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DRL LINE ITEM 7

MSC 04482
SD 72-SA-0007

ORBITAL OPERATIONS STUDY

APPENDIX C

DATA SOURCES AND VEHICLE DESCRIPTIONS

FINAL REPORT

MAY 1972

APPROVED BY:

L. R. Hogan

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Study Manager
ORBITAL OPERATIONS STUDY

Space Division
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TECHNICAL REPORT INDEX/ABSTRACT

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*DATA SOURCES, *BIBLIOGRAPHY, *VEHICLE INVENTORY, *PROGRAM ELEMENTS

ABSTRACT

THIS DOCUMENT IS APPENDIX C OF THE FINAL REPORT OF THE ORBITAL OPERATIONS STUDY. THE BIBLIOGRAPHY OF PUBLISHED DOCUMENTS REFERRED TO THROUGHOUT THE STUDY IS INCLUDED. A BRIEF DESCRIPTION OF ALL OF THE SPACE PROGRAM ELEMENTS INCLUDED IN THE STUDY VEHICLE INVENTORY IS PRESENTED.

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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

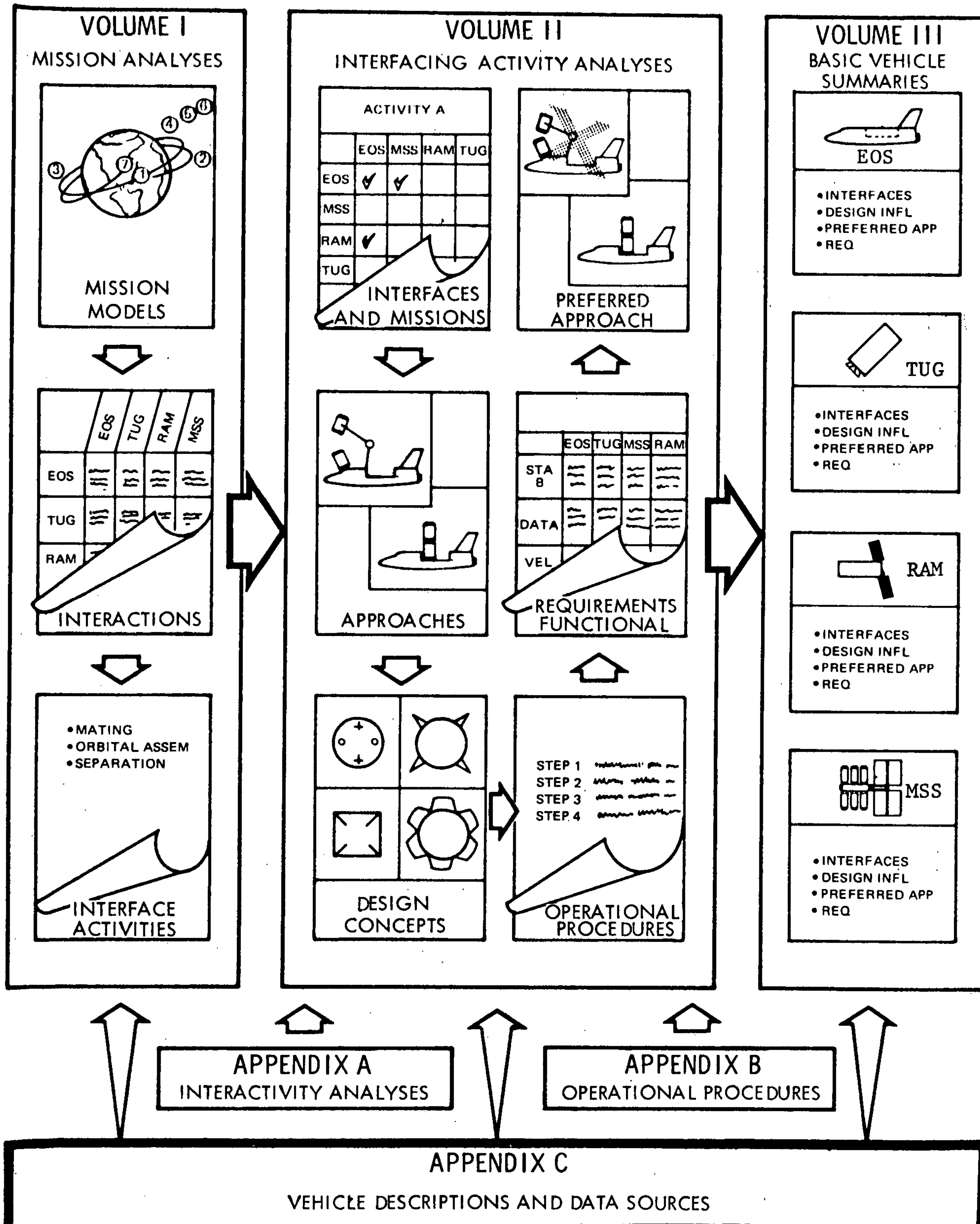
Volume III - BASIC VEHICLE SUMMARIES, contains a condensed summary of the study data pertaining to the following elements:

- 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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1.0 INTRODUCTION

This appendix provides supplemental data to the main body of the Orbital Operations Study final report. It is divided into two main sections: 2.0, Data Sources, and 3.0, Vehicle Descriptions.

Section 2.0 serves a dual purpose. It provides a list of all documents that are referenced in the various volumes and appendixes of this final report. In addition, this section lists all of the formal documentation that has been reviewed in the conduct of this study, but not necessarily referenced in the text.

Section 3.0 presents a description, in terms of configuration and performance, of the space elements considered in the Orbital Operations Study. The material included in this section was extracted from Appendix II of the study contract and was prepared originally by the NASA. The vehicles described herein have been used in this study, where appropriate, as representative models. However, the analyses conducted and the results obtained in this study, in most cases, are not sensitive to exact configuration or performance data.

2.0 DATA SOURCES

This section lists, by major categories (i.e., program elements), all documentation (except NR informal letters) that have been reviewed in the Orbital Operations Study. The reference numbering system was set up early in Task 1.0 and was designed to accommodate subsequent growth. Blocks of numbers (50 to a block) were set aside for each major program element (Table 2.0-1). The large number of earth orbital shuttle (EOS) reports reviewed required assignment of an additional block of numbers to the EOS, resulting in a large number gap between the two blocks. This numbering system results in gaps of unassigned numbers occurring in the latter part of each block of numbers. Also, additional gaps occur where numbers were assigned to informal NR letters, which are not included herein. The data source documentation list is presented on Table 2.0-2.

Table 2.0-1

Data Source Documentation List Numbering System

	Block of Assigned Numbers
Earth Orbital Shuttle (EOS)	100 - 149 550 - 599
Research and Applications Module (RAM)	150 - 199
Modular Space Station (MSS)	200 - 249
Tug	250 - 299
Chemical Propulsion Stage (CPS)	300 - 324
Reusable Nuclear Shuttle (RNS)	325 - 349
Orbiting Lunar Station (OLS)	350 - 399
Lunar Surface Base (LSB)	350 - 399
Shuttle Orbital Applications and Requirements (SOAR)	400 - 449
Orbital Propellant Depot (OPD)	450 - 499
General	500 - 549

Table 2.0-2. Data Source Documentation List

Document Code No.	Report Number	Date	Title	Organization
100	SD 71-114-1	6-25-71	Space Shuttle Program, Phase B, Final Report Volume I, Executive Summary	NR
101	SD 71-114-2	6-25-71	Same as 100, Volume II, Tech. Summary Book 1, Space Shuttle Program Definition	NR
102	SD 71-114-2	6-25-71	Same as 101, Book 2, Orbiter Veh. Def. (Part 1 of 2)	NR
103	SD 71-114-2	6-25-71	Same as 102 (Part 2 of 2)	NR
104	SD 71-114-2	6-25-71	Same as 101, Book 3, Booster Veh. Def.	NR
105	SD 71-103-1	6-25-71	Space Shuttle Program Operations Plan for Phase C/D, Volume I, Shuttle System	NR
106	SD 71-103-2	6-25-71	Same as 105, Volume II, Orbiter	NR
107	SD 71-103-3	6-25-71	Same as 105, Volume III, Booster	NR
108	SD 70-600-1	9-9-70	Rescue Mission Analysis	NR
109	SD 70-600-3	9-15-70	Example Payloads	NR
110	SD 70-600-7	9-28-70	Integral Passenger Cabin versus Cargo Bay Personnel Module	NR
111	SD 70-600-12	10-15-70	30-Day Mission Impact on Orbiter Subsystems	NR
112	SD 70-600-24	10-29-70	Shuttle Operations and Test Requirements Identification and Documentation	NR

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
113	SD 70-600-33	12-10-70	Traffic Model Analysis	NR
114	SD 70-600-36	12-22-70	Shuttle - Ground Communication Interfaces Trade Study	NR
115	SD 70-600-4	9-15-70	30-Day Mission Definition	NR
116	SD 70-546-1	Jan 1971	Shuttle-Launched Modular Space Station Volume I, Concept Definition	NR
117	SD 71-206	6-1-71	Modular Space Station Program Phase B Def. Shuttle Model	NR
118	MDC E0308 Part III-3	6-30-71	Space Shuttle Phase B Sys. Std. Final Report Program Acquisition Plans "Operations"	MDAC
119	MDC Spec. No. IF255G700	6-30-71	Preliminary Orbiter/Payload ICD for the Space Shuttle System	MDAC
120	GAC B35-43RP-5	12-31-70	Alternate Space Shuttle Concepts Mid-Term Report, Vol. II, Concept Definition, Planning and Cost Data, Part 1 - Concept Analysis and Definition	GAEC
121	"	12-31-70	Same as 120 (Appendixes C through F)	GAEC
122	"	12-31-70	Same as 120 (Appendixes G through O)	GAEC
123	"	12-31-70	Same as 120, Vol. I, Executive Summary	GAEC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
124	LMSC-A951701	5-26-69	Space Shuttle System Evaluation	Lockheed
125	GDC DCB-69-049	11-6-69	Space Shuttle An Integral Launch and Reentry Vehicle System, Final Oral Briefing	GDC
126	MDC E0056 Vol. I	12-15-69	A Two-Stage Fixed Wing Space Transportation System, Final Report, Volume I, Condensed Summary	MDAC
127	MDC Space Shuttle MSC Briefing	12-15-69	MSC Briefing Space Shuttle Program, MDC	MDAC
128	MDC-E0051	11-5-69	A Two-Stage Fixed Wing Space Transportation System, ILRV-MSC Oral Briefing	MDAC
129	M-69-28	11-6-69	A Two-Stage Fully Reusable Space Transportation System Concept, Phase A Oral Presentation	Martin
130	MSC-04058	3/15-18/71	Space Shuttle Crew Operations & Training	NASA (MSC)
131	B35-43RP-6	12-18-70	Alternate Space Shuttle Concepts Study	GAEC
132	IN-71-FM-75/ MSC-3998	3-17-71	An Approximate Method for Sizing A Space Shuttle	NASA (MSC)
133	MDC E0308, Part II-2(A)	6-30-71	Space Shuttle System Phase B Study Final Report, Part II-2(A) Technical Summary, Orbiter	MDAC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
134	MDC E0308, Part II-2(B)	6-30-71	Same as 133, Part II-2(B) Technical Summary, Orbiter	MDAC
135	MDC Spec. No. IF255G800	6-30-71	Preliminary Orbiter/Launch Facilities and Ground Support Facilities ICD	MDAC
136	SD 71-127 Appendix B (MSC 03305)	7-12-71	Final Submittal Interface Control Document (ICD) Orbiter Vehicle to Payload	NR
137	AIAA Paper No. 71-811	7/19-20/71	Payload Handling for the Space Shuttle	NR
138	STAR Briefing	July 1971	STAR (Shuttle for Telescope Activation and Resupply)	NASA (GSFC)
139	SD 71-154	June 1971	161C Orbiter Timelines with Prel. ACPS Propellant Budget Reqmts for the Three Basic Reference Missions	NR
140	MSC-03810(A)	7-6-71	Alternate Space Shuttle Concepts Study, Part II, Technical Summary, Volume I, Shuttle Definition	GAEC
141	MSC-02542 Volume 1	6-23-70	Typical Shuttle Mission Profiles and Attitude Timelines, Volume I, Space Station Resupply Missions	NASA (MSC)
142	MSC-02542 Volume 2	9-28-70	Same as 141, Vol. 2 - Four Scientific Support Missions	NASA (MSC)

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
143	MSC-02542 Volume 3	12-11-70	Same as 141, Volume 3, First 10 Shuttle Missions	NASA (MSC)
144	MSC-02542 Volume 4	3-1-71	Same as 141, Volume 4, Four Shuttle Mission Profiles	NASA (MSC)
145	MSC-03809 Part 1	7-6-71	Alternate Space Shuttle Concepts Study, Part 1, Executive Summary	GAEC
146	MSC-03810 (B-1)	7-6-71	Same as 145, Part II, Tech. Summary, Volume II, Orbiter Definition	GAEC
147	MSC-03810 (B-2)	7-6-71	Same as 146	GAEC
148	MSC-03810 (B-3)	7-6-71	Same as 146	GAEC
149	MSC-03810 (B-4)	7-6-71	Same as 146, Vol. II, Orbiter Def. Appendixes	GAEC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
150	Briefing	June 1971	RAM Pallet Shuttle Sortie	NASA (MSFC)
151	Charts	June 1971	RAM Mission Charts	GDC
152	Letter (Un-numbered)	6-4-71	RAM Payload Definitions	GDC
153	GDC DAA-70-004 Volume V	Oct. 1970	Exp. Mod. Concepts Study	GDC
155	--	Aug. 1971	Payload Design Requirements for Shuttle/Payload Interface	NASA (MSFC)
156	RAM-71T-119	7-17-71	RAM Payload and Mission Requirements	GDC
157A	GDCA-DDA71-003 (Summary)	8-28-71	RAM Preliminary Tech. Data Reqmts, "Requirements Analysis and Definition"	GDC
157B	" (App. A)	8-28-71	RAM Preliminary Tech. Data Reqmts. App. A, "Derived System Requirements"	GDC
157C	" (App. B)	8-28-71	RAM Preliminary Tech. Data Reqmts. App. B, "Experiment Requirements"	GDC
157D	" (App. C)	8-28-71	RAM Preliminary Tech. Data Reqmts. App. C	GDC

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
158A	GDCA-DDA71-004 (Vol. II, Book 1)	12-17-71	RAM Preliminary Technical Data Document Concept Anal. Eval. & Synthesis, Book 1, System Design	GDC
158B	GDCA-DDA71-004 (Vol. II, Book 2)	12-17-71	RAM Prelim. Tech. Data Document, Concept Eval. & Synthesis, Book 2, System Analysis	GDC
159	GDCA-DDA71-005	12-10-71	RAM Phase B Study, Technical Data Summary Briefing Brochure	GDC
160	72-3339	1-18-72	Overview Presentation - RAM Subsystem Review	GDC

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
201	SD 71-206	1 June 71	MSS Program Phase B Definition - Shuttle Model	NR
202	SD 70-155-2-2	July 1970	Solar-Powered Space Station Definition Mission Operations and Payload Anal.	NR
203	SD 70-510-1	July 1970	Solar-Powered Space Station Preliminary Performance Specification	NR
204	MDC G0787	Feb. 1971	Space Station - Crew Cargo Module Def.	MDAC
205	MDC G0778	Jan. 1971	Space Station - Report on MSS Buildup Concept	MDAC
206	MDC G0624	July 1970	Space Station - Space Flight Equipment End Item Design Sheets	MDAC
207	ERB No. 39	-	MSS Docking/Berthing Comparison	NR
208	SD 71-205	13 July 71	MSS System Requirements Book	NR
209	SD 70-540	Jan. 1971	Cargo Module Definition	NR
211	UCN S7201	26 Jan. 71	Operational Buildup Options	NR
212	MDC G0605 DRL 8	July 1970	Space Station Definition, Volume III, Analysis of Operations	MDAC
216	MDC G2367	July 1971	Space Station Program Extension Period Second Performance Review	MDAC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
217	ERB 58	8-6-71	Integrated Buildup Operations	NR
219	ERB 24 UCN S810013		Module Docking/Berthing Interface Study - MSS	NR
220	ERB 18 Minutes UCN S810002	3-24-71	Preliminary Manipulator Concepts	NR
221	DRL 68		ISS Installation Characteristics	NR
222	DRL 47	Jan. 1971	Cargo Module Definition	NR
224	SD 70-155-4 (MSC-00717)	July 1971	Solar-Powered Space Station, Vol. IV, Config. Analysis/Payload Accommodation	NR
225	SD 71-235 (MSC-02467)	9-2-71	MSS Phase B Extension Second Quarterly Review	NR
226	SD 70-162 (MSC-00722)	July 1970	Space Station Advanced Logistics System Requirements	NR
227	SD 70-155-2-2 (MSC-00717)	July 1970	Solar-Powered Space Station Definition Vol. II - Mission Ops. and Payload Anal.	NR
228	--	Nov. 1969	Space Station Technology Program Plan - A Compilation of Requirements and Projected Utilization with Current Technology Status and Future Technology Projections	NASA (MSC)

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
231	UCN 523A270	1-21-70	Space Station - Cargo Resupply and Storage Accommodation	NR
232	SD 71-218 (MSC-02472)	July 1971	Space Station Crew Operations Definition	NR
234	MSC 03696	May 1971	MSS Guidelines/Constraints	NASA (MSC)
235	SSD 00596R	Jan 1971	Parametric Analysis of RF Communications and Tracking Systems for Manned Space Station	Hughes
236	MSC-EG-71-19 MSC-04752	7-30-71	Study Analysis Report of the Space Station Separation, Transposition and Docking Simulation	NASA (MSC)
237	SD 70-163 (MSC 00723)	July 1970	Solar-Powered Space Station - Mass Properties	NR
238	SD 70-541 DRL 48	Dec 1970	Cargo Module Design Sheets	NR
239	SD 70-511-1	10-7-70	Nuclear Reactor Powered Space Station Design Sheets	NR
240	SD 71-217-6	Jan 1972	Modular Space Station Phase B Extension Preliminary System Design	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
241	SID 64-1344B	Jan 1968	CSM Tech. Specification, Block II	NR
242	SD 71-217-5	Jan 1972	Modular Space Station Phase B Extension, Preliminary System Design, Volume 5, Configuration Analysis	NR
243	SD 71-202	May 1971	Sizing and Evaluation Models for Modular Space Station	NR
244	SD 71-221	12-7-71	Shuttle Interface Requirements	NR

