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Space Shuttle Program

MSC-03321

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Phase B Final Report
Expendable Second Stage
Reusable Space Shuttle Booster
Volume VI. Interface Control Drawings

Contract NAS9-10960, Exhibit B
DRL MSFC-DRL-221, DRL Line Item 6
DRD MA-078-U2
SD 71-140-6
25 June 1971

Space Division • North American Rockwell 12214 Lakewood Boulevard, Downey, California 90241

SD 71-140-6
(MSC-03321)

25 June 1971

PHASE B FINAL REPORT
EXPENDABLE SECOND STAGE
REUSABLE SPACE SHUTTLE BOOSTER

Volume VI
Interface Control Drawings

Contract NAS9-10960, Exhibit B
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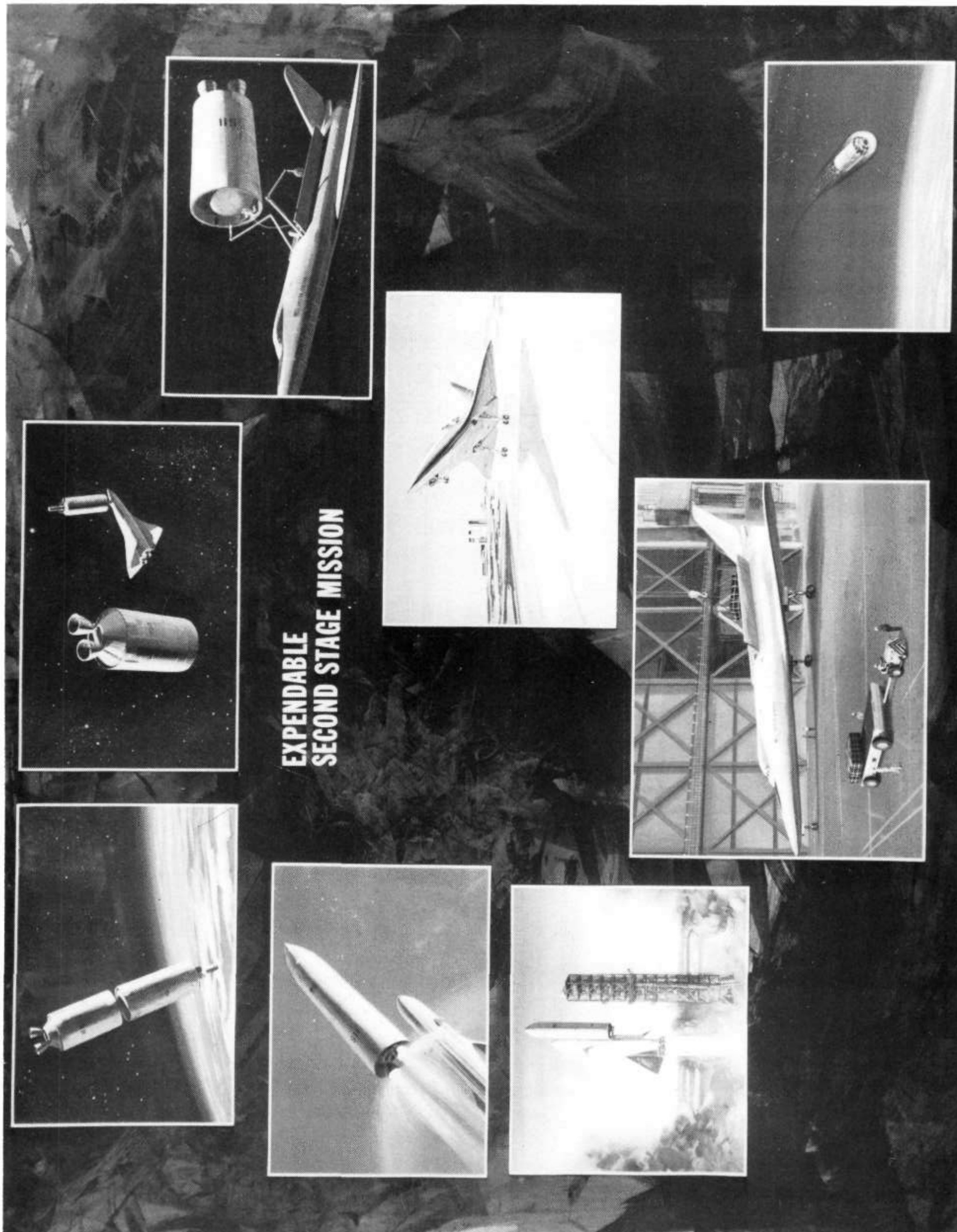
Approved by

