✓		✓	✓			✓		✓	✓
320	LUN RESUP MOD-LUN RESUP MOD	✓	✓	✓													✓		✓	✓		✓	✓	✓	✓	✓
321	LUN RESUP MOD-LSB	✓	✓	✓													✓		✓	✓		✓	✓	✓	✓	✓
322	LUN RESUP MOD-OPD	✓		✓			✓										✓		✓	✓			✓		✓	✓
323	LSB-LSB	✓	✓	✓	✓	✓											✓		✓	✓		✓	✓	✓	✓	✓
325	OPD-OPD	✓	✓	✓	✓	✓											✓		✓	✓	✓	✓	✓	✓		

* See Figure 3.0-1 for definitions

** See Table 1.0-1 for definitions

*** See Figure 1.0-2 for definitions

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4.0. PROGRAM ELEMENT OPTIONS

The major contributor to the potential number of procedural options that could be included in the Orbital Operations study is the relatively large number of elements in the inventory of this study. By appropriate grouping of related elements and careful selection of a singular element concept, the number of specific procedures can be reduced to a manageable level.

The evaluation criteria were developed in such a manner that no element of the inventory was permanently "screened out." Rather, the characteristics of each of the elements were analyzed to establish groups of families of elements. One element, which encompasses the activities of the group, was selected as representative of the entire group and will be analyzed specifically in subsequent study tasks.

Upon completion of the detailed analyses, the procedures and design concepts of the representative elements were evaluated in conjunction with the appropriate elements of the entire study inventory. This approach reduced significantly the mechanics of the study tasks without adversely affecting the end results or the breadth of applicability of the data.

The criteria that were developed to select the representative elements are as follows:

1. Interface activity commonality--Related elements with common interfacing activities were identified. The element with the broadest spectrum of activities was selected for specific additional analysis.

2. Multi-generation concepts--Some of the elements in the inventory are more indicative of an evolutionary development in capability, application, and/or complexity of operation rather than a unique space program element. The element within this family that has the broadest spectrum of earth orbital interfaces and activities was selected for specific additional analysis.

3. Alternate element concepts--Some of the elements in the inventory have significantly different alternate design concepts and correspondingly different interfaces. The basic difference is whether they are compatible with shuttle orbiter delivery or require the orbit insertion stage for delivery to earth orbit. The more complex interfaces within the scope of this study occur in the case of the shuttle compatible concepts. Where practical, only those concepts that are compatible with orbiter delivery were selected for specific additional analysis.

4. Primary interface driver--The primary driver on the element-to-element interface may be other than earth orbit operation. Only element interfaces that are driven by orbital operations were selected for further analysis.

5. Operations similarity--The inventory breakdown includes potential applications as well as unique elements. In some cases, the applications or operations of elements have adequate similarity that the interfacing activities of one encompass those of another. The operational concept with the broadest spectrum of interfaces and activities was selected for further analysis.

6. Applicable approach--An element may be more indicative of an alternate approach to an interfacing activity rather than a required unique space element. Such an element is not included as a specific item in the inventory in subsequent study tasks. However, that element's operations, interfaces, and functional requirements will be included as a subset of the the analyses and procedures of the applicable interfacing activity.

Table 4.0-1 presents the element grouping that results from the application of the previously listed criteria to the vehicle inventory of this study. This title does not include the total list of elements to be specifically evaluated in procedures development. Some elements could not be effectively grouped and will be evaluated on an individual basis. The complete revised inventory list that will be specifically analyzed at the procedural level is as follows:

1. Shuttle orbiter (EOS)
2. Returnable nonreusable tug
3. Space-based tug
4. EOS and modular space station (MSS attached and detached research and application modules (RAM)
5. EOS and EOS plus third stage emplaced satellites, including both retrieval and resupplied satellite concepts
6. Earth orbit resupply modules
7. Low earth orbit MSS
8. Orbit insertion stage
9. Tandem, non-modular, chemical propulsion stage (CPS) cislunar shuttle
10. Modular reusable nuclear cislunar shuttle
11. Modular orbiting lunar station

Table 4.0-1. Grouping of Elements and Operations

Element Grouping	Representative Element for Detailed Analysis	Rationale
Nonreusable, nonreturnable tug Nonreusable, returnable tug	Nonreusable, returnable tug	Comparable interface activities Broadest Spectrum of activities
Ground-based tug Space-based tug Lunar unmanned tug Lunar manned tug	Space-based tug (includes manned and unmanned)	Multigeneration concept Broadest spectrum of interfaces and activities
Earth orbit resupply modules Lunar orbit resupply modules	Earth orbit resupply modules	Comparable interface activities
Low earth orbit MSS Geosynchronous orbit MSS	Low earth orbit MSS	Comparable interface activities
Chemical propulsion stage (CPS)		
Orbit insertion stage	Orbit insertion stage*	*Except separation event because primary driver is boost environment
Modular Nonmodular	Nonmodular	Comparable interface activities, compatible with OIS, unique modular aspects included in RNS
Single stage Tandem	Tandem	Comparable interface activities Broadest spectrum of activities

Table 4.0-1. Grouping of Elements and Operations (Continued)

Element Grouping	Representative Element for Detailed Analysis	Rationale
CPS (continued) High-energy earth orbit Cislunar shuttle	Cislunar shuttle	Similarity of operations Broadest spectrum of interfaces
Reusable nuclear shuttle (RNS) Modular Nonmodular	Modular	Compatible with shuttle orbiter delivery
High-energy earth orbit Cislunar shuttle	Cislunar shuttle	Similarity of operations Broadest spectrum of interfaces
Orbiting lunar station (OLS) Modular Representative	Modular OLS	Comparable interface activities Compatible with shuttle orbiter delivery
Lunar surface base		
Orbital propellant depot (OPD)	--	This element is more indicative of an alternate approach to the propellant transfer interfacing activity.

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