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
250	ASR-PD-DO-TI-5	3-31-71	The Conceptual Definition of Space Tugs for Earth Orbital Missions	NASA (MSFC)
251	SD 71-292-2	3-22-71	Pre-Phase A Study for an Analysis of a Reusable Space Tug - Final Report, Vol. 2, Technical Summary	NR
253		2-11-71	Pre-Phase A Technical Study for Use of SAT V, INT-21 and Other SAT V Derivatives to Determine an Optimum Fourth Stage (Space Tug); Data provided by SAMSO for use in Task 8.0 of the OOS Feasibility Study (Fleming Model)	SAMSO
255	HSD TP 7227A	Jan. 1971	Pre-Phase A Study - European Space Tug Study Digest	ELDO
256		10-15-71	Pre-Phase A Study - Mid-Term Presentation, European Space Tug	ELDO
257			European Space Tug System Study, Mid-Term Presentation	ELDO
258		Feb. 1971	European Space Tug Engine Study - Presentation to NASA	ELDO
261	SD 70-630-1	12-8-70	Technical Proposal for Orbit-to-Orbit Shuttle (Chemical) Feasibility Study (OOS)	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
262	SD 71-530-1	5-21-71	Orbit-to-Orbit Shuttle (Chemical) Feasibility Study (OOS) Interim Report, Volume I, System Requirements	NR
263	SD 71-530-2	-	Orbit-to-Orbit Shuttle (Chemical) Feasibility Study (OOS) Interim Report, Vol. II, Mission and Operations Analysis	NR
264	SD 71-530-3	-	Orbit-to-Orbit Shuttle (Chemical) Feasibility Study (OOS) Interim Report, Vol. III, System Requirements Analysis	NR
265	SD 71-292-5		Pre-Phase A Study for an Analysis of a Reusable Space Tug - Final Report, Volume 5, Subsystems	NR
266	Not Numbered	None	MMB Group Space Tug System Study Pre-Phase A/Ext.	ELDO/NASA
267	HSD TP 7264A	1971	European Space Tug--Pre-Phase A Study, Part 2, Study Digest	ELDO
268	SAMSO-TR-71-238, Vol. IV-B	Oct. 71	Final Report--Orbit to Orbit Shuttle Feasibility Study, Vol. IV, System Design Appendix B--Avionics Studies	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
300	SD 71-245-3	4-24-71	S-II Stage Interorbital Shuttle Capability Analysis (Sys. Reqmts., Mission Capability, and Operations Analysis	NR
301	SD 71-245-2	4-24-71	S-II Stage Interorbital Shuttle Capability Analysis (Technical Summary)	NR
302	MDC G0994	April 1971	Chemical Interorbital Shuttle Capability Study (Mission and System Anal.)	MDAC
303	71 MA 4763 DPD No. 264	8-13-71	First Monthly Report, Design and Sys. Analysis of a Chemical Interorbital Shuttle (Phase A Study)	NR

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
325	SD 71-466-1	April 1971	Nuclear Flight System Definition Study - Phase III Final Report, Vol. I, Executive Summary	NR
326	SD 71-466-2	April 1971	Nuclear Flight System Definition Study - Phase III Final Report, Vol. II, Concept and Feasibility Analysis	NR
327	SD 71-466-3	April 1971	Nuclear Flight System Definition Study - Phase III Final Report, Vol. III, Part B, Baseline System Definition	NR
328A	LMSC-A984555	5-1-71	Nuclear Shuttle Systems Definition Study Phase III, Vol. II, Concept and Feasibility Analysis, Part A	Lockheed
328B	LMSC-A984555	5-1-71	Same Part B	Lockheed
329A	MDC G2134	May 1971	Nuclear Shuttle System Definition Study, Phase III, Final Report, Vol. II, Concept and Feasibility Analysis, Part A, Book 1	MDAC
329B	MDC G2134	May 1971	Same Part A Book 2	MDAC
329C	MDC G2134	May 1971	Same Part B Book 1	MDAC
329D	MDC G2134	May 1971	Same Part B Book 2	MDAC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
350A	SD 71-207 Volume II	April 1971	OLS Mission Operations	NR
350B	SD 71-207 Volume III	April 1971	OLS Performance Requirements	NR
351	SD 71-208	April 1971	OLS Condensed Summary Report	NR
352A	SD 71-477-1 Volume I	5-15-71	LSB Executive Summary	NR
352B	SD 71-477-2 Volume II	5-15-71	LSB Mission Analysis and Lunar Base Synthesis	NR
352C	SD 71-477-3 Volume III	5-15-71	LSB Shelter Design	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
400	MDC G2327	May 1971	SOAR/Shuttle Data Book	MDAC
401	Letter	March 1971	SOAR Monthly Progress Report	MDAC
402	MDC G2327	May 1971	SOAR First Quarterly Review	MDAC
403	MDC G2356	July 1971	SOAR Mid-Term Review	MDAC
404	Not Numbered	5-7-71	Performance Requirements Documents	MDAC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
450	SD 70-554-1	3-31-71	S-II Stage Orbital Propellant Storage System Feasibility Study (Tech. Summary)	NR
451	SD 70-554-2		S-II Stage Orbital Propellant Storage System Feasibility Study	NR
452	NASA TMX-64538	7-1-70	An Analysis of Potential Orbital Propellant Storage Requirements and Modes of Operation	NASA (MSFC)
453		4-14-70	Fuel Depot - Project Description Document	NASA (MSC)
454	71MA5253	9-10-71	In-Space Propellant Logistics and Safety Study - Progress Report No. 2	NR
455	DR MA-03 DPD #262	10-6-71	In-Space Propellant Logistics and Safety, First Performance Review for Period 26 June through 15 September 1971	NR
456	DR MA-02 DPD 262	12-10-71	In-Space Prop. Log. and Safety Study - Letter Activity Report No. 4, Period 1 November 1971 through 30 Nov. 1971	NR
457	SD 72-CE-0001	1-12-72	In-Space Prop. Log. and Safety - Mid-Term Performance Review	NR
458	SD 72-268	Dec 1971	Saturn S-II Adv. Technol. Studies - Study 8, Cryogenic Acquisition and Transfer	NR
459	DR MA-02 DPD 262	2-10-72	In-Space Prop. Log. and Safety Study - Letter Activity Report No. 5, Period 12/1/71 through 1/31/72	NR

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
500A	Not Numbered Volume I	4-28-71 Rev. 1	Experiment Requirements Summary for MSS and EOS Orbital Applications Requirements	Martin
500B	Not Numbered Volume II	"	"	Martin
501A	00.676 Tech. Summary	11-1-65	Advanced Orbital Launch Operations, Phase B	LTV-Aerospace
501B	00.676, Vol. II Tech. Report	11-1-65	"	LTV-Aerospace
502	Not Numbered	11-3-70	NASA Index of Assorted Reports	NASA (MSC)
503	RFP 20388/245	6-11-71	TDRSS Configuration and Trade-Off Study	NASA (GSFC)
504	NASA IL	5-21-71	Model for Ground Network and Synchronous Satellite Communications System	NASA Hdqtrs
505	Not Numbered	5-24-71	Advanced Studies Planning Data Book (Preliminary)	NASA (MSC)
506	Not Numbered	April 1971	Space Shuttle Payload and Traffic Model	NASA (MSC)
507	ASP-556A-R-14	5-26-71	Study Plan for Assembly and Docking of Spacecraft in Earth Orbit	GAEC

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
508	PD-SA-0-70-1	1-8-70	A Preliminary Survey of Opera. Interfaces of the Integrated Space Program	NASA (MSFC)
509	MSFC-STD-267A	9-23-66	Standard - Human Engineering Design Criteria	NASA (MSFC)
510	Briefing	Undated	STAR	NASA (GSFC)
511	Briefing	May 1971	STAR/LST Requirements for Early Shuttle Flights	NASA (GSFC)
512	MSC 00197 Volumes I through IV	6-30-70	Information Management Study Final Report, Overall Results Summary	MITRE
513	Series of Papers	Aug. 1968	Second National Conference on Space Maintenance and Extravehicular Activities	USAF & NR
514	ASP-946-R-52	8-31-71	Study of Requirements for Assembly and Docking of Spacecraft in Earth Orbit "Stylized Problem Definition"	GAEC
515	MG-403	1-31-71	MSFN Equipment Allocations Handbook, Part 1, Systems Sequence	Bendix
516	629.45W(3)	1963	Flight Performance Handbook for Orbital Operations	STL/John Wiley and Sons

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
517	E-2451	11-69	Apollo GN&C Operations & Functions of the Apollo Guidance Computer During Rendezvous	MIT
518	SD 71-569	10-15-71	Interim Draft of Final Report, Volume II Analysis Report--Task I Safety in Earth Orbit Study	NR
519	Not Numbered	8-6-71	Technical Requirements for Compatible USA and USSR Docking Systems	NASA (MSC)
520	MSC-04487	None	Neuter Docking Mechanism Study	NASA (MSC)
521	MSC-01296	1-7-70	Apollo Mission Techniques Mission H-2 and Subs "Abort from Lunar Powered Descent and Subsequent Rendezvous"	NASA (MSC)
522	EL-239, 244, 245, Vol. 1	1-30-70	Space Station and Logistics System, Integrated IMS Requirements, Space Station/Logistics System Interfaces Definition of Crew Operations in Space Station, Vol. I, IMS System Requirements	G.E.
523	OWS-646-42	--	Illumination Requirements for the NASA Space Station/Space Base/Mass Mission	Sylvania Electronic Systems
524	SD 71-684	11-5-71	International Docking System Development Plan	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
525	Not Numbered	8-6-71	Technical Requirements for Compatible USA and USSR Docking Systems	NASA (MSC)
526	SD 71-592	Nov. 1971	Safety in Earth Orbit Study--DRL No. 3	NR
527	NASA SP-3006	1964	NASA Bio-Astronautics Data Book	NASA
528	MSC-03909 Volume 2	7-31-71	Habitability Data Handbook--Architecture and Environment	NASA
529	67 SD 4441	12-31-67	Study for the Collection of Human Engineering Data--Contract NAS8-18117	GE
530	SD 71-566	Oct. 1971	Orbital Operations Study--Orbital Interface Operations and Requirements (Interim Report)	NR
531	Not Numbered	Oct. 1971	Design of a Scanning Laser Radar for Spaceborne Applications Final Report Contract NAS8-23973, Phase III	ITT Aerospace/ Orbital Div.
536	Not Numbered	1-10-68	Docking Aids Subsystem, History and Analysis of Status	NR
538	SD 72-CE-0004	1-14-72	Interface Definition Study of the Space Shuttle and Large Space Telescope	NR

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Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
550	MSC-03812 (G)	7-6-71	Same as 145, Part III, Operations Plan	NASA (MSC)
551	Not Numbered	6-21-71	Space Shuttle Users Guide	NASA (MSC)
552	MSC-04411	May 1971	Space Shuttle Sys. Payload Handling and Docking	NASA (MSC)
554	--	Aug. 1971	Requirements for Shuttle Manipulators	Martin
556+	SD 71-001-061	9-9-71	Generation I Orbiter Orbital Missions Definition	NR
558	TM X-58063 Volumes I, II, & III	5-11/13-71	Proceedings of the Space Shuttle Integrated Electronics Conference	
562	Un-numbered	3-19-71	Space Shuttle Vehicle Docking Considerations	NASA (MSC)
563	--	8-9-71	Payload Design Requirements for Shuttle/Payload Interface	NASA (MSFC)
565	TOR-0059 (6758-02)-1	7-1-70	EOS/Payload Interface Definition	Aerospace
567	SD 70-600-39	1-5-71	Space Station Docking and P/L Transfer Trade Study Results	NR

Table 2.0-2. Data Source Documentation List (Continued)

Document Code No.	Report Number	Date	Title	Organization
568	G-570 NAS9-11932	8-16-71	Preliminary Design of a Shuttle Docking and Cargo Handling System	Martin-Denver
569	MSC 01497	9-30-71	Preliminary Design Requirements for Shuttle EVA/IVA Orbiter Support	NASA
570	FS-201	12-10-71	Remote Manipulator System (RMS) Shuttle/Orbiter	NR
571	MDC E0308	6-30-71	Space Shuttle System, Part II, Technical Summary	MDAC
572	YG1092 21602-1.4.5	5-1-71	Space Shuttle - Guidance, Navigation, and Control, Vol. OVI, Orbiter Navigation	Honeywell

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3.0 VEHICLE DESCRIPTIONS

Presented in this section are text, sketches, and performance data describing the space program elements which comprise the vehicle inventory of the Orbital Operations Study. Most of the information in this section was extracted from Appendix II of the study contract. With few exceptions, the data developed in this study are not sensitive to exact weights, dimensions, or performance of the elements considered. However, for convenience, and where appropriate, the vehicle physical and performance data included herein have been used in the analyses as representative model data.

Section 3.1 presents currently planned basic advanced space programs and associated space elements. Section 3.2 describes several potential add-on programs and elements that are under consideration for the mid-1980's. Table 3.0-1 presents an approximate timetable for the availability of the elements of the basic program and of the potential add-ons.

Table 3.0-1. Timetable for Initial Operational Capability of Space Systems

	C Y
Basic Operational Capabilities	
Skylab	1973
Earth-to-Orbit Shuttle (First Manned Orbital Flight - 1978)	1979
Sortie Mission Module	1979
Interim Tug	1979
Permanent Space Station	1981
Space Tug	1985*
Potential Add-On Components	
Chemical Propulsion Stage	1983
And one or more of the following:	
High Energy Automated Landers and Intelligence Modules	1983
Geosynchronous Space Station	1983
Lunar Surface Logistics Vehicle (Tug Derivative)	1983
Orbiting Lunar Station	1983
Lunar Surface Base	1983

*European Space Tug (limited capability) as early as 1981/1982

3.1 THE BASIC PROGRAM ELEMENTS

In recent months, the advanced planning organizations within the OMSF have generated several potential programs for the late 1970's and the decade of the 1980's. The material provided in this section represents a basic earth orbital program, keyed to the use of the earth-to-orbit shuttle (EOS). Operational dates have been adjusted to reflect the current forecasts from NASA Central Planning. Project descriptions, flight rates, and inventory requirements are detailed. Figure 3.1-1 provides a pictorial representation of the types of activities contained in the basic program.

The EOS is planned to become operational in 1979. For the subsequent two years, the manned space program will be conducted using the EOS with shuttle-carried sortie modules.

In 1981, the six-man space station will be launched by the EOS. This is assumed to be an earth observation station. The EOS provides crew rotation and resupply. In 1982, a second six-man space station will be added for astronomy applications. In 1983, one of the existing six-man space stations will be expanded to a 12-man capability. The 12-man space station provides much greater long-term space operations capability through its increased redundancy and maintenance facilities.

During this same time period, the EOS will be used to support the unmanned automated research and applications program. An interim space tug (Agena, Centaur, or similar derivatives) will be used with the EOS to deliver, revisit, or return unmanned automated space vehicles.

In 1985, the space tug will become operational. The greater payload capability and versatility of the space tug will greatly enhance the capability for satellite delivery and servicing.

The following sections, 3.1.1 through 3.1.5, describe in more detail the component projects of the basic program. These sections discuss the specific hardware elements and missions which comprise the basic program. Each element is briefly described, a summary of the performance parameters is discussed, and the interrelationships of the elements to the total program are given.

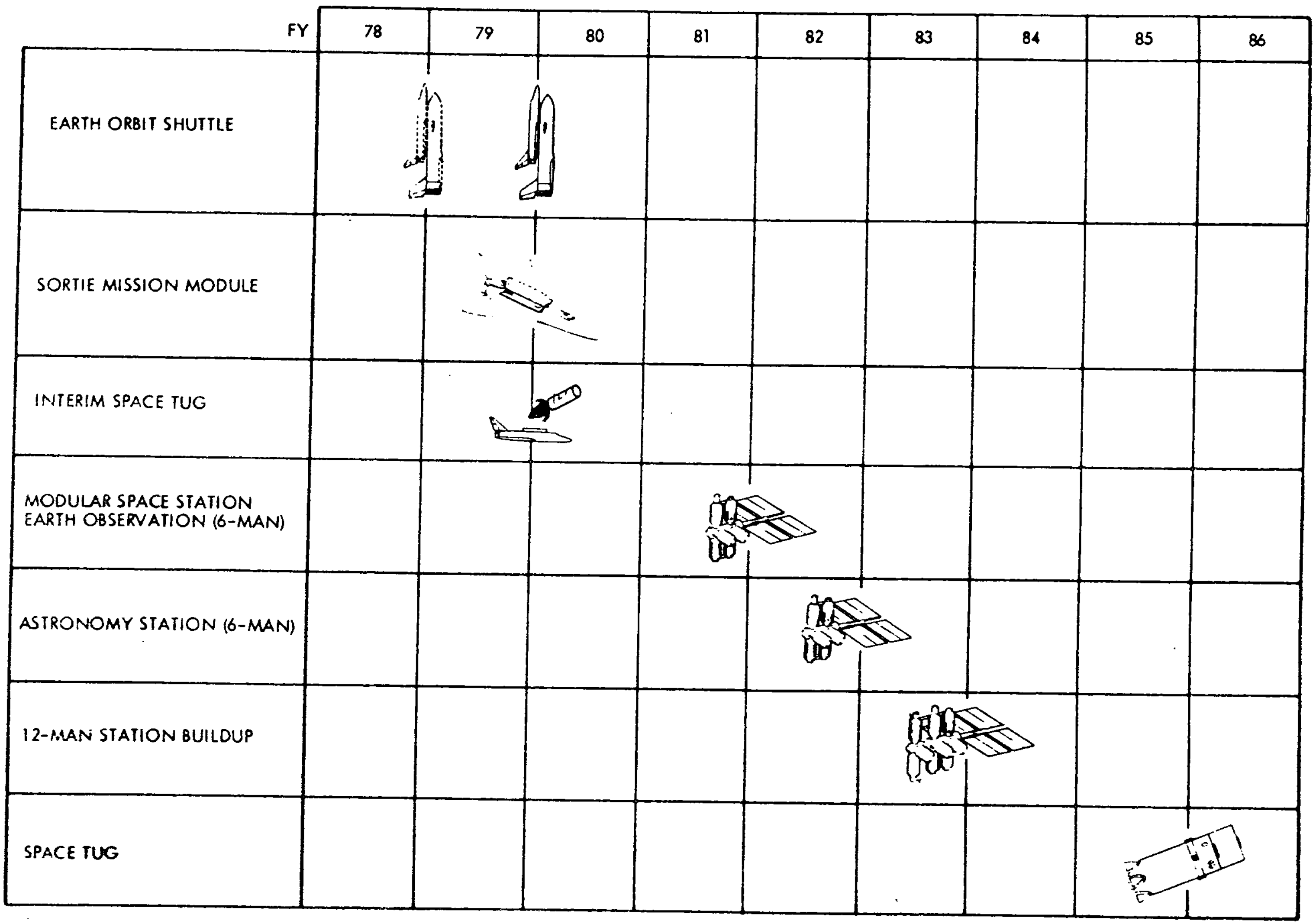

Figure 3.1-1. Phasing for the Basic Program

3.1.1 EARTH-TO-ORBIT SHUTTLE

The earth-to-orbit shuttle is a two-stage reusable vehicle that will begin operations before the end of this decade to serve a broad range of functions. The design of the EOS will emphasize versatility and economy to maximize the extent of the EOS capability.