B. Hello
Vice President and General Manager
Space Shuttle Program

Space Division • North American Rockwell 12214 LAKEWOOD BOULEVARD • DOWNEY, CALIFORNIA 90241


EXPENDABLE
SECOND STAGE MISSION

FOREWORD

The Space Shuttle Phase B studies are directed toward the definition of an economical space transportation system. In addition to the missions which can be satisfied with the shuttle payload capability, the National Aeronautics and Space Administration has missions planned that require space vehicles to place payloads in excess of 100,000 pounds in earth orbit. To satisfy this requirement, a cost-effective multimission space shuttle system with large lift capability is needed. Such a system would utilize a reusable shuttle booster and an expendable second stage. The expendable second stage would be complementary to the space shuttle system and impose minimum impact on the reusable booster.

To assist the expendable second stage concept, a two-phase study was authorized by NASA. Phase A efforts, which ended in December 1970, concentrated on performance, configuration, and basic aerodynamic considerations. Basic trade studies were carried out on a relatively large number of configurations. At the conclusion of Phase A, the contractor proposed a single configuration. Phase B commenced on February 1, 1971 (per Technical Directive Number 503) based on the recommended system. Whereas a large number of payload configurations were considered in the initial phase. Phase B was begun with specific emphasis placed on three representative payload configurations. The entire Phase B activity has been directed toward handling the three representative payload configurations in the most acceptable manner. Results of this activity are reported in this 12-volume Phase B final report.

Volume I	Executive Summary	SD 71-140-1
Volume II	Technical Summary	SD 71-140-2
Volume III	Wind Tunnel Test Data	SD 71-140-3
Volume IV	Detail Mass Properties Data	SD 71-140-4
Volume V	Operations and Resources	SD 71-140-5
Volume VI	Interface Control Drawings	SD 71-140-6
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Volume VIII	Preliminary CEI Specification - Part 1	SD 71-140-8
Volume IX	Preliminary System Specification	SD 71-140-9
Volume X	Technology Requirements	SD 71-140-10
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This document is Volume VI, Interface Control Drawings.

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ILLUSTRATIONS

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1.0 INTRODUCTION

The intent of this document is to define the major Expendable Second Stage (ESS) interfaces that must be controlled in the development of the ESS. The Interface Control Drawings (ICD's) in this volume are contained in the following appendixes:

A - Booster/Expendable Second Stage (ESS)(S080-1001)

B - Space Shuttle Engine (SSE)/Expendable Second Stage (S080-1002)

C - ESS/GSE (S080-1003)

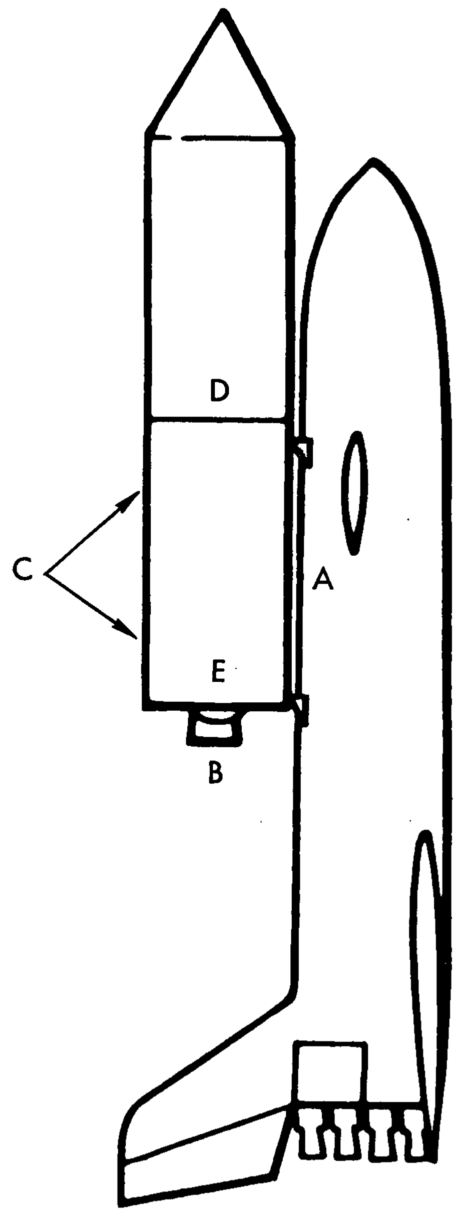
D - ESS/Payload (S080-1004)

E - Orbiter/ESS (S080-1005)

2.0 INTERFACE CONTROL DOCUMENTATION REQUIREMENTS

Data Requirement Description (DRD) SE-002M dated 22 May 1970 establishes the requirements for the preparation and submittal of the ESS Study Interface Control Documentation including the stringent microfilm requirements of NB1440.4A. The documentation consists of physical, functional, and procedural ICD's. At the conclusion of the Phase B Study, very few physical interface requirements have been determined; therefore, only in a gross sense can these items be documented. The intent of this document is to encompass the full scope of interfaces which must be controlled in development of the Expendable Second Stage system. Since ICD's must normally be negotiated by the interested parties, any ICD's prepared during Phase B can only be considered as criteria recommended to the development contractor for use during Phase C-D.

During the preparation of the ESS ICD's, the format and philosophy of the Saturn V vehicle was followed. Each of the ICD's is divided into functional (electrical, mechanical), physical, and procedural sections. Figure 1 graphically identifies the major interfaces to be controlled.



A. SSB/ESS

B. SPACE SHUTTLE ENGINE/ESS

C. ESS/GSE

D. ESS/PAYLOAD

E. SPACE SHUTTLE ORBITER/ESS

Figure 1. Expendable Second Stage Interface

3.0 PREPARATION OF INTERFACE CONTROL DOCUMENTATION

Interface identification and definition starts with the ESS vehicle system specification and the interface requirements specified herein. The top-level Schematic Block Diagram (SBD) shown in Figure 2, which is also a part of the System Specification, graphically identifies and grossly defines the main interfaces to be controlled.

At this time, ICD's are being identified between a particular vehicle element and items of support. Although it should be noted that, for items of support equipment peculiar to a particular vehicle element, control of the interface may be internal to the contractor and not the subject of an external ICD.

For the ICD's included in this document, the approach was to structure each so as to allow growth into an ICD suitable for Phase C-D negotiation. Data believed necessary to control the interface has been identified and described even if it is not available now and can only be identified as "TBD." The following considerations were kept in mind during ICD preparation:

(a) The ICD is a legal document, equivalent to a contract, which binds two or more parties to satisfy explicitly stated requirements. It shall be considered and negotiated as a contract.

(b) The ICD is to be incorporated in each specification controlling vehicle elements meeting at an interface.

(c) Define the interface, not the equipment/software items which interface; viz., include only the requirements/criteria necessary to define and control the interface.

The ESS Preliminary CEI Specification, CP613M0003 contains references to these defined requirements.