Among the items presently included in this capability are:

1. Safe, economical, and efficient transport of men and equipment to and from space

2. Economical transport of spacecraft to low earth orbit in preparation for their subsequent transfer by a space tug into the desired orbit or escape trajectory

3. Return spacecraft from low earth orbit to the earth for repair, refurbishment and replacement

4. Emplace large telescope or observatory modules in orbit and revisit them periodically to change experiments, retrieve data, and service the modules

5. House, within its cargo compartment, a variety of experiment modules that provide a laboratory environment and living accommodations where specialists can conduct scientific and technological observations and experiments in earth orbit on brief "sorties" for periods extending from several days to a week or more

6. Transport space station modular elements and bulk cargo into orbit, thus facilitating assembly of an orbiting space station and subsequent logistic support

Utilization of the EOS for such operations will permit an entirely new approach to the design and development of spacecraft and experiments. Advantage can be taken of the opportunity for on-orbit checkout and activation, repair and refurbishment, relaxation of weight and volume constraints, and simplified manned on-orbit operations.

This new capability and approach to system development will allow the introduction of a new and more productive era of space activities without concomitant increases in investment.

Figure 3.1-2 and Table 3.1-1 present salient features and characteristics of a current EOS design concept.

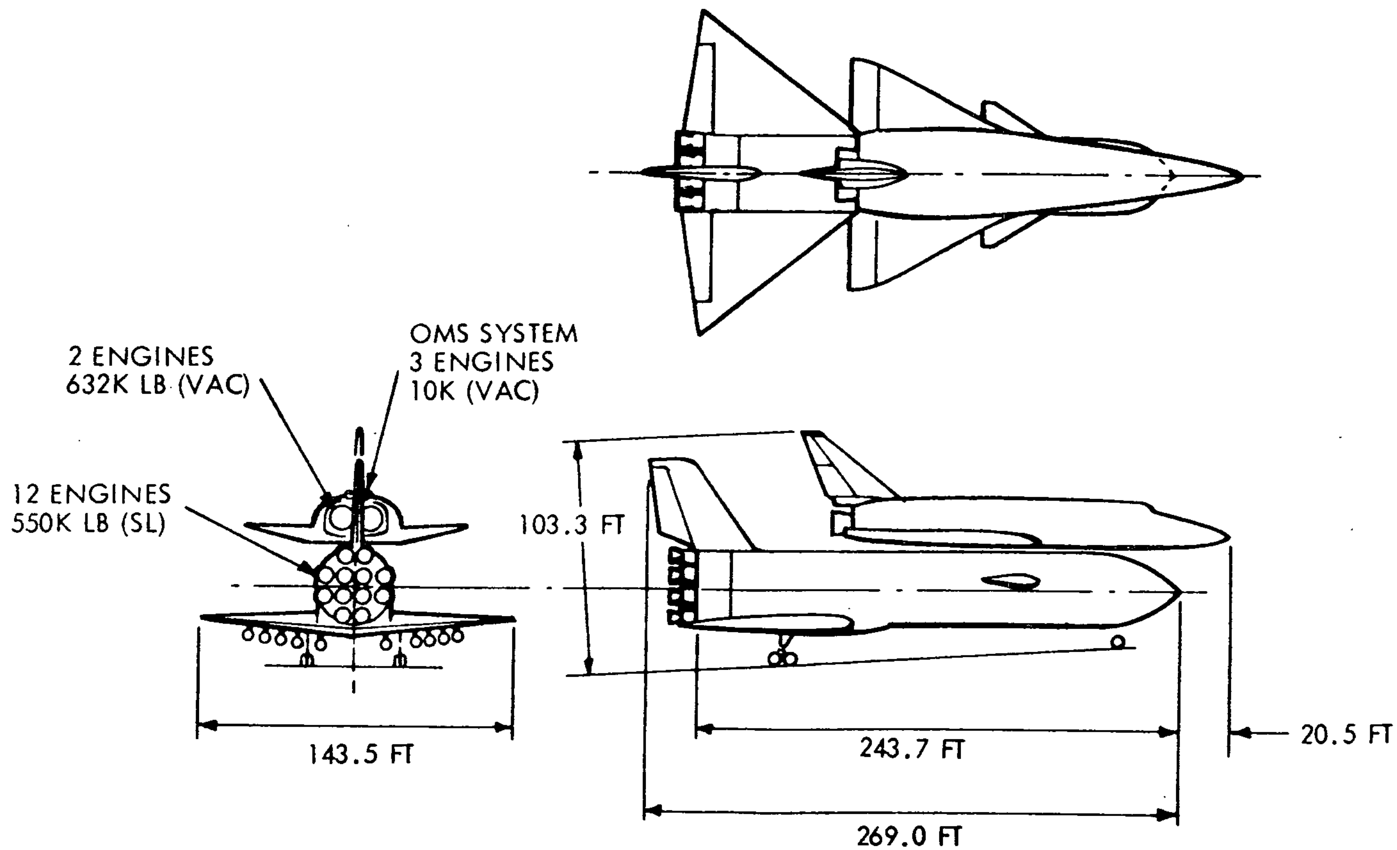

Figure 3.1-2. Earth-to-Orbit Shuttle Configuration - Delta Wing

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Table 3.1-1. Earth-to-Orbit Shuttle Characteristics

- VEHICLE CHARACTERISTICS*

LIFTOFF GROSS WEIGHT (LB)	5,047,457	
LIFTOFF THRUST TO WEIGHT	1.308	
	BOOSTER	ORBITER
GROSS STAGE WEIGHT (LB)	4,188,223	859,234
THRUST (SEA LEVEL) (LB)	6,600,000	----
THRUST (VACUUM) (LB)	7,243,500	1,263,810
I_{SP} (VACUUM) (LB)	439	459
MAIN ASCENT PROPELLANT (LB)	3,376,547	555,377
OMS, PROPELLANT (LB)	----	19,526
OMS ΔV, (FPS)	----	1,000
BOOSTER FLYBACK PROPELLANT (LB)	149,427	----
BOOSTER FLYBACK RANGE (N MI)	417	----
LANDING WEIGHT (LB)	630,153	268,007

- PERFORMANCE

MISSION	INCLINATION	ALTITUDE	ABES	OMS ΔV	PAYLOAD
STATION RESUPPLY	55°	270 N MI CIRCULAR	IN	1500 FPS	25,000 LBS
PAYLOAD DELIVERY	SOUTH POLAR	100 N MI CIRCULAR	OUT	580 FPS	40,000 LBS
SATELLITE PLACEMENT AND/OR RETRIEVAL	28.5°	100 N MI CIRCULAR	OUT	1030 FPS	65,000 LBS

- PAYLOAD BAY - 15 FT DIAMETER X 60 FT LENGTH
- DEVELOPMENT TIME
  6 YEARS FROM START OF PHASE C (TO FIRST MANNED ORBITAL FLIGHT)

---

*BASED ON 65,000 LB TO 100 N MI DUE EAST CIRCULAR ORBIT WITH ORBITER AIR BREATHING ENGINES REMOVED

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3.1.2 RESEARCH AND APPLICATIONS MODULE

The research and applications module (RAM) program consists of many potential elements, all designed to provide and enhance the capability to conduct experiments in earth orbit. To satisfy user, program and design oriented requirements, modular elements are being considered. To accommodate the primary requirements of habitability and access to experimental equipment, pressurized elements are being assessed. Modular buildup of subsystems to permit flexibility in operational capability and to meet various program funding constraints are being considered. The unpressurized RAM element is being considered as a low-cost, flexible payload carrier that provides unobstructed viewing when access to the payload is not required. To satisfy requirements for high pointing accuracy, low contamination, and long-duration observations, free-flying unmanned RAM's are necessary. In addition, these RAM's will be designed to be man-tended from the shuttle. A version of the pressurized RAM element is to be capable of operating as a service element when attached to the free-flying RAM.

Missions and operations analyses have identified potential RAM elements which are candidates for inclusion in an earth-orbital research program. These elements are pressurized RAM's, unpressurized RAM's (pallet), and free-flying RAM's. Within these broad generic classifications there are specific characteristics which further define these RAM elements.

Sortie Mission - Three sets of desirable characteristics for pressurized RAM's are identified. The first is a minimum-volume, minimum-weight with minimum subsystems for support of austere payloads. It is a minimum-weight configuration which can be carried to polar orbits. The second has a full complement of subsystems for supporting large payloads and provides crew habitability for experiment crews greater than two. The third is a large pressurized volume for housing advanced payloads. An unpressurized RAM (pallet) is also identified for use with payloads which require added mounting surfaces.

Free-Flying Mission - Two RAM configurations are identified for this mode. A free-flying RAM which provides subsystems for payload support along with an extremely stable platform, low contamination, and a pressurizable volume for manned servicing of the payload. The second is a pressurized RAM which provides storage volume and subsystem support for free-flying RAM's during manned servicing periods.

Station-Attached Mission - A single RAM configuration has been identified. It is characterized by a large pressurized volume; it receives subsystem support from the Space Station (except thermal control).

Figure 3.1-3, illustrates typical configurations being considered. The larger of the two payload modules is a candidate for an MSS attached RAM.

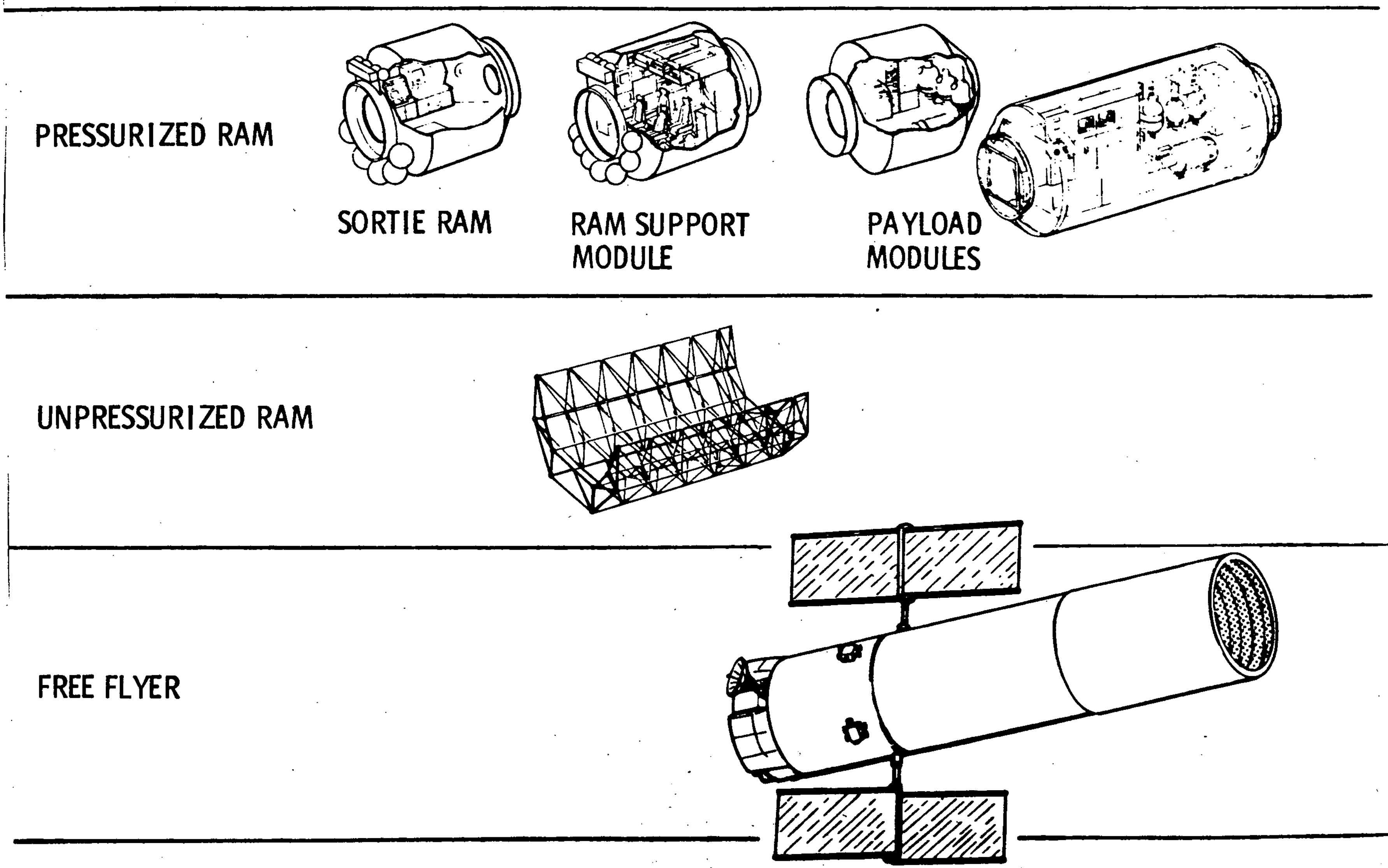

Figure 3.1-3. Typical Configurations for RAM Elements

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3.1.3 EARTH ORBIT SPACE STATION

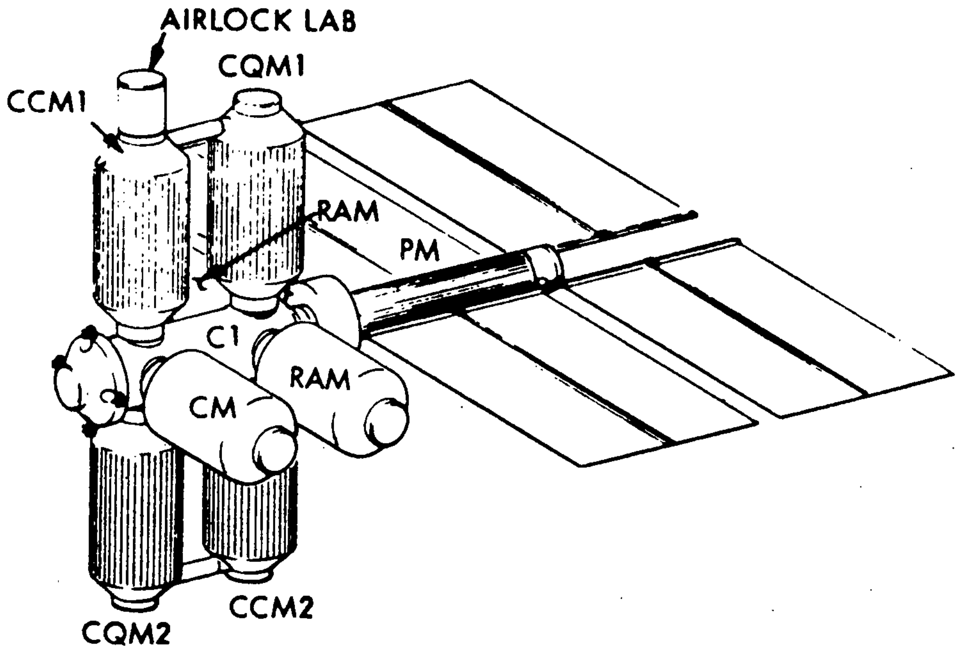
The assembly of a space station in earth orbit is planned to begin in the early 1980's. The space station will extend the capability of the sortie module to operate continuously and autonomously in space for long periods of time. The size and capability of the space station will be flexible in that it can be placed in operation, then extended or modified to satisfy changing requirements. Its modules will be launched into earth orbit and provided periodic logistics support by the EOS.

Since it will be a relatively permanent as well as flexible laboratory, the space station will make it possible to conduct diverse experiments in space. These experiments further broaden the scope of science and applications information available, observe the physical and psychological behavior of varied groups of individuals and the performance of their support equipment over extended periods of time, and develop experience in the operation of systems requiring long operating lifetimes in space. The space station will thus complement the short duration sortie missions through its capability to extend almost indefinitely the periods of observation in space.

The EOS-launched space station configuration described in Figure 3.1-4 and Table 3.1-2 can be readily adapted to other applications. For example, with minor modifications, the modules can be applied to a geosynchronous space station or an orbiting lunar station. With more extensive modifications, the modules could be assembled into a lunar surface base. By adding modules of similar design, the initial six-man station can be extended to a 12-man capability.

The 12-man space station described in Figure 3.1-5 and Table 3.1-3 is assembled from modules identical to those of the six-man station. Additional elements required include experiments and maintenance modules and a medical and exercise unit. The increased redundancy in the 12-man station greatly improves its long-term space operations capability.

The basic modular station design is derived from the EOS-sortie module; each module is compatible with the EOS payload bay, and only the EOS is required for launch into earth orbit. The design provides for periodic replacement of the environmental control life support system. A two-year replacement cycle has been assumed.



INITIAL STATION

Figure 3.1-4.

EOS-Launched Space Station Configuration -
Initial Six-Man Station

Table 3.1-2.