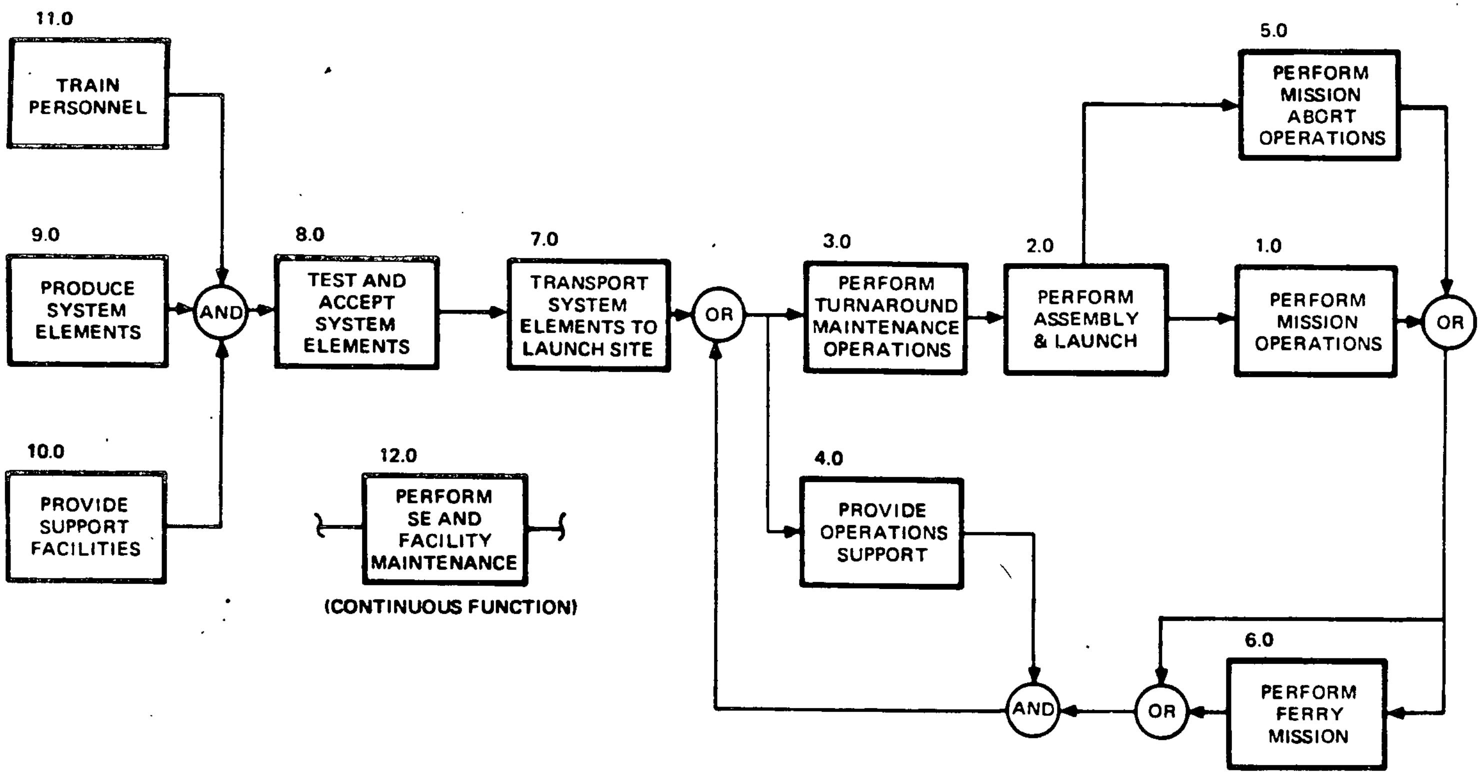


Figure 2. Top Level Functional Flow Diagram

VOLUME 6
APPENDIX A

SPACE SHUTTLE BOOSTER (B-9U) EXPENDABLE SECOND STAGE (ESS) INTERFACE REQUIREMENTS

S080-1001

SPACE DIVISION

NORTH AMERICAN ROCKWELL CORPORATION

SPACE SHUTTLE BOOSTER/ESS INTERFACE REQUIREMENTS
INTERFACE CONTROL DRAWING

CONTENTS

1.0 SCOPE

This document specifies the functional, physical and procedural interface of the B-9U Space Shuttle Booster/Expendable Second Stage (ESS). It defines the requirements and criteria to be observed in the design of interfacing equipment.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATION

(a) Specification No. SS613M001, Addendum (TBD), System Specification for a Space Shuttle System

(b) Specification No. 76Z0500, Addendum I, Booster Vehicle Prime Item Part I

(c) CP613M0003, Expendable Second Stage, Preliminary CEI Part I Specification

2.2 INTERFACE CONTROL DOCUMENTS/DRAWINGS

TBD

2.3 MANUALS AND HANDBOOKS

TBD

2.4 DRAWINGS

TBD

3.0 ABBREVIATIONS AND SYMBOLS

CSM	Command Service Module
ESS	Expendable Second Stage
ICD	Interface Control Document/Drawing
TBD	To Be Determined
SSB	Space Shuttle Booster
VAB	Vertical Assembly Building
LUT	Launch Umbilical Tower

4.0 FUNCTIONAL REQUIREMENTS

4.1 FLUID REQUIREMENTS

None

4.2 STRUCTURAL REQUIREMENTS

4.2.1 Structural Loads

The ESS shall be supported by the SSB by means of the separation linkage. The SSB/ESS interface structure shall be designed to withstand the load conditions shown in Figures A-1, A-2, and A-3 and the separation link loads as shown in Figures A-4 and A-5.

4.2.2 Factor of Safety

The ESS shall be designed to a factor of safety of 1.4 for ultimate and 1.1 for yield.

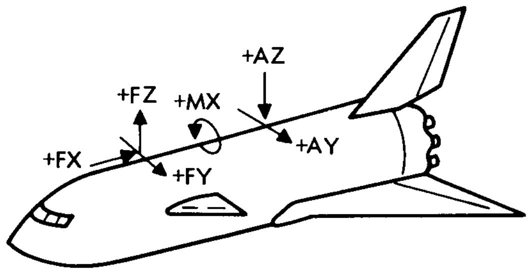
4.3 ELECTRICAL REQUIREMENTS

4.3.1 Connector Definition

The electrical interface of the Booster/ESS shall consist of 2 TBD pin connectors. The definition and function of each interface connector are presented in following paragraphs:

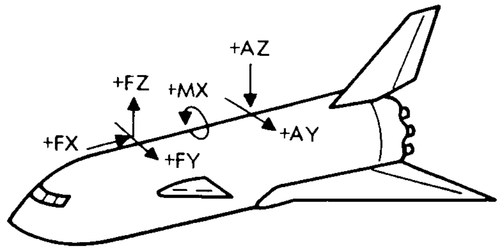
1. Booster/ESS Interface Connector No. 1 -
   The purpose of this connector is to provide a path for the Booster crew to monitor critical ESS functions during the mated ascent phase and, if necessary, initiate the separation phase for abort purposes. The connector also provides the capability to update the ESS navigation equipment prior to Booster/ESS separation.

2. Booster/ESS Interface Connector No. 2 -
   The purpose of this connector is to provide a redundant path for Connector No. 1.



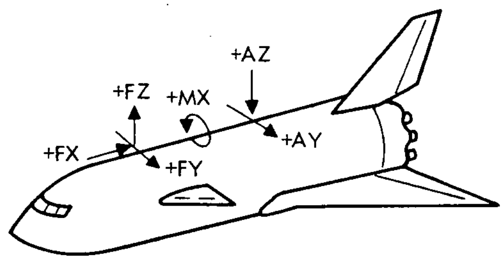
CONDITION	WIND	Fx (x 10^3 lb)	Fy (x 10^3 lb)	Fz (x 10^3 lb)	Ay (x 10^3 lb)	Az (x 10^3 lb)	Mx (10^6 in/lb)
TWO WEEK GROUND WINDS UNFUELED	HEAD TAIL SIDE	276 276 276	 ±354	244 -286 68.8	 ∓92.0	165 -15.6 76.4	 ∓59.0
1 HOUR GROUND WINDS FUELED UNPRESSURIZED	HEAD TAIL SIDE	991 991 991	 ±97.4	293 148 245	 ∓25.3	297 247 272	 ∓15.44
DYNAMIC LIFT OFF + 1 HOUR GROUND WINDS	HEAD TAIL SIDE	1397 1397 1397	 ±79.5	372 251 336	 ∓39.6	426 356 391	 ∓8.86
MAX. α-q	HEAD TAIL	2055 1964		508 203		744 255	
MAX. β-q	SIDE	1806	±223	320	∓158.0	399	∓15.5
2.06g MAX. THRUST	-	2239		486		669	
BOOSTER BURNOUT	-	2217		377		746	

Figure A-1. ESS/Booster MDAC Stage (Limit Loads)