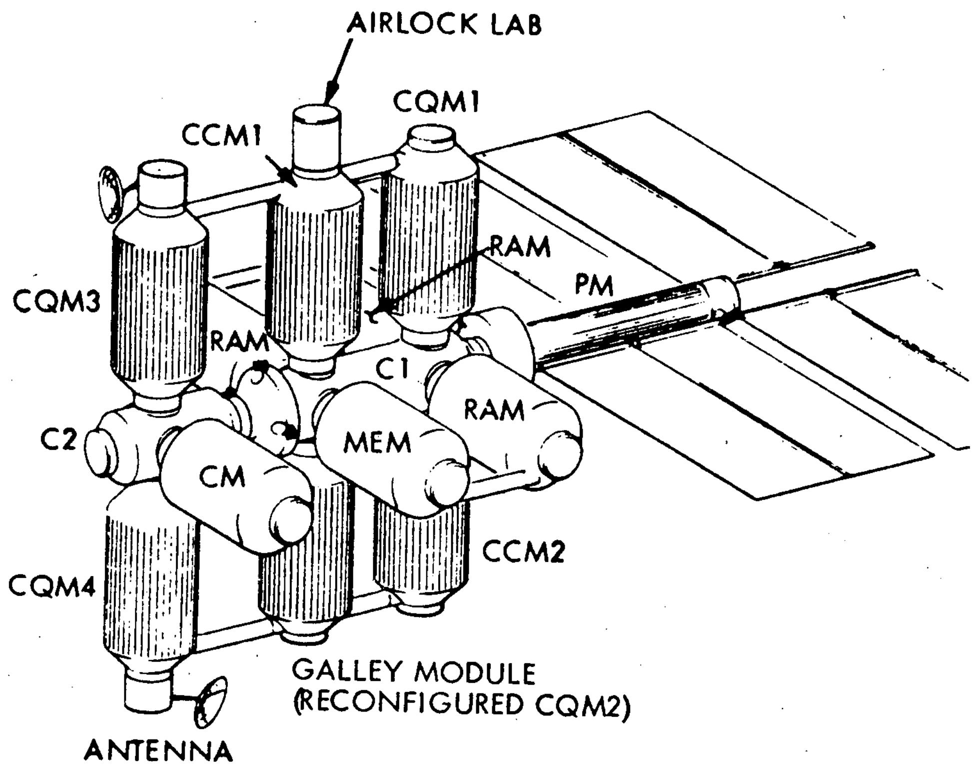
EOS-Launched Space Station Characteristics -
Initial Six-Man Station

- WEIGHT STATEMENT

ITEM	WEIGHT (LBS)	LAUNCH
CORE MODULE #1 (C1)	28,220	1
POWER MODULE #1 (PM)	15,420	2
CREW QUARTERS MODULE #1 (CQM 1)	12,950	3
CARGO MODULE (CM)	20,000	4
CONTROL CENTER #1 (CCM1)	17,280	5
RESEARCH & APPLICATIONS MODULE (RAM)	20,000	6
CONTROL CENTER #2 (CCM2)	19,270	7
CREW QUARTERS MODULE #2 (CQM2)	14,060	8
RESEARCH & APPLICATIONS MODULE (RAM)	20,000	9
GROSS (LESS CREW)	167,200	

- CAPABILITY
  - 6 MAN
  - 16.5 KW
  - ZERO-G

- DEVELOPMENT TIME
  - 5 YEARS FROM START OF PHASE C



GROWTH STATION

Figure 3.1-5. Shuttle-Launched Space Station Configuration - Twelve-Man Growth Station

Table 3.1-3. EOS-Launched Space Station Characteristics - Twelve-Man Growth Station

- WEIGHT STATEMENT

ITEM	WEIGHT (LBS)	LAUNCH
CORE MODULE #2 (C2)	9,700	10
CREW QUARTERS MODULE #3 (CQM3)	12,570	11
POWER MODULE #2 (PM)	17,000	11
RESEARCH & APPLICATIONS MODULE (RAM)	20,000	12
MEDICAL/EXERCISE MODULE (MEM)	13,550	13
CREW QUARTERS MODULE #4 (CQM4)	9,980	14
ANTENNA POD (ON CQM3)	1,950	14
ANTENNA POD (ON CQM4)	1,950	14
12 MAN GROSS (LESS CREW)	241,220	

- CAPABILITY
  - 12 MAN
  - 26.5 KW
  - ZERO-G

- DEVELOPMENT TIME
  - 5 YEARS FROM START OF PHASE C

3.1.4 SPACE TUG

The space tug is a propulsive stage capable of being carried into orbit in the EOS cargo bay. Once in orbit, it will be capable of performing missions ranging from placing spacecraft into orbits different from that of the EOS to the insertion of spacecraft into geosynchronous orbit, or injection into escape trajectories. Although the ultimate performance objectives for this propulsive stage include manned applications, spacecraft retrieval, and reusability of the propulsive stage itself, the early capability may be somewhat more restricted. Studies are currently underway both in the United States and in Europe to define the performance and operating requirements of the space tug and to identify and evaluate alternate design approaches. It is envisioned that a space tug with limited capability could be available by the early 1980's (European tug) and that a system embodying the full performance objectives could be in operation by the mid-1980's.

In the interim before the space tug becomes operational, it is planned that a derivative of an existing stage, such as Centaur, Agena, Titan Transtage or Burner II, will be adapted to fulfill the functions of inserting spacecraft into orbits different from that of the shuttle, into geosynchronous orbit, and injection into escape trajectories. This vehicle is identified as an interim tug and could become operational concurrently with the EOS.

It is conceived that the interim tug could initially be operated in an expendable mode and later be operated in a reusable mode with ground-based replenishment of expendables. The exception is the Burner II stage which uses a solid propellant and is always expended. From the standpoint of operational complexity, particularly for initial EOS/tug operations, it is desirable to launch the interim tug mated with its payload, i.e., in one EOS flight. Thus, for this case, the gross weight (tug plus payload) is limited to the EOS payload capability at the required orbital inclination. Orbital inclination requirements for identifiable tug payloads tend to be grouped at or near equatorial, 30-degree, 55-degree, or polar orbits. When launched from either the Eastern or Western Test Range, the EOS is limited to an operational orbit of 28.5 degrees or greater inclination. Gross weight limits of 65,000, 55,000, and 40,000 pounds are representative of the EOS payload capabilities to a 100 nautical mile circular orbit at inclinations of 28.5, 55, and 90 degrees, respectively (payload capability decreases as orbital inclination increases). These limits were used in illustrating the performance capabilities of the various tug candidates. Gross weight-limited performance is representative of totally ground-based operations in which no orbital assembly or orbital propellant loading is required. Tug propellants are off-loaded as payload is increased in order to stay within the gross weight limits.

Figures 3.1-6 through 3.1-13 illustrate the characteristics and configurations of the Agena and Centaur derivatives, the Titan Transtage, and Burner II, which represent vehicles that could be used as interim space tugs. Interim tugs could also comprise slightly modified current operational versions of the Agena or Centaur. Figures 3.1-14 and 3.1-15 illustrate a possible configuration for the European space tug. Figures 3.1-16 and 3.1-17 describe the characteristics of a full capability new development space tug.

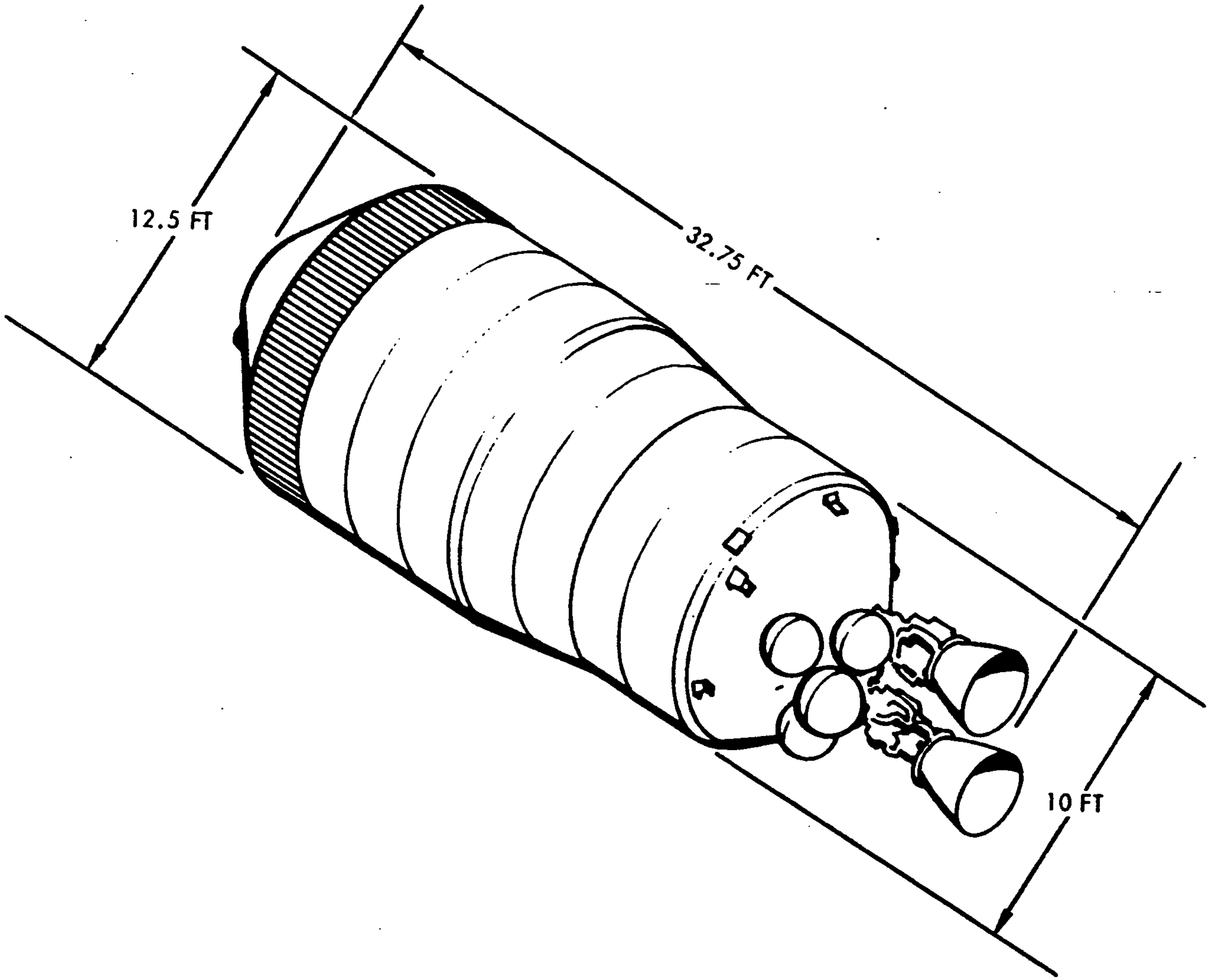


Figure 3.1-6. GT Centaur Configuration

- WEIGHT STATEMENT

STAGE INERT	5,251 LBS
PROPELLANT	45,000 LBS

- DEVELOPMENT TIME
  ≈3 YEARS FROM START OF PHASE C

- PERFORMANCE

- PROPULSION CHARACTERISTICS

ENGINE TYPE	RL10A-3-3
THRUST	29,700 LBS
BURN TIME	670 SEC
I_{SP}	444 SEC
MASS FRACTION	0.895
FUEL	LH_2
OXIDIZER	LO_2

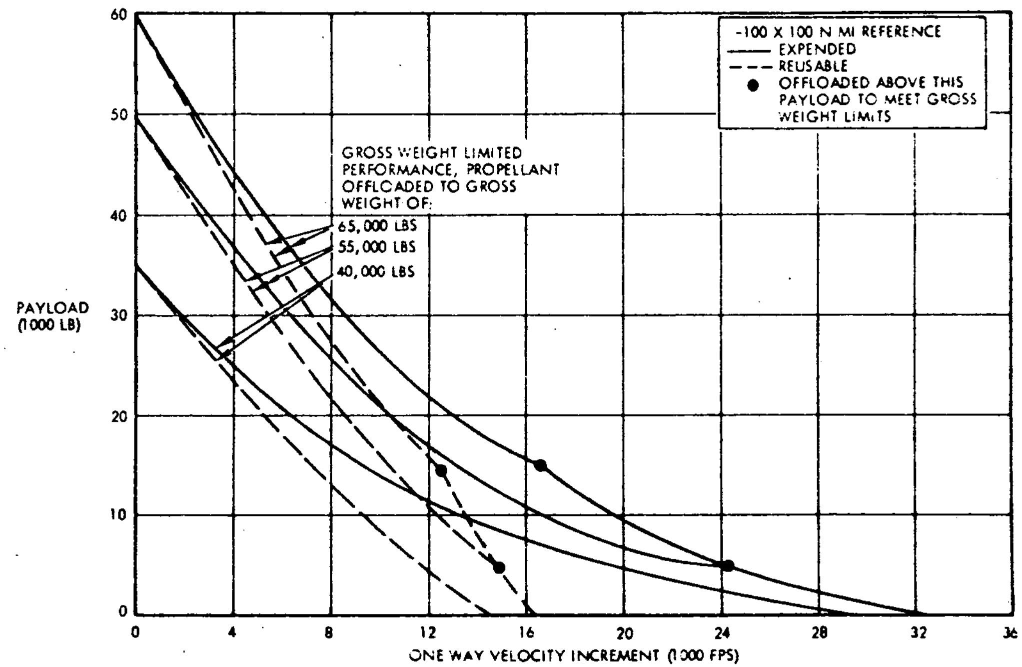


Figure 3.1-7. GT Centaur Characteristics

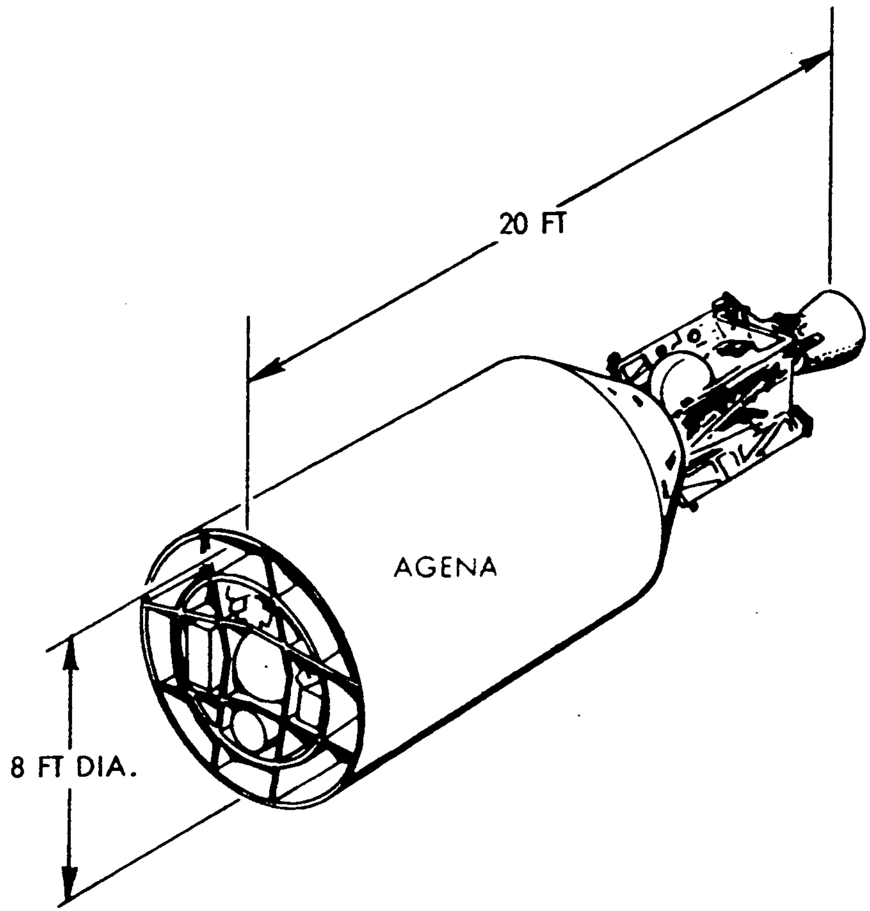


Figure 3.1-8. Large Tank Agena Configuration

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- WEIGHT STATEMENT

  STAGE INERT 1,707 LBS
  PROPELLANT 35,000 LBS

- DEVELOPMENT TIME

  2 YEARS FROM START OF PHASE C

- PERFORMANCE

- PROPULSION CHARACTERISTICS

ENGINE TYPE	BAC 8096
THRUST	16,000 LBS
BURN TIME	240 SEC
I_{SP}	299.5 SEC
MASS FRACTION	0.95
FUEL	UDMH
OXIDIZER	HDA (+1%SILICONE)

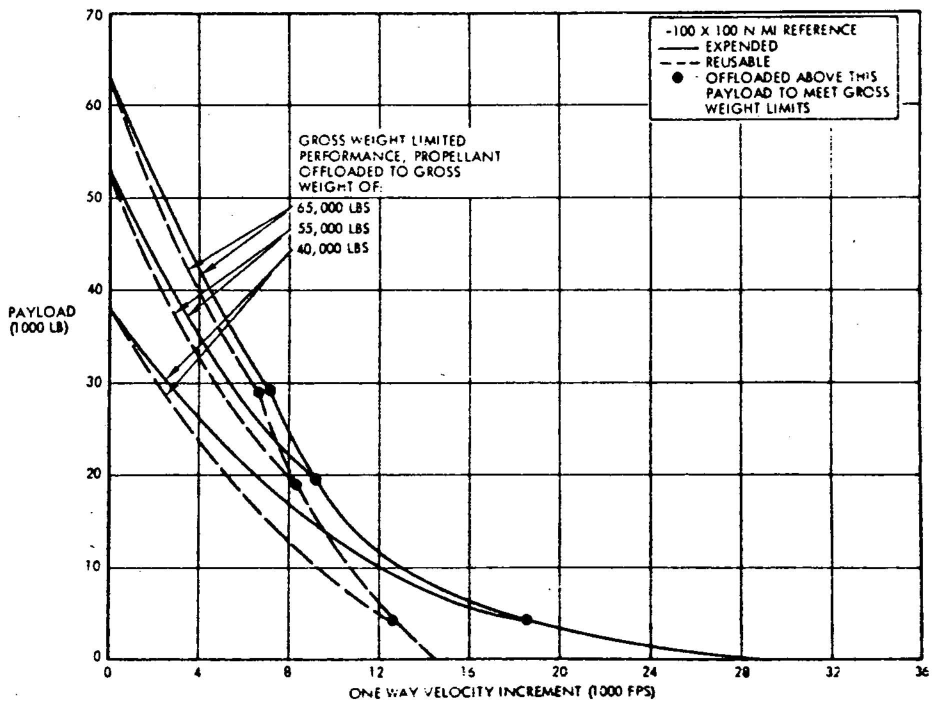

Figure 3.1-9. Large Tank Agena Characteristics

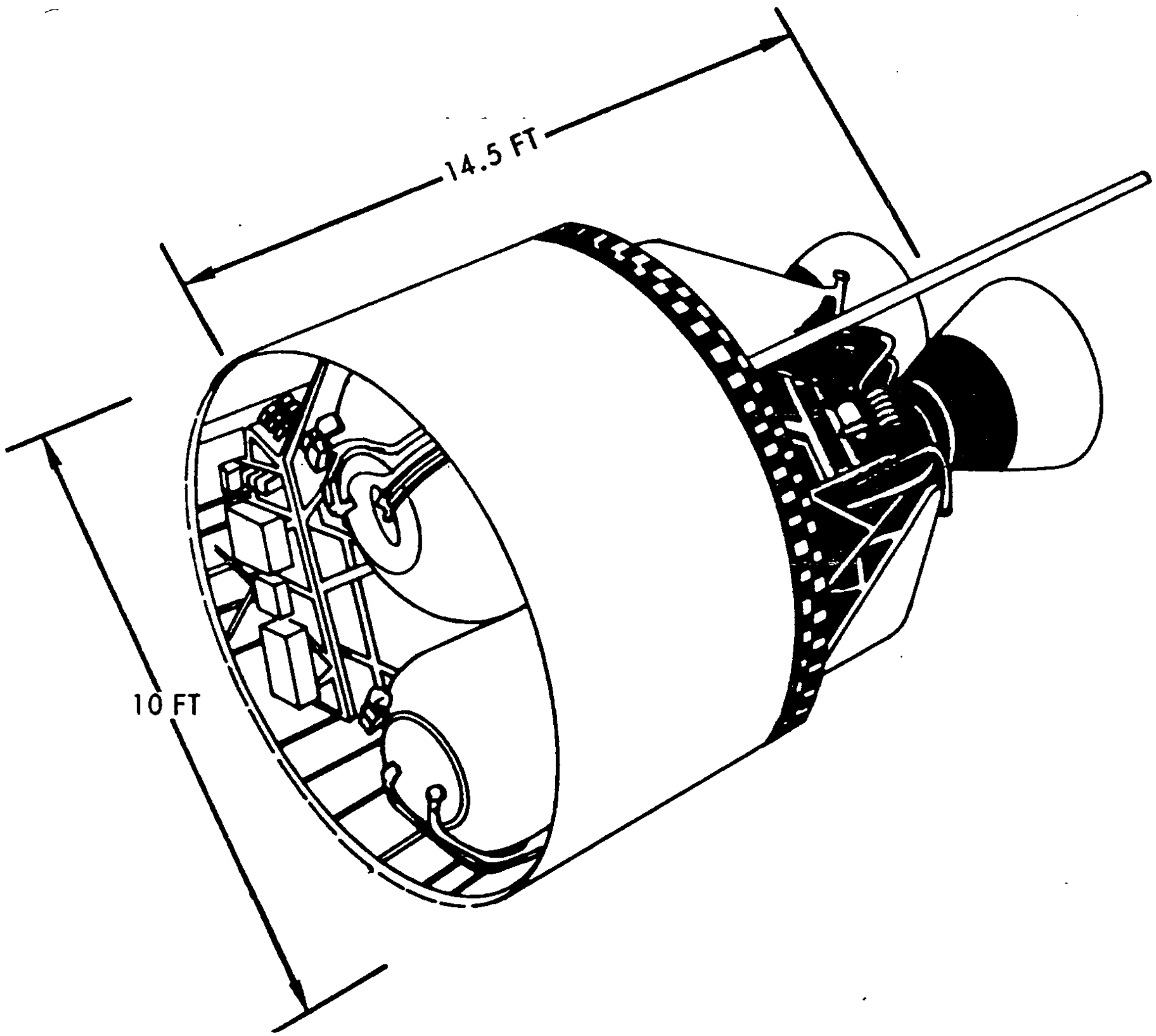

Figure 3.1-10. Titan Transtage Configuration

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- WEIGHT STATEMENT

STAGE INERT	4,065 LBS
PROPELLANT	23,400 LBS

- PRESENTLY OPERATIONAL
- PERFORMANCE

- PROPULSION CHARACTERISTICS

ENGINE TYPE	AJ10-138
THRUST	16,000 LBS
BURN TIME	441 SEC
I_{SP}	302 SEC
MASS FRACTION	0.852
FUEL	AEROZINE-50
OXIDIZER	NITROGEN TETROXIDE