CONDITION	WIND	Fx (x 10^3 lb)	Fy (x 10^3 lb)	Fz (x 10^3 lb)	Ay (x 10^3 lb)	Az (x 10^3 lb)	Mx (10^6 in/lb)
TWO WEEK GROUND WINDS UNFUELED	HEAD TAIL SIDE	195 195 195	± 554	426 -495 48.7	∓230	289 -175 54.0	∓70.8
1 HOUR GROUND WINDS FUELED UNPRESSURIZED	HEAD TAIL SIDE	669 669 669	±149	270 16.7 166	∓63.1	249 121 185	∓18.9
DYNAMIC LIFT OFF + 1 HOUR GROUND WINDS	HEAD TAIL SIDE	946 946 945	±130	322 97.1 232	∓80.8	341 187 263	∓11.4
MAX. α-q	HEAD TAIL	1243 1237		409 -130		567 -124	
MAX. β-q	SIDE	1234	±247	161	∓182	237	∓13.3
2.5g MAX. THRUST	-	1818		405		544	
BOOSTER BURNOUT	-	1797		343		592	

Figure A-2. ESS/Booster Nuclear Stage (Limit Loads)



CONDITION	WIND	Fx (x 10^3 lb)	Fy (x 10^3 lb)	Fz (x 10^3 lb)	Ay (x 10^3 lb)	Az (x 10^3 lb)	Mx (10^6 in/lb)
TWO WEEK GROUND WINDS UNFUELED	HEAD TAIL SIDE	216 216 216	 ±161	96.7 -108.0 52.6	 ∓1.61	82.9 56.9 58.5	 ∓33.3
1 HOUR GROUND WINDS FUELED UNPRESSURIZED	HEAD TAIL SIDE	691 691 691	 ± 44.2	184 128 172	 ∓.443	197 190 191	 ∓9.17
DYNAMIC LIFT OFF + 1 HOUR GROUND WINDS	HEAD TAIL SIDE	975 974 974	 ±34.2	274 204 241	 ∓9.81	283 262 269	 ∓5.23
MAX. α-q	HEAD TAIL	1506 1422		366 249		511 308	
MAX. β-q	SIDE	1389	±125	302	∓38.8	393	∓18.65
2.47g MAX. THRUST	-	1874		423		556	
BOOSTER BURNOUT	-	1860		353		616	

Figure A-3. ESS/Booster - Space Tug (Limit Loads)