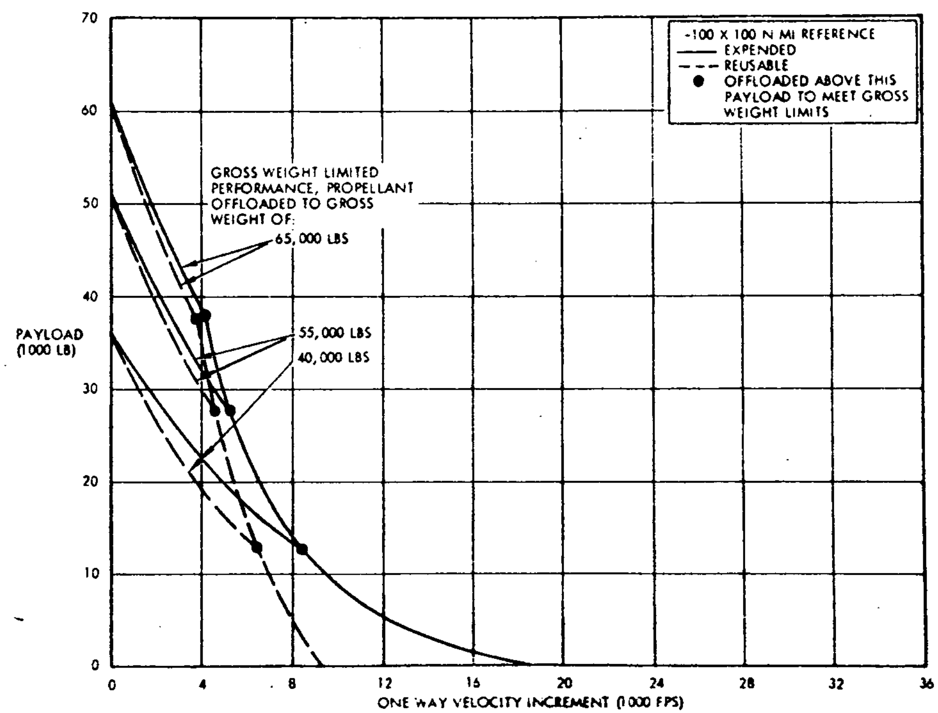

Figure 3.1-11. Titan Transtage Characteristics

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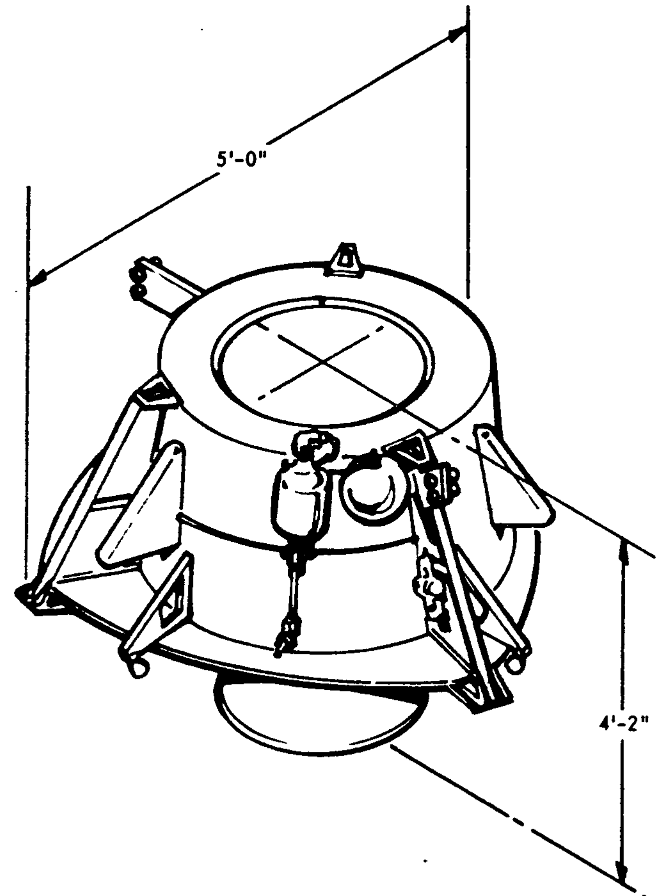

Figure 3.1-12. Burner II Configuration

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- WEIGHT STATEMENT

BURNOUT WEIGHT	311 LBS
PROPELLANT WEIGHT	1440 LBS
IGNITION WEIGHT	1787 LBS

- PROPULSION CHARACTERISTICS

ENGINE TYPE	TE-M-364-2 MOTOR
THRUST (VAC)	9240 LBS
BURN TIME	45 SEC
ISP	284 SEC
PROPELLANT	SOLID

- STATUS - OPERATIONAL
- PERFORMANCE

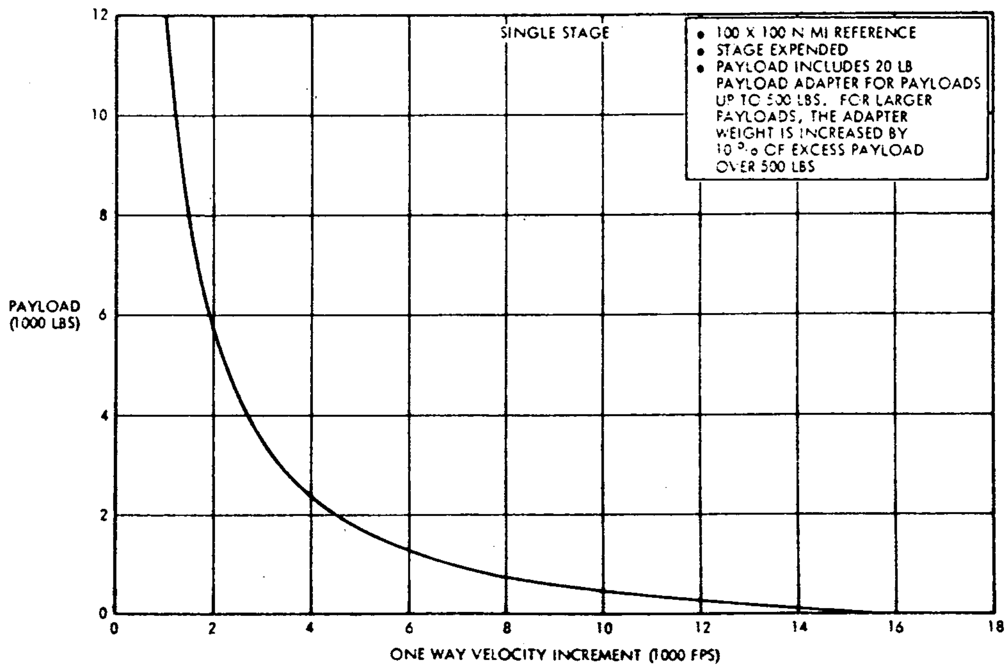

Figure 3.1-13. Burner II Characteristics

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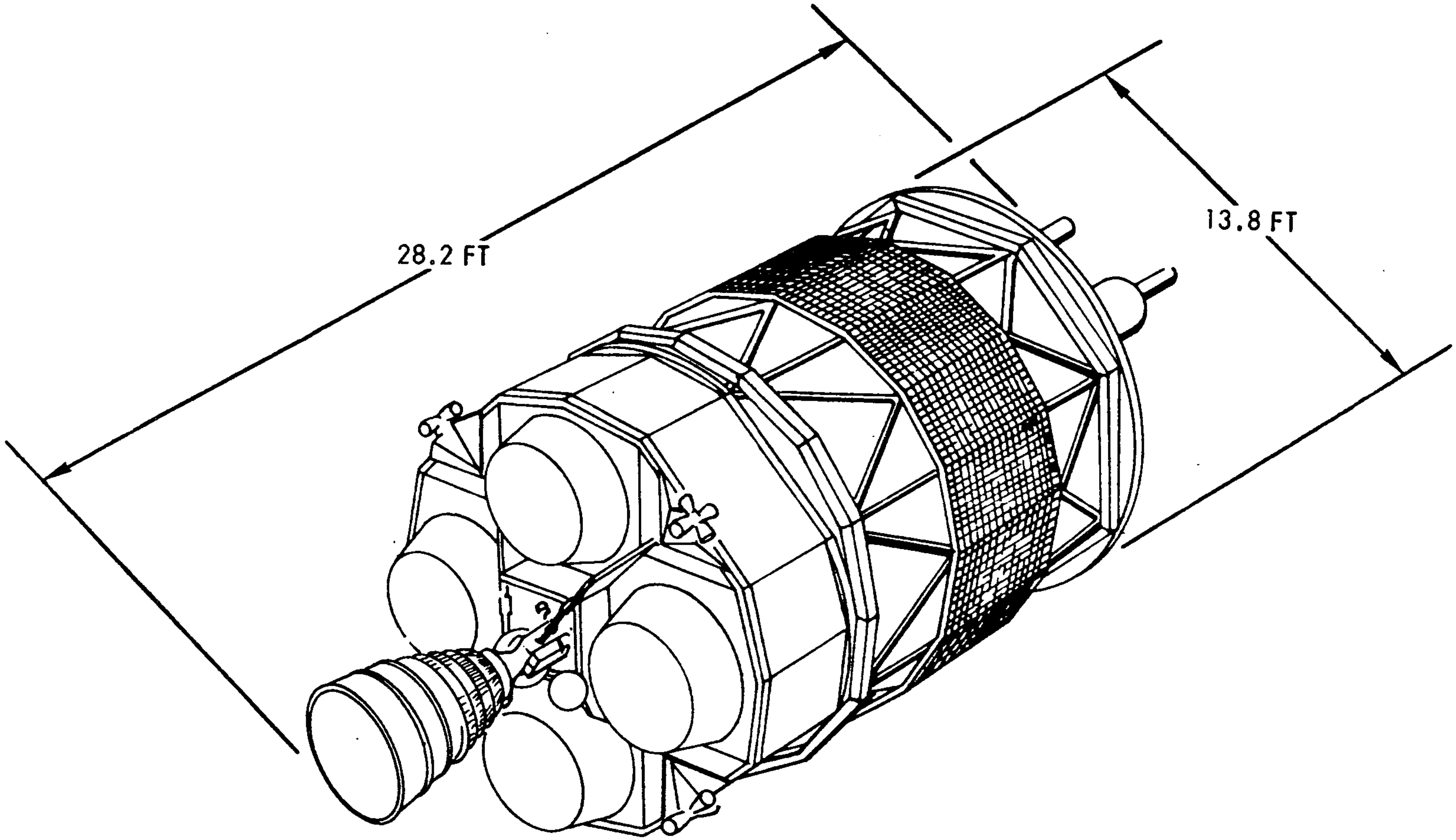

Figure 3.1-14. European Space Tug Configuration

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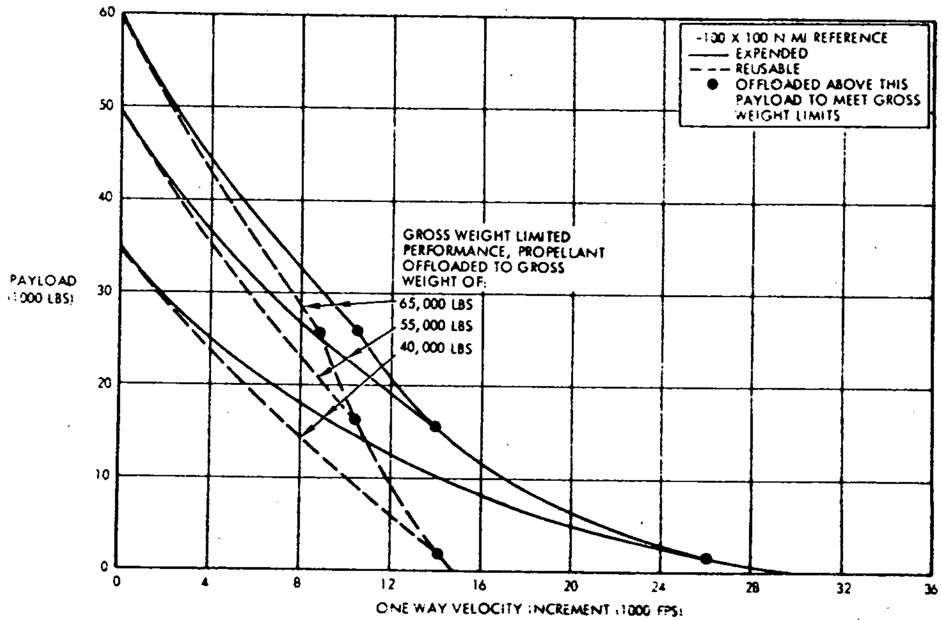
- WEIGHT STATEMENT *

STAGE INERT	5,135 LBS
PROPELLANT	33,075 LBS

- DEVELOPMENT TIME

  7 YEARS FROM START OF PHASE C (EXPENDABLE)
  9 YEARS FROM START OF PHASE C (REUSABLE)

- PERFORMANCE



- PROPULSION CHARACTERISTICS

THRUST	11,000 LBS
ISP	460 SEC
MASS FRACTION	0.865
FUEL	LH_2
OXIDIZER	LO_2

* BASED ON STUDY RESULTS PRESENTED 3 FEBRUARY 1971

Figure 3.1-15. European Space Tug Characteristics

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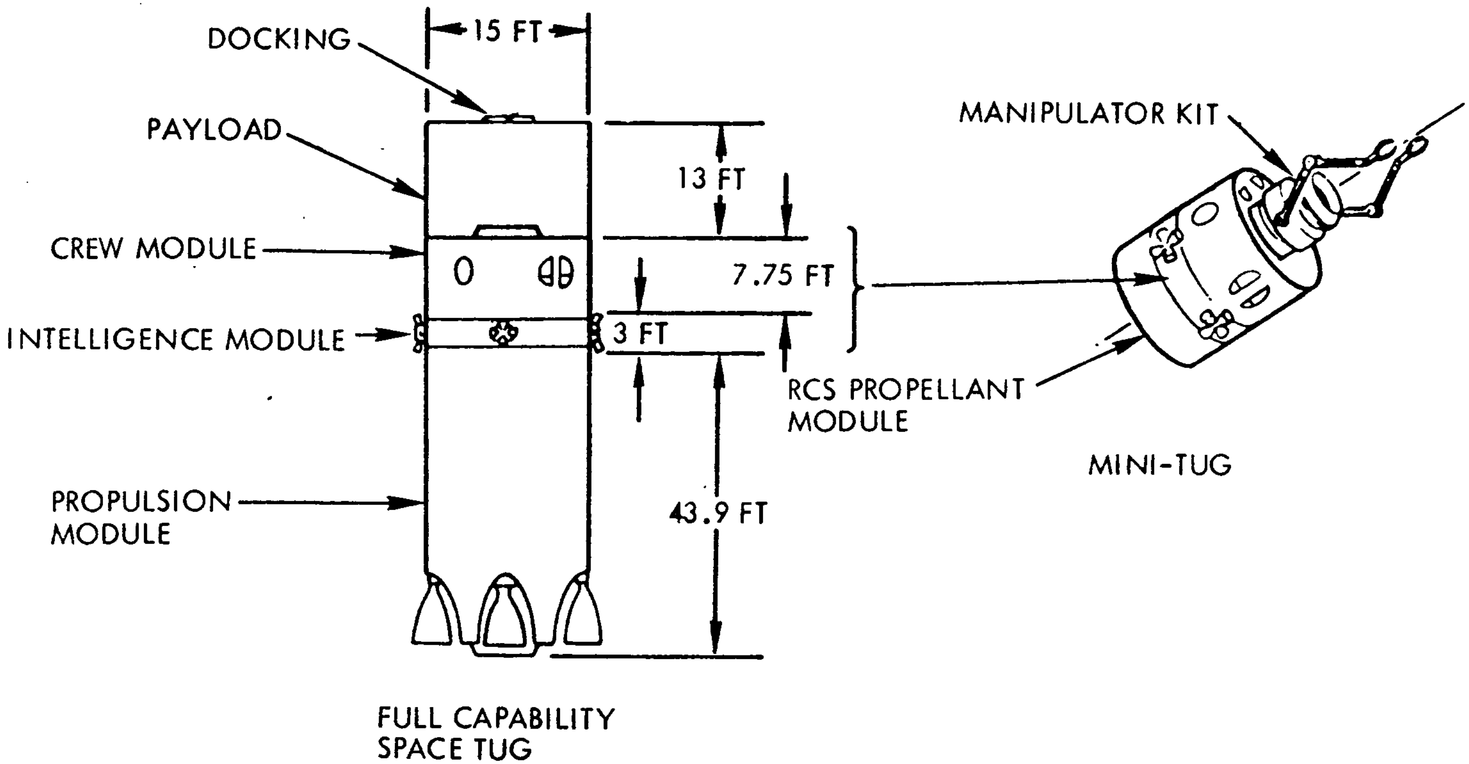