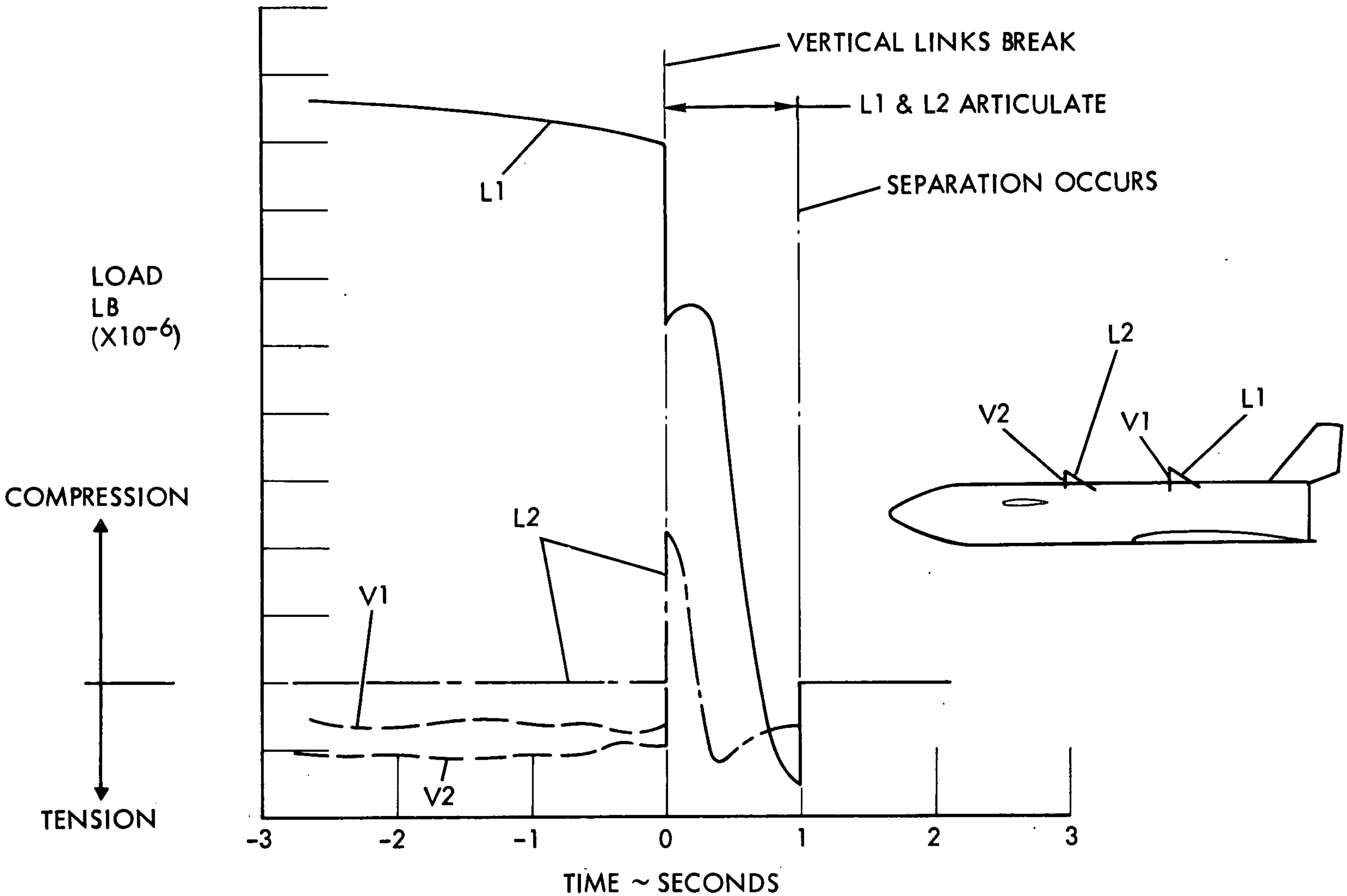


Figure A-4. Separation System Link Loads, ESS With RNS Payload
(One ESS Engine Operative)