Figure 3.1-16. Space Tug Configuration

- WEIGHT STATEMENT

ITEM		GEOSYNCHRONOUS APPLICATION WEIGHT (LBS)	MINI-TUG APPLICATION WEIGHT (LBS)
PROPULSION MODULE			
INERT WEIGHT	6,670		
PROPELLANT	78,946		
GROSS		85,610	---
INTELLIGENCE MODULE		3,440	3,440
CREW MODULE		- -	9,500
MANIPULATOR MODULE		- -	2,200
RCS PROPELLANT MODULE		- -	1,460
TOTAL		89,050	16,460

- PROPULSION CHARACTERISTICS

ENGINE TYPE	RL10A-3-8A
NUMBER OF ENGINES	4
NOZZLE TYPE	2 POSITION
AREA RATIO	250/100
SPECIFIC IMPULSE	461/450 SEC
MAX THRUST (EACH)	23,400 LBS
FUEL	LH_2
OXIDIZER	LO_2

- DEVELOPMENT TIME - 9 YEARS FROM START OF PHASE C
- PERFORMANCE

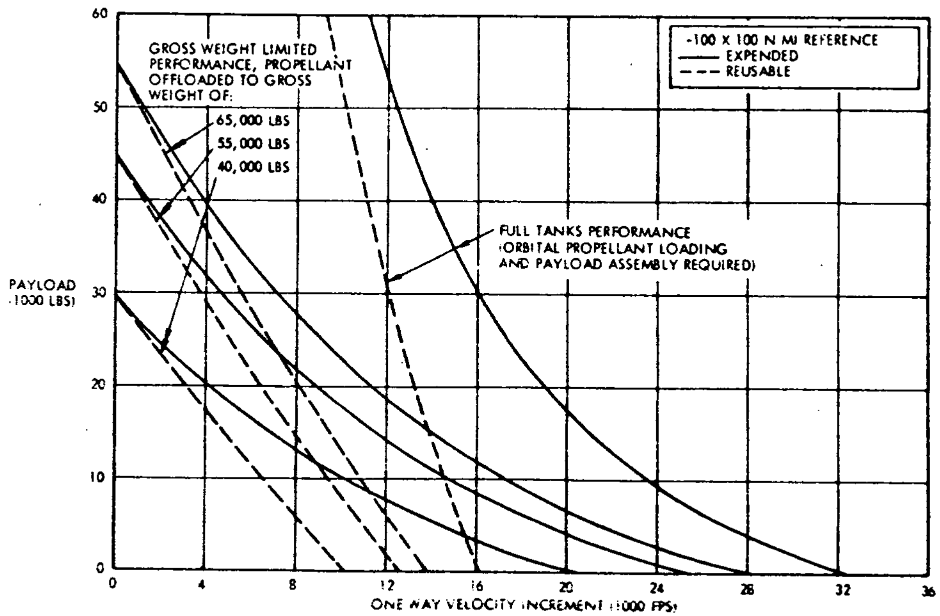

Figure 3.1-17. Space Tug Characteristics

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3.1.5 AUTOMATED PAYLOADS

The combination of earth-to-orbit shuttle and space tug will provide the capability to deliver, service, and return to earth virtually all automated scientific payloads within the current inventory or planning stages.

Tables 3.1-4 through 3.1-8 detail the weight, dimensions, and orbital parameters associated with candidate shuttle/tug automated payloads under consideration for the 1978-1990 time period. It should be understood that several of these missions may be replaced by sortie or space station experiments. Also, these dimensions are based on current expendable launch vehicle configurations. Configurations may vary considerably if payloads are redesigned for launch in the EOS for maintainability and reuse.

Items denoted by an asterisk have been identified in current planning activities as prime candidates for EOS launch.

Table 3.1-4. Automated Payloads, Earth Orbit Program - Equatorial Synchronous

PAYLOAD	DIMENSIONS				LAUNCH DATES													
	WEIGHT (LB)	DIAMETER (FT)	LENGTH (FT)	DENSITY (LB/FT^3)	78	79	80	81	82	83	84	85	86	87	88	89	90	
GEO. MULTI-DISCIPLINE EARTH OBSERVATIONS	1,000	6.5	12	2.5	X		X		X		X		X		X		X	
PRECISION POSITION DETERMINATION SATELLITE	1,000	6.5	12	2.5	3		3											
*APPLICATION TECHNOLOGY SATELLITE	4,000	12	21	1.7	X		X		X	X		X		X	X		X	1 REVISIT PER YEAR
*COOPERATIVE APPLICATION SATELLITE	700	6.5	12	2.5		X			X		X							1 REVISIT PER YEAR
*SYSTEM TEST SATELLITE	2,000	12	15	1.2	2	2	2	2	2	2	2	2	2	2	2	2	2	1 REVISIT PER YEAR
INTELSAT V	5,000	10	22	2.9	X	X	X											
**S/S SYNC PLASMA PHYSICS	5,000	15	20	1.4								4	4	4	4	4	4	
*COMM & NAV 1	400	4.0	12	2.6			2	4	1	2		1		3	1	2		
*COMM & NAV 2	1,000	6.5	12	2.5	5	3	1	3	2	1	1	1	2	3	1	1	1	
*COMM & NAV 3	2,000	12	15	1.2	2		2	2		1	1		2	1	1		2	
*COMM & NAV 4	3,000	12	21	1.2	2	3	3	2	1	3	1	3	2	2	4	3		
*EARTH RESOURCES	1,000	6.5	12	2.5	1		2		4		4		4		4		4	

* PRIME CANDIDATES FOR EOS
** CONSIDERS GEOSYNCHRONOUS SPACE STATION

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Table 3.1-5. Automated Payloads, Earth Orbit Program - Other Synchronous

PAYLOAD	WEIGHT (LB)	DIMENSIONS DIAMETER (FT)	LENGTH (FT)	INCLI-NATION (DEG)	DENSITY (LB/FT^3)	LAUNCH DATES 78	79	80	81	82	83	84	85	86	87	88	89	90
*SOLAR OBSERVATORY PAIR A	1,000	10	12	30	1.06		X					X						
OPTICAL INTERFEROMETRY	1,500	10	15	30	1.3			X					X			X		X
*LARGE RADIO OBSERVATORY	20,000	15	50	30	2.3							X						
*SMALL ATS(D) (VARIOUS ALTITUDES 700 - 19,800 VARIOUS INCLINATIONS 0 - 90 DEG)	600	6.5	12		1.1	2	2	2	2	2	2	2	2	2	2	2	2	2

* PRIME CANDIDATES FOR EOS

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Table 3.1-6. Automated Payloads - Other Nonplanetary Payloads

PAYLOAD	DIMENSIONS WEIGHT (LB)	DIAMETER (FT)	LENGTH (FT)	INCLINATION (DEG)	ALTITUDE (N MI)	LAUNCH DATES 78	79	80	81	82	83	84	85	86	87	88	89	90
*HIGH ENERGY ASTRON. OBSERV.	25,000	15	60	15	230 CIRCULAR		X	X	X									
*LARGE STELLAR TELESCOPE	25,000	15	60	30	400 CIRCULAR			X										
*LARGE SOLAR OBSERVATORY	22,000	15	60	30	350 CIRCULAR					X								
*SOLAR-ORBIT PAIR B	1,000	10	12	28	1 A. U.		X					X					X	
OPTICAL INTERFEROMETRY - B	1,500	10	15	28	1 A. U.			X					X					X
*RADIO INTERFEROMETRY	10,000	15	60	30	40,000 CIRCULAR				X							X		
KILOMETER WAVE RADIO	2,000	15	60	30	40,000 CIRCULAR									X				
LOWER MAGNETOSPHERE	1,200	4	8	90	18,000 x 180	X	X	X	X	X	X	X	X	X	X	X	X	X
MIDDLE MAGNETOSPHERE	1,000	6	8	28	100,000 x 1,000	X	X	X	X	X	X	X	X	X	X	X	X	X
UPPER MAGNETOSPHERE	600	4	6	28	1 A. U.	X	X	X	X	X	X	X	X	X	X	X	X	X
MODIFICATION EXP. LAB.	7,500	7	12	55	8,000 CIRCULAR							X		X		X		X
*GRAVITY/RELATIVITY HELIOCENTRIC	500	4	7	28	0.5 A. U.				X						X			
BIO-EXPLORER	400	4	4	28	300 x 150	X	X	X	X	X	X	X	X	X	X	X	X	X
GRAVITY/RELATIVITY EXP.	1,500	7	5	90	300 CIRCULAR		X					X						
SOLAR SYSTEM ESCAPE AND SOLAR PROBES	500	4	5	28	SOLAR	X			X			X		X				
*TIROS	1,200	5	6	101	900 CIRCULAR			X										
IMPROVED TIROS	800	5	6	101	900 CIRCULAR	X	X	X	X	X	X	X	X	X	X	X	X	X
MULTI-DISCIPLINE EARTH OBS.	2,500	10	12	90	2,500 CIRCULAR	X	X	X	X	X	X	X	X	X	X	X	X	X
*SMALL APPL. TECH (D)	600	6.5	12	0-90	700-19,300 CIRCULAR	3	3	3	3	3	3	3	3	3	3	3	3	3
BIO-PIONEER	400	4	4	28	HELIOCENTRIC	X		X		X		X		X		X		X
*SMALL ATS (S)	300	3.5	12	8-90	300-3,000	3	3	3	3	3	3	3	3	3	3	3	3	3
*COMM & NAV V	300	3.5	12	90	500-250			X		X				X		X		
*EARTH RESOURCES	2,500	10	12	100	500 CIRCULAR	4	4		4		4		6		6		6	
*EARTH RESOURCES	2,000	12	13	98	500 CIRCULAR	X		X		2		2		4		4		

* PRIME CANDIDATES FOR EOS

Table 3.1-7. Automated Payloads - Planetary Flights

MISSION	WEIGHT (LB)	V_C (FT/SEC)	DIMENSIONS DIAMETER (FT)	DIMENSIONS LENGTH (FT)	LAUNCH DATES 78	79	80	81	82	83	84	85	86	87	88	89	90
VIKING	9,700	39,400	10	13		NOV 30 DAY WINDOW											
MARS HIGH DATA RATE ORBITER	7,000	37,800	10	13				DEC 20 DAY WINDOW									
*EXPLORERS	900	38,500	4	8							FEB 15 DAY WINDOW		MAR		JUNE		SEPT
*VENUS EXPLORER PROBES	900	38,500	4	8	2												
*VENUS EXPLORER ORBITER	900	38,500	4	8								JAN 15 DAY WINDOW		JULY		MAR	OCT
VENUS HIGH DATA RATE ORBITER	7,000	38,500	10	13				NOV 20 DAY WINDOW									
VENUS LANDER (1ST GEN)	6,000	38,500	10	13						APR 30 DAY WINDOW							
VENUS LANDER (2ND GEN)	4,000	38,500	10	13												OCT 30 DAY WINDOW	
MERCURY ORBITER	8,000	39,600	10	13											MAR 15 DAY WINDOW		
JUP-URAN-NEP SWINGBY	1,500	51,000	4	8		2											
*PIONEER JUP ORBITER	900	47,800	4	8					JAN 15 DAY WINDOW								
JUPITER FLYBY/PROBE	2,400	48,500	6	10							MAR 15 DAY WINDOW						
JUPITER ORBITER	2,200	47,800	6	10									MAY 15 DAY WINDOW		JULY		
SAT ORB/PROBE	2,000	48,500	6	10							JAN 15 DAY WINDOW						
ASTRO BELT SURVEY	1,500	38,500	4	8				MAR. UNLIMITED WINDOW									
ASTEROID DOCKING	2,500	38,000	6	10									X				X
HALLEY'S COMET FLYTHROUGH	1,200	38,500	4	8									JAN 20 DAY WINDOW				

* PRIME CANDIDATES FOR EOS

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Table 3.1-8. Automated Payloads - Additional Payloads Currently Under Consideration

Meteoroid Technology Satellite

Earth Observation Satellite

Synchronous Earth Observation Satellite

Earth Physics Satellite

Data Relay

Planetary Relay

Medical Network

Educational Broadcast

Space Physics Explorer

Astronomy Explorer

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3.2 ADD-ON PROGRAM ELEMENTS

This section describes several potential program additions for the 1980's. Depending on priorities and budget restrictions, any one or a combination of several of these 1980 programs might be added.

A space transportation vehicle having greater payload capability than the EOS alone or the EOS/space tug combination would be required in order to implement most of the potential program additions. A chemical propulsion stage (CPS) could be mated with the EOS booster (in place of the EOS orbiter) and used as an orbit insertion stage to place large payloads into earth orbit. After placement into earth orbit the CPS could be refueled and used as a high energy translunar shuttle. Another contender for the translunar shuttle role is the reusable nuclear stage.

Four potential add-on program options consist of:

1. A multi-space stage program. This add-on option builds from the 18-man space population of the basic program to 54 men through the addition of three 12-man modular earth orbital space stations. These additional stations are launch in 1983, 1984, and 1985.

2. A six-man geosynchronous space station. This station is placed in orbit in 1983 and supplied through the use of the EOS in conjunction with the chemical propulsion stage.

3. An independent lunar surface program. Along with the EOS and chemical propulsion stage, a new lunar landing vehicle is required (space tug derivative). This program, beginning in 1983, is an Apollo-type mission with no orbiting lunar space station. Two landings are performed each year.

4. Full lunar program. This program includes an eight-man lunar orbit space station in 1983, followed by a permanent 12-man lunar surface base in 1987. The program requires the EOS, the CPS, a lunar landing vehicle, as well as a modular orbiting lunar station and a station-derived lunar surface base. Significantly higher funding levels are required for this add-on option than the preceding four options.

Figure 3.2-1 pictorially represents the potential add-on options. Key elements of the basic program are shown for reference.

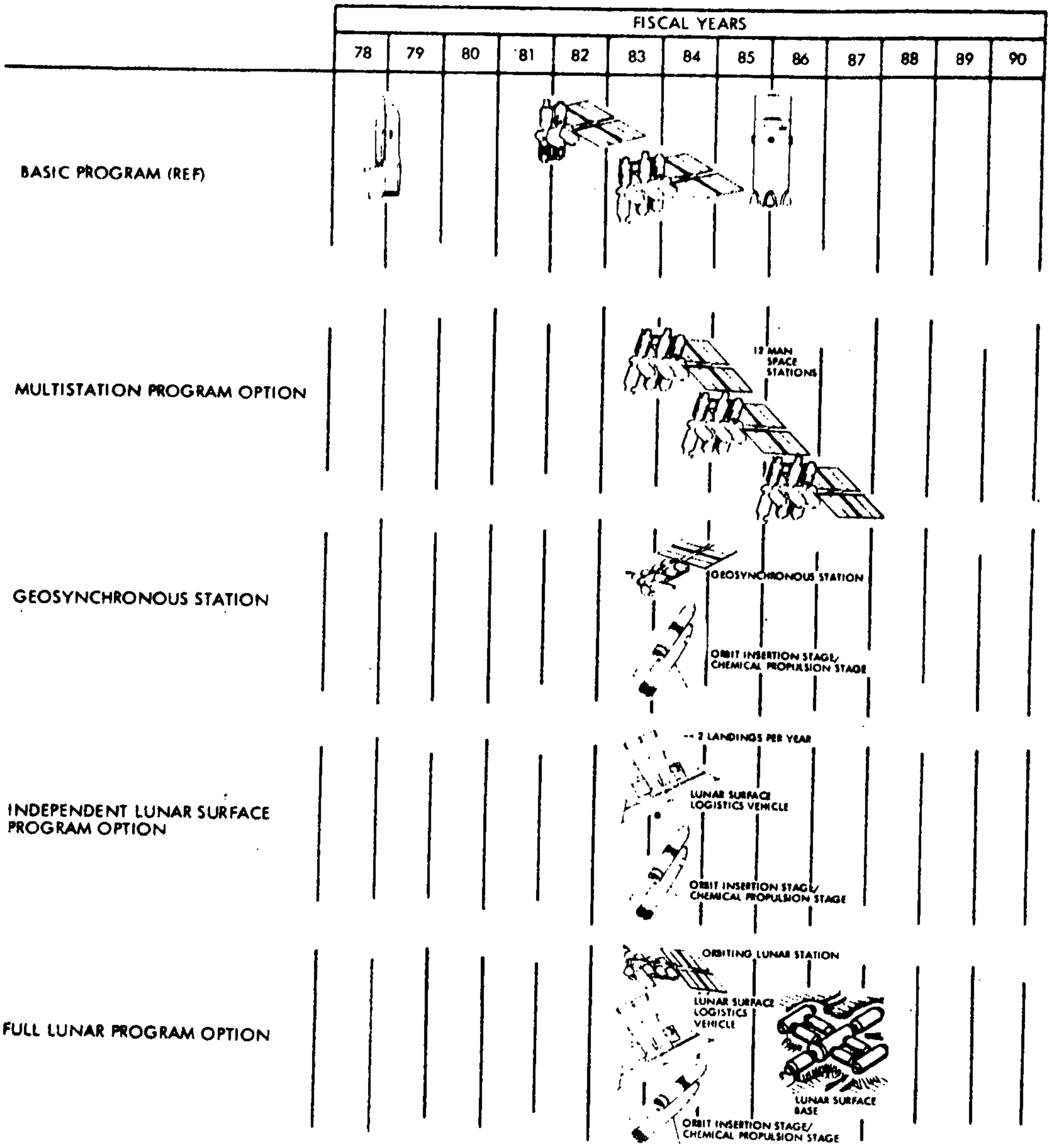

Figure 3.2-1. Time Phasing of Add-On Options

This section shows the characteristics of potential new hardware to be added to the NASA inventory if the four add-on programs are flown. They include:

1. The chemical propulsion stage - required for add-on options 2, 3, and 4.

2. The reusable nuclear stage - an alternate to the CPS for add-on options 2, 3, and 4.

3. The orbiting lunar or geosynchronous space station - required for add-on options 2 or 4.

4. The lunar surface logistics vehicle (tug derivative) - required for add-on options 3 or 4.

5. The lunar surface base - required for add-on option 4.

3.2.1 CHEMICAL PROPULSION STAGE

The CPS, mated with the earth-to-orbit shuttle booster, serves as a launch vehicle capable of inserting heavy payloads into low earth orbit (150,000 to 200,000).

Once in orbit, the CPS can be refueled (using EOS tankers) and employed for a variety of orbit-to-orbit functions. This stage is assumed to be reusable for approximately 20 missions.

Options shown in this guide assume use of the CPS for deep space, high-energy automated missions, as an orbit-to-orbit shuttle for future manned or automated lunar missions, and as a delivery and resupply vehicle for manned geosynchronous missions.

The vehicle may be used as a single stage vehicle or in tandem operations. Typical configurations and data are shown in Figures 3.2-2, 3.2-3 and 3.2-4. Figure 3.2-2 depicts a possible configuration showing the orbit insertion stage capability. Figure 3.2-3 illustrates the orbit-to-orbit stage configuration. The design characteristics of the stage are listed in Figure 3.2-4.

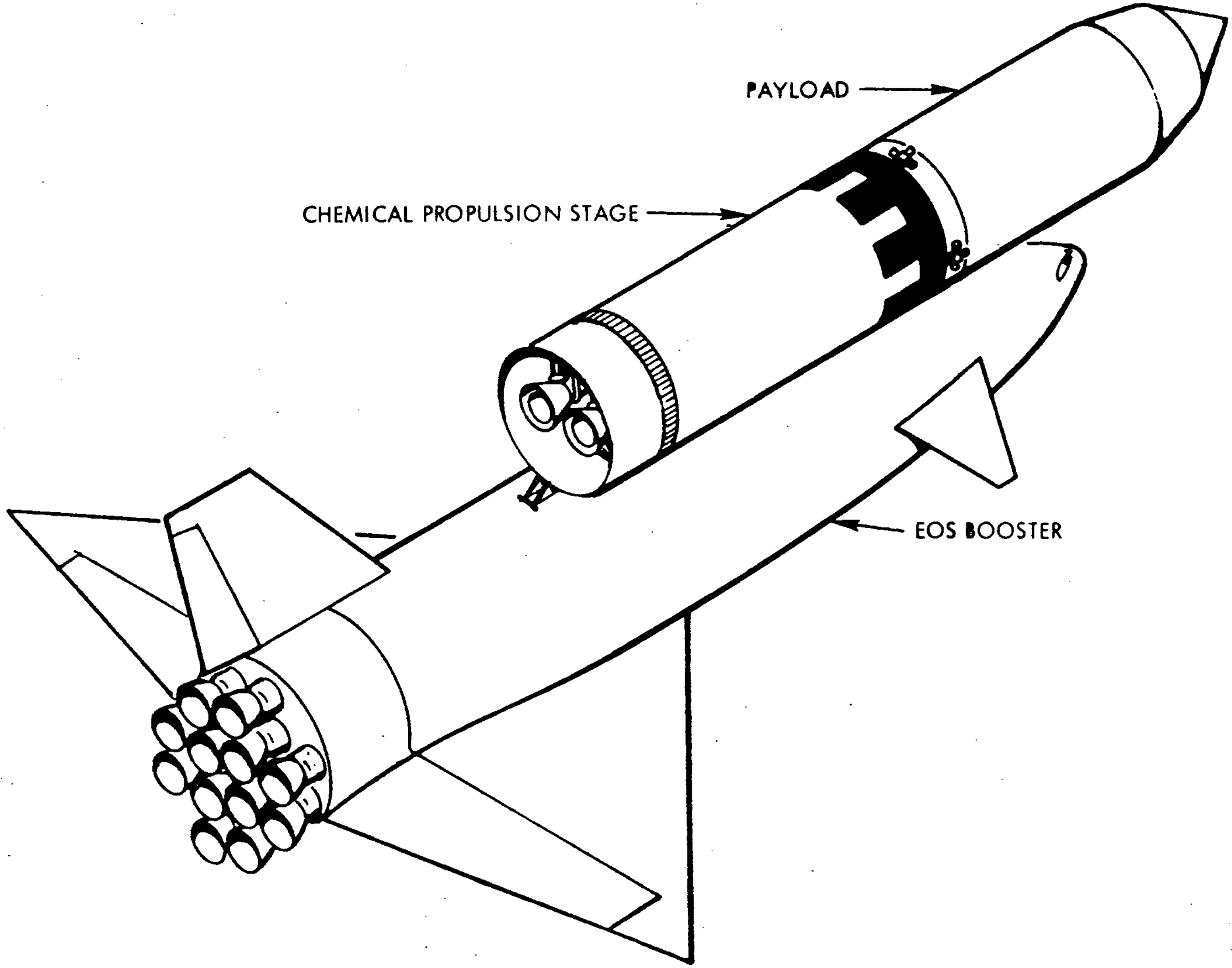

Figure 3.2-2. Chemical Propulsion Stage - Orbit Insertion Stage Application

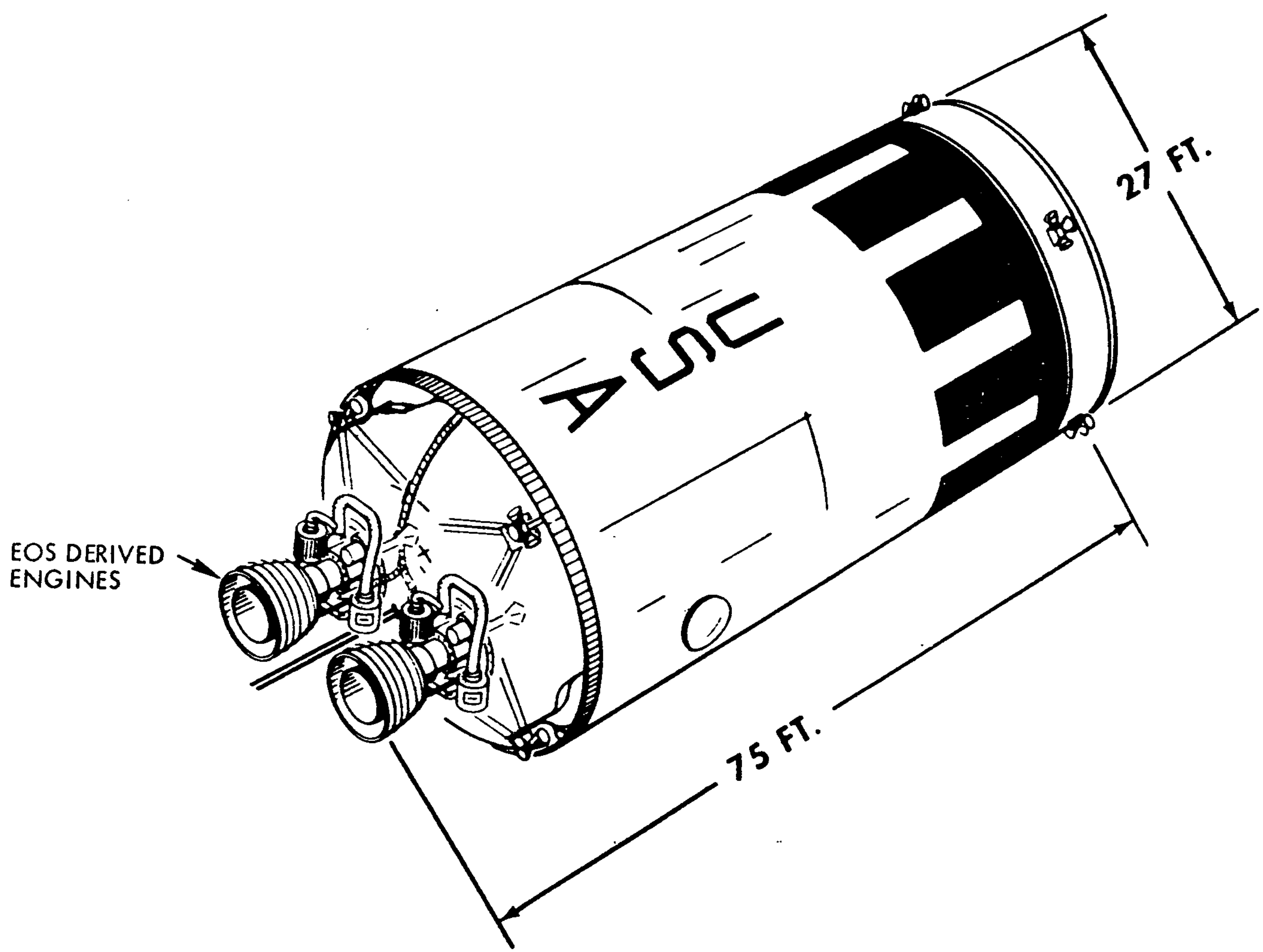

Figure 3.2-3. Chemical Propulsion Stage Configuration

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- WEIGHT STATEMENT

STAGE INERT	60,000 LBS
PROPELLANT	540,000 LBS

- DEVELOPMENT TIME

  4.5 YEARS FROM START OF PHASE C

- PERFORMANCE

- PROPULSION CHARACTERISTICS

ENGINE TYPE	EOS DERIVED
THRUST (EACH)	480,000 LBS
ISP	460 SEC
MASS FRACTION	0.9
FUEL	LH_2
OXIDIZER	LO_2
MIXTURE	6:1

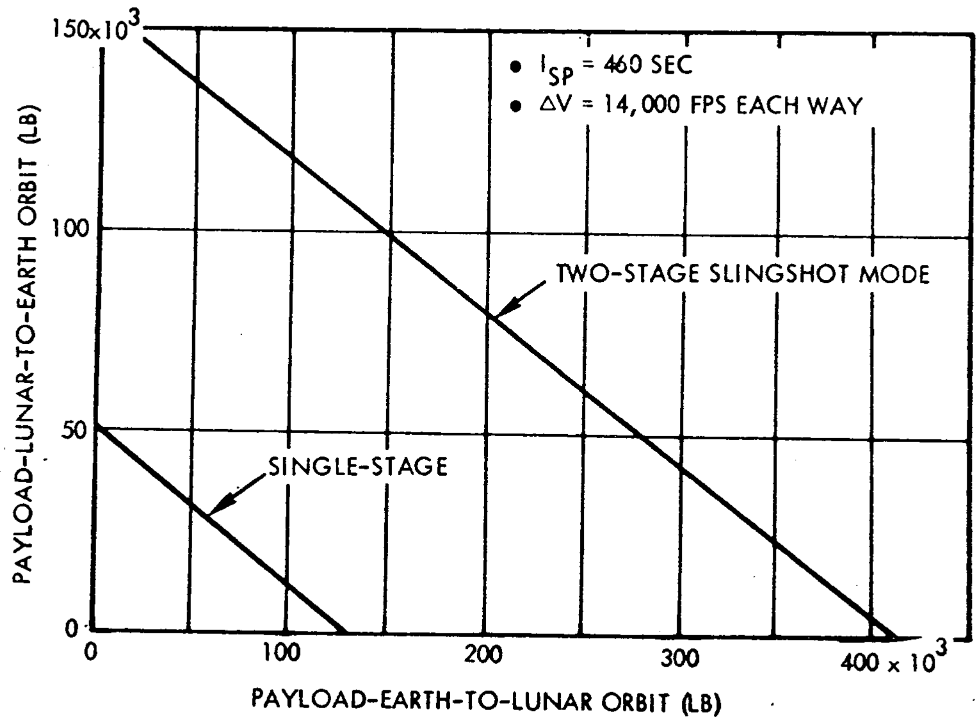

Figure 3.2-4. Chemical Propulsion Stage Characteristics

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3.2.2 NUCLEAR STAGE

The nuclear stage is an alternate to the CPS for all applications except that of payload delivery to low earth orbit.

The nuclear stage is conceptually made up of a propulsion module, propellant module(s), and a command and control module. The propulsion module consists of a NERVA engine and a small propellant (run) tank, and is sized for launch in the EOS orbiter bay. The propellant module(s), along with the run tank, provide a propellant capacity of about 300,000 pounds of liquid hydrogen (LH_2).

Two propellant module configurations are possible; a singular version sized for launch on the EOS/CPS launch vehicle, and a modular version sized for launch in the EOS orbiter bay. These alternative configurations are illustrated in Figure 3.2-5.

The command and control module fulfills all RCS, intelligence, and payload docking functions. It is sized for launch in the EOS orbiter bay and conceptually can either be replenished in earth orbit after each mission or the entire unit can be recycled to the ground with each payload.

Additional vehicle and performance data for the nuclear stage are provided in Figure 3.2-6.

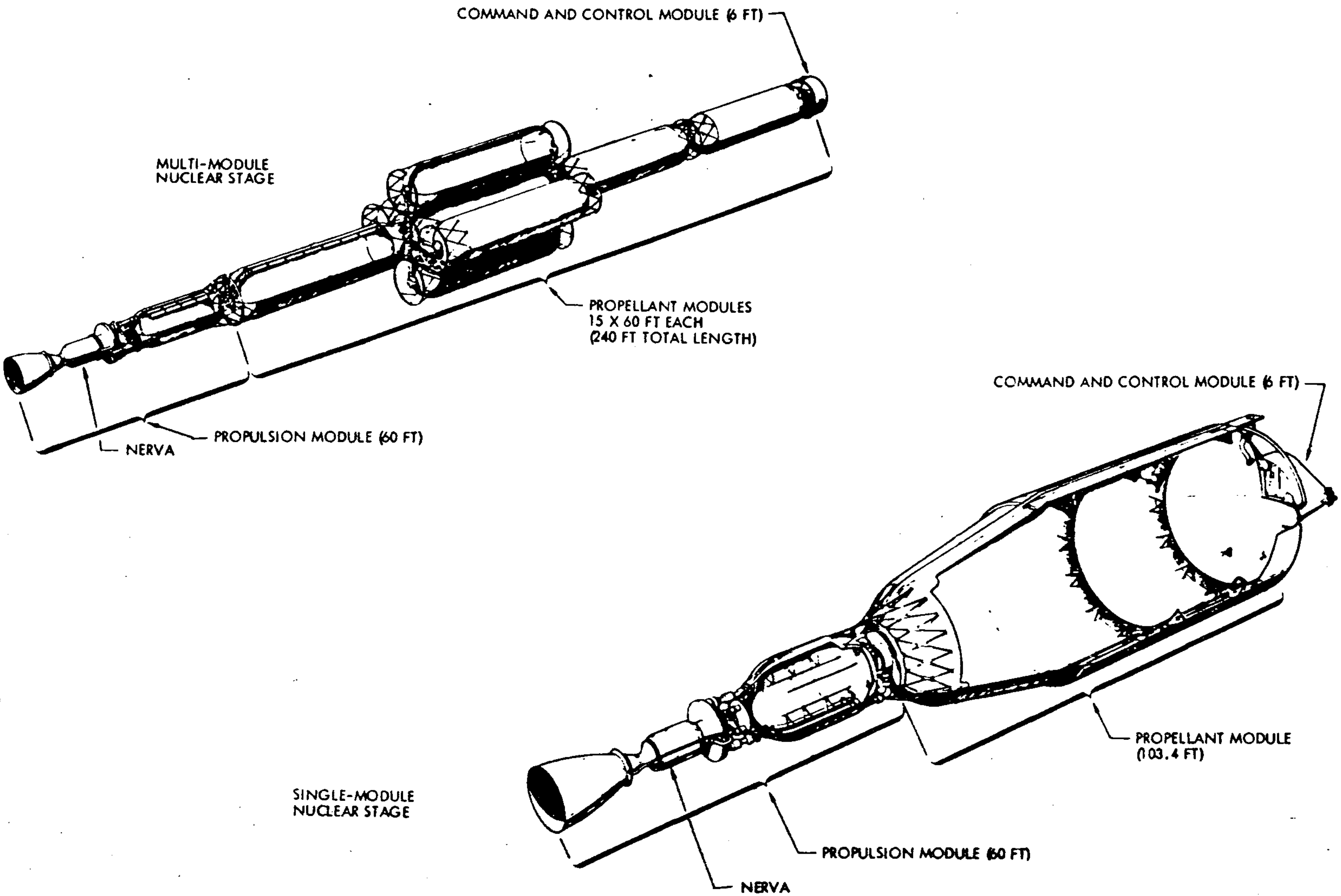

Figure 3.2-5. Reusable Nuclear Stage Configuration

- WEIGHT STATEMENT

ITEM	WEIGHT (LBS) SINGLE-MODULE	MULTI-MODULE
STAGE INERT	78,715	89,170
USABLE PROPELLANT	292,582	300,218

- PROPULSION CHARACTERISTICS

THRUST	75,000 LBS
I_{SP}	
DESIGN POINT	825 SEC
EFFECTIVE	790 SEC
MASS FRACTION	
SINGLE-MODULE	.788
MULTI-MODULE	.771
PROPELLANT	LH_2

- DEVELOPMENT TIME (STAGE ONLY)

  5 YEARS FROM START OF PHASE C

- PERFORMANCE

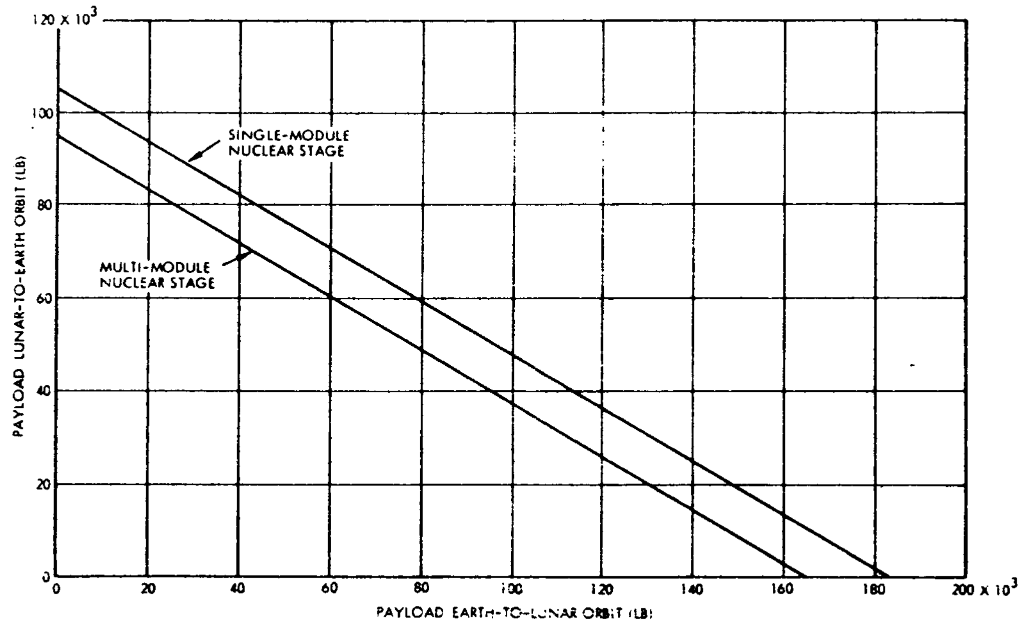

Figure 3.2-6. Reusable Nuclear Stage Characteristics

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3.2.3 ORBITING LUNAR STATION

Among the alternatives for add-on options, use of space station technology to extend manned exploration of the solar systems appears to be attractive. One of the locations to be considered is lunar orbit. The immediate apparent scientific return from an orbiting lunar station is relatively low, but the station serves a valuable purpose in the transportation chain for lunar surface exploration, whether by small expeditions or by operations from a fixed lunar surface base.

Two leading space station configurations that are adaptable to lunar orbit are depicted in Figures 3.2-7 and 3.2-8. Figure 3.2-7 shows the baseline station, derived from the basic earth orbiting configuration and the transportation capability of the OIS/CPS. Figure 3.2-8 shows a modular counterpart, derived from the EOS-launched (modular) space station which was an element of the basic program.

It is likely that the configuration of an orbiting lunar station will be based upon other elements of the overall program. For example, if the modular configuration is selected for the earth observation stations, development cost considerations may dictate selection of a modular approach for all other station-type programs. On the other hand, an integral station, similar to the baseline design, may prove to be a valuable precursor to other long-duration spacecraft missions.

The configurations shown here are designed to accommodate a crew of eight men. Early studies have shown that six crewmen will be occupied with the scientific experiments and observations. Two additional crewmen are provided to assist the with deployment and operation of landing parties.

A comparison of some of the basic characteristics of the two designs is made in Table 3.2-1.

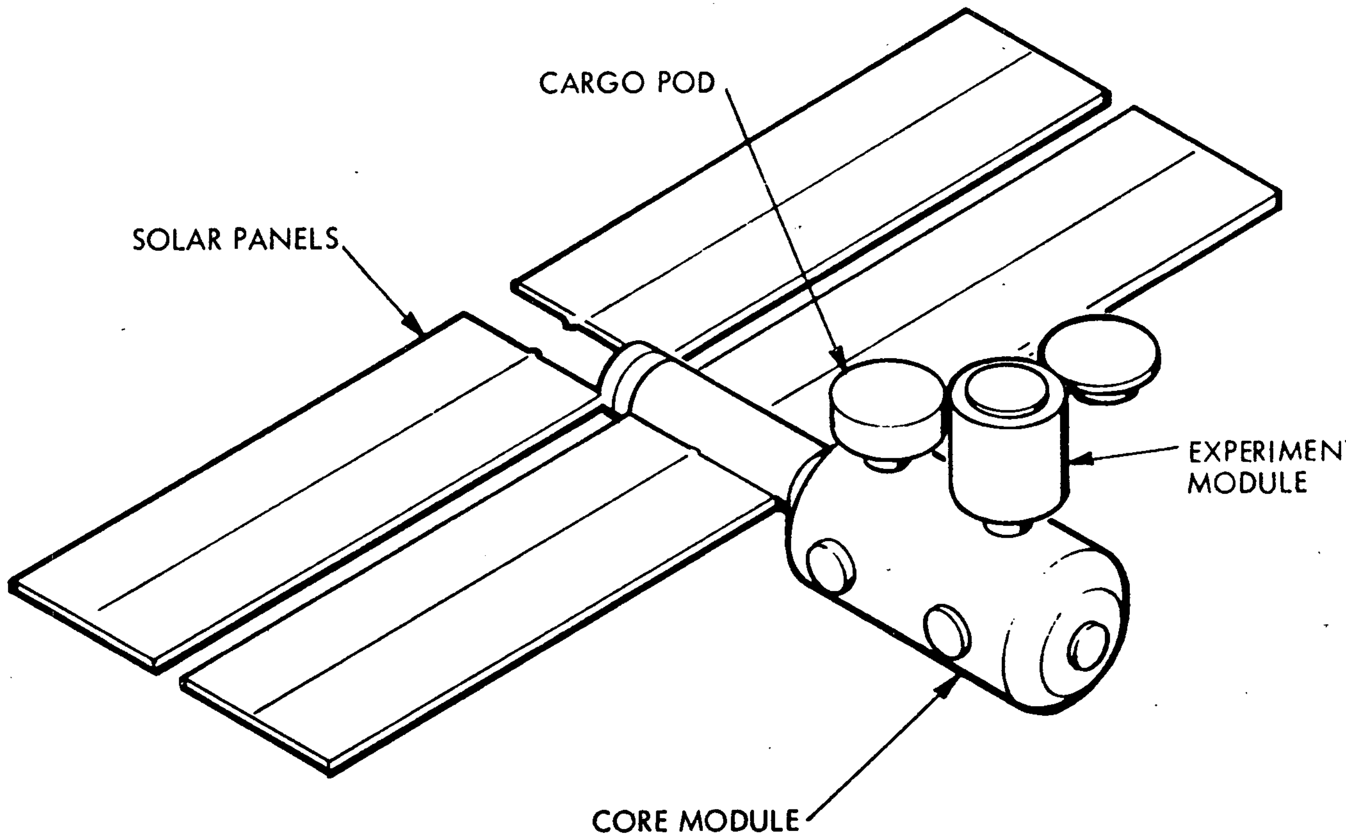

Figure 3.2-7. Baseline Orbiting Lunar Station

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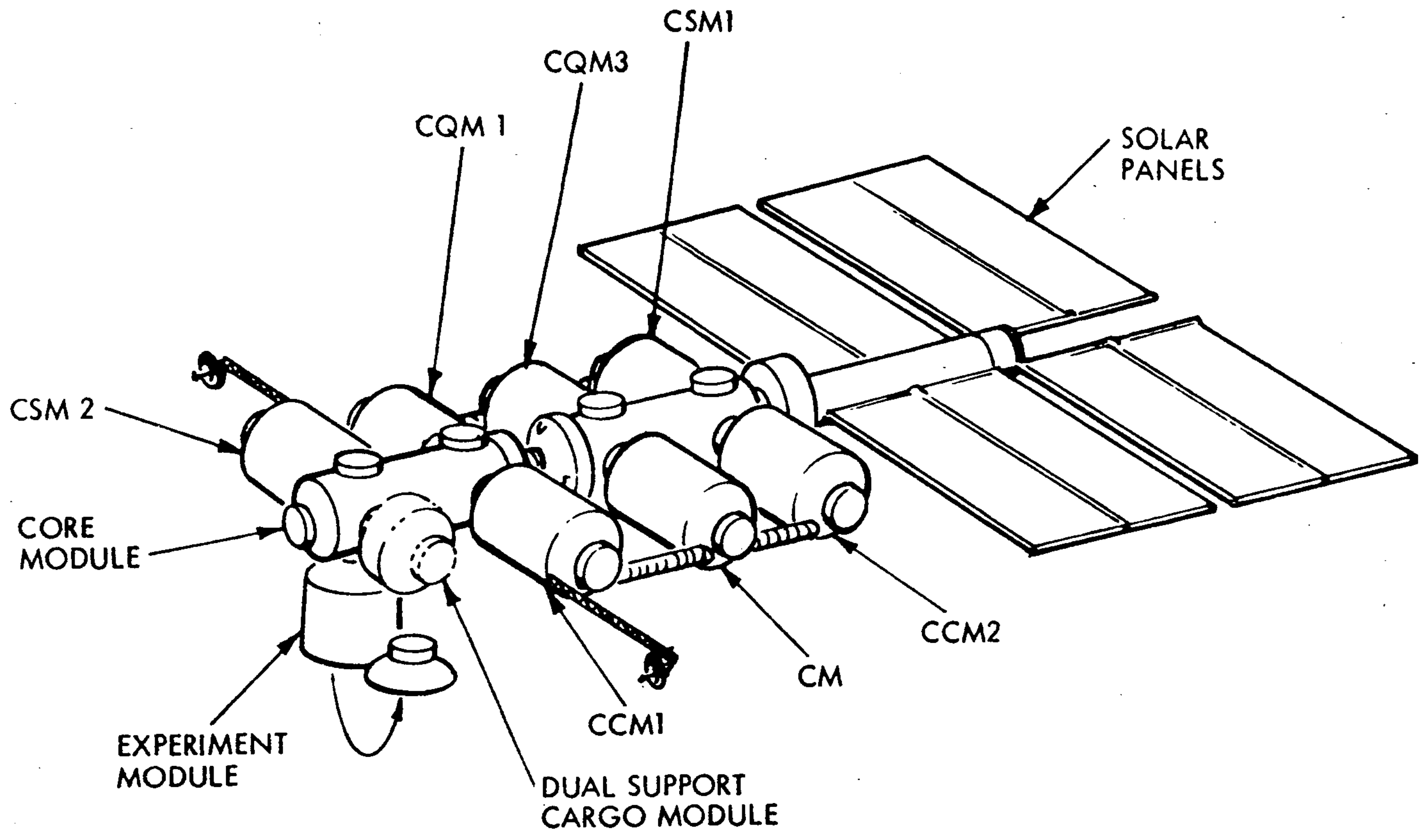

Figure 3.2-8. Earth Orbit Space Station Derivative Orbiting Lunar Station

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Table 3.2-1. Orbiting Lunar Station - Characteristics

- WEIGHT STATEMENT

BASELINE OLS

ITEM	WEIGHT (LBS)
CORE MODULE	85,155
POWER MODULE	11,300
EXPERIMENT MODULE	11,000
TOTAL DRY WEIGHT	107,455
INERT FLUIDS	21,900
TOTAL INERT WEIGHT	129,355
CONSUMABLES	26,650
CREW (8)	1,600
TOTAL OLS WEIGHT	157,605

EARTH ORBIT SPACE STATION DERIVATIVE

ITEM*	WEIGHT (LBS)
CORE MODULE 1A	31,580
CORE MODULE 1B	25,120
POWER MODULE (PM)	24,250
CRYO MODULE (CSM 1)	9,660
CRYO MODULE (CSM 2)	26,100
CONTROL CENTER MODULE (CCM 1)	36,600
CONTROL CENTER MODULE (CCM 2)	12,490
CREW QUARTERS MODULE (CQM 1)	15,160
CREW QUARTERS MODULE (CQM 3)	12,750
GALLEY MODULE (GM)	15,710
EXPERIMENT MODULE	11,000
CREW (8)	1,600
TOTAL OLS WEIGHT	222,020

*INCLUDES CONSUMABLES

- CAPABILITY
  - 8 MAN
  - 20 KW
  - ZERO-G

- DEVELOPMENT TIME
  - 5 YEARS FROM START OF PHASE C

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3.2.4 GEOSYNCHRONOUS SPACE STATION

Preliminary studies have shown that a geosynchronous space station could be supported with approximately the same resources required for the orbiting lunar station. An earth-fixed orbital location may prove useful for earth surveillance or communications support activities.

The configurations and characteristics for the modular earth orbit space station (previously described) and for the orbiting lunar station appear well-suited to the geosynchronous station. A six-man crew presumably can handle the work load, since no landing missions are supported from the station.

3.2.5 LUNAR SURFACE LOGISTICS VEHICLE

The lunar surface logistics vehicle is a derivative of the reusable space tug. The crew module and cargo module are located aft near the surface at lunar landing as shown in Figure 3.2-9. This provides better visibility, better surface access, a low center of gravity, and lower design structural loadings. The engines are extended outboard to accommodate the aft crew module location. The engines are retracted for launch by the EOS. Deployment of the engines and assembly of the crew module, cargo modules, and landing gear to the propulsion module is performed in earth orbit. More detailed characteristics of the lunar surface logistics vehicle are provided in Table 3.2-2.

3.2.6 LUNAR SURFACE BASE

The lunar surface base (LSB) will probably be an adaptation of the space stations employed earlier in the program. If the space stations previously in use are modular, the lunar surface base may be modular. An integral design for the space stations may dictate similar design constraints for the LSB.

Establishing a lunar surface base will require commitment of substantially greater resources to the space program. It requires the longest and most complex logistics lines of any of the programs being considered.

Radiation and meteorite protection as well as thermal stability questions pose difficult problems for the lunar surface base designer. One concept, illustrated in Figure 3.2-10, provides this protection by banking lunar soil over the modules of the LSB.

The postulated purposes of the LSB concept shown here are to support a lunar observatory, deep drilling operations, and remote surface exploration sorties. For this concept, four men each are required to support the observatory and exploration functions, and two men are required for the deep-drilling operation. The base is sized to support 12 men and includes two drive-in garage/warehouse modules. The surface vehicles are required to support a maximum surface sortie duration of 90 days.

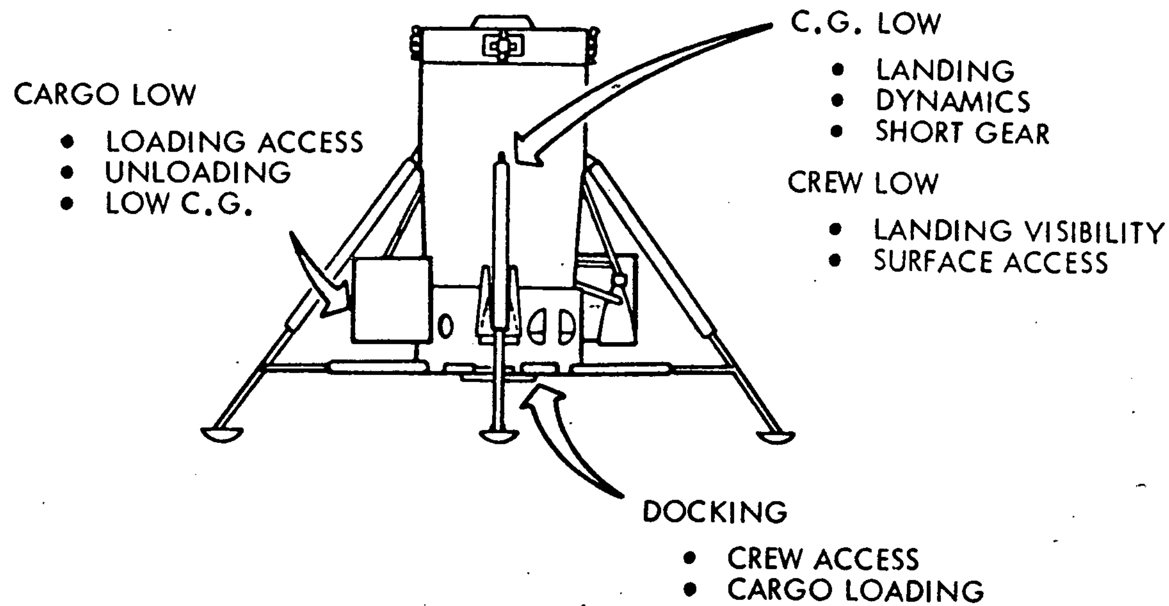

Figure 3.2-9. Lunar Surface Logistics Vehicle - Configuration

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Table 3.2-2. Lunar Surface Logistics Vehicle - Characteristics

- WEIGHT STATEMENT - LUNAR LANDING CONFIGURATION

ITEM		WEIGHT (LB)
PROPULSION MODULE		
INERT WEIGHT	7,710	
PROPELLANT	64,360	
GROSS		72,070
INTELLIGENCE MODULE		4,350
PAYLOAD (ROUND TRIP)		10,000
CREW MODULE		9,500
LUNAR LANDING GEAR		3,200
		99,120

- PERFORMANCE

ENGINE TYPE - RL10A-3-8A	SPECIFIC IMPULSE - 461/450 SEC
NUMBER OF ENGINES - 4	MAX THRUST (EACH) - 23,400 LB
NOZZLE TYPE - 2 POSITION	FUEL - LH_2
AREA RATIO - 250/100	OXIDIZER - LO_2
CREW SIZE - 4 MEN	SURFACE DURATION - 28 DAYS

- DEVELOPMENT TIME

5 YEARS FROM START OF PHASE C

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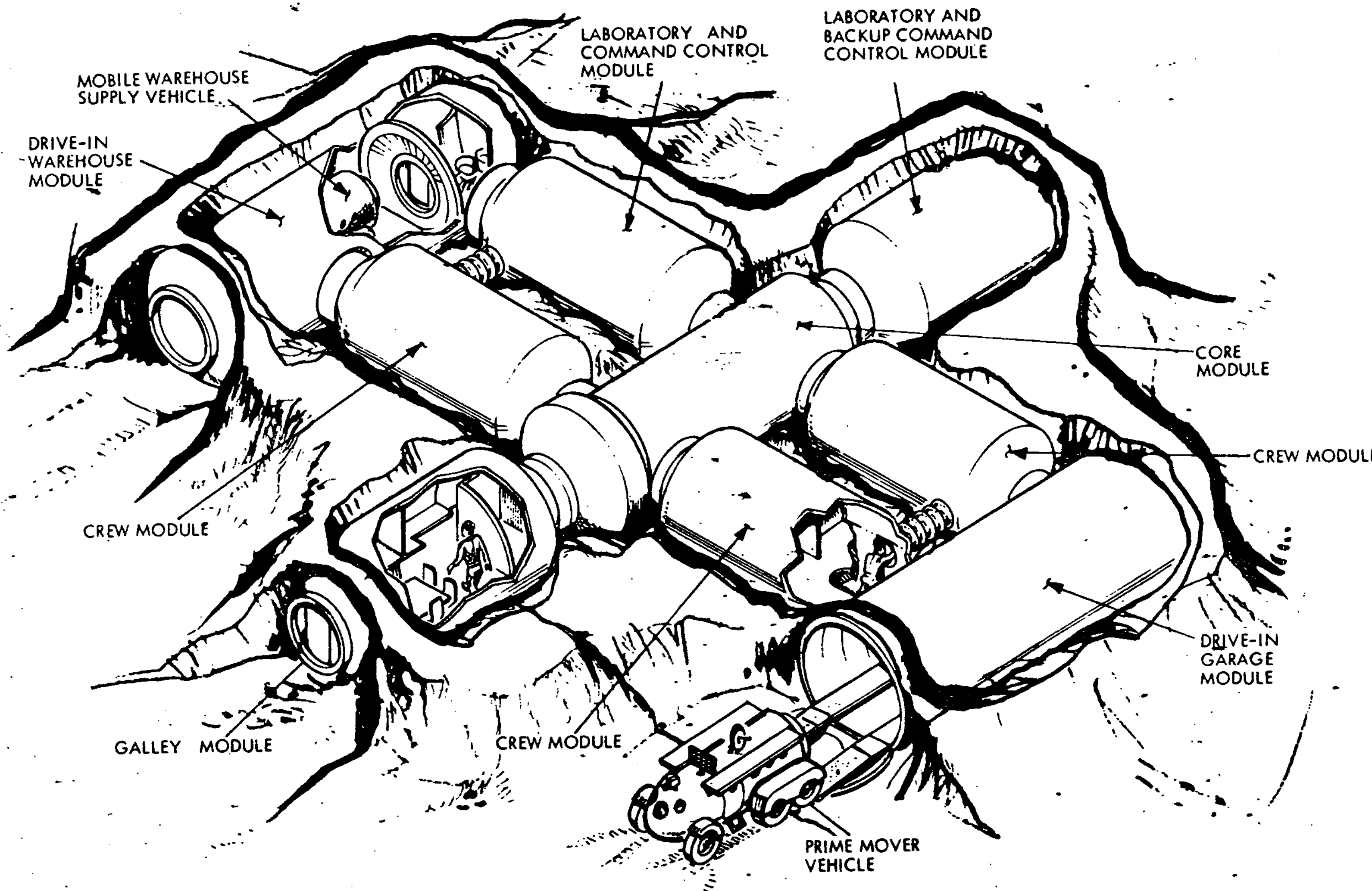

Figure 3.2-10. Lunar Surface Base

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