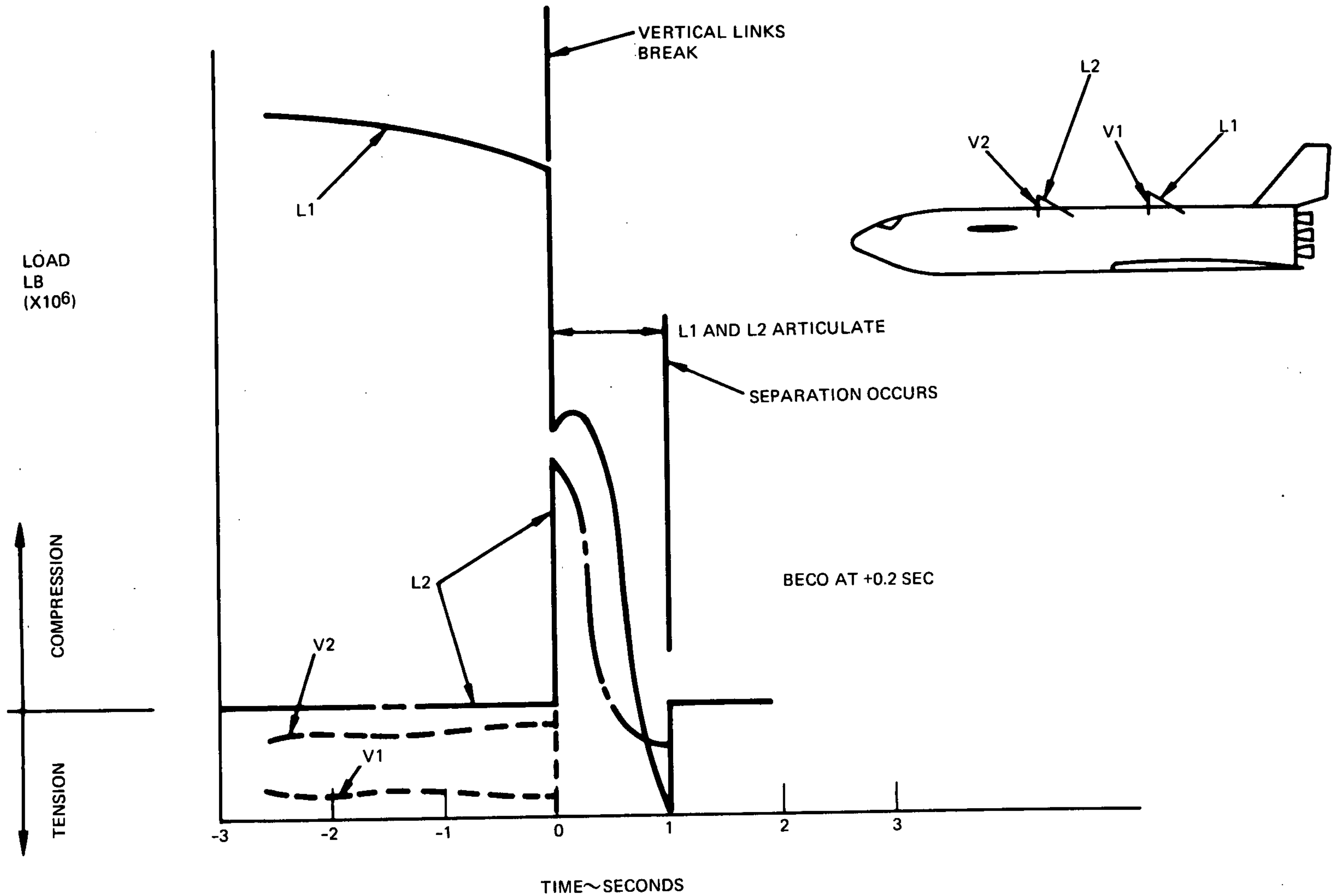


Figure A-5. Separation System Link Loads, Normal Staging of ESS With MDAC Space Station Payload

4.3.1.1 Detailed Characteristics

Characteristics of each interface connector should be defined in subsequent phases of the ESS study. These characteristics should include the following:

a. Connector Type

b. Pin Assignments

c. Signal Function (Command/Measurement)

d. Signal Characteristics (Analog/Discrete and Voltage)

e. Load/Waveforms

4.3.2 Confidence Loop

A circulating confidence loop shall be provided through all the connectors in series to provide an indication to the Booster or GSE that connectors are properly mated.

4.4 FLIGHT MECHANICS

4.4.1 Acceleration

Maximum axial acceleration of the mated SSB/ESS shall not exceed 3 g's.

4.4.2 Dynamic Pressure

Maximum dynamic pressure (q) shall not exceed 484 PSF. Maximum $q\alpha$ shall not exceed +1500 and -2900 PSF-degrees, including abort separation.

4.5 SEPARATION PARAMETERS

The separation of the SSB/ESS vehicle shall occur at the structural attachment interface upon command from the Space Shuttle Booster.

4.5.1 Separation System Performance

At the nominal separation point, the SSB shall be capable of releasing a fully-functioning ESS at a prearranged attitude (point vector) $\pm$ 2 degrees about all three body axes. The ESS body rates at release shall be (TBD) degrees/second in pitch and zero $\pm$ 2 degrees/second in yaw and roll. Under these nominal conditions, the minimum axial clearance between the ESS main engines and SSB hard structure shall not be less than 35 feet; the minimum clearance (between skinlines) shall not be less than the mated position.

At any point on the ascent trajectory, the SSB shall be capable of safely releasing a fully-functioning ESS within 5.0 seconds from a separation signal. The elapsed time from the separation signal to 1000 feet (vector-sum) clearance shall be within the envelope given in Figure A-6.

Under emergency conditions, the SSB shall be capable of safely releasing a non-thrusting ESS within 1.5 seconds and attaining zero thrust within 3.0 seconds of an emergency releasing signal.

4.5.2 Separation Design Criteria

a. The separation subsystem structural components shall be capable of withstanding all loads imposed during ground operations and mated flight.

b. The system shall provide safe separation during normal staging with one or two ESS engines operating and a maximum of two SSB engines inoperative.

c. Capability shall be provided for abort separation (two ESS engines inoperative) at normal staging points of the trajectories (SSB propellant depleted).

d. The mating/separation system mechanical/structural components shall have FO/FO capability. For purposes of interpreting the redundancy requirements, the primary load paths through the link, joints, pivots and bearings of the ESS interconnect structure and separation system are considered primary structure.

e. Operation of the separation system shall not produce any debris (including explosive residue) which could damage the SSB or ESS.

f. The separation system shall provide a redundant means of separation control from the SSB. Control shall depend upon monitored inputs from the ESS as well as from the SSB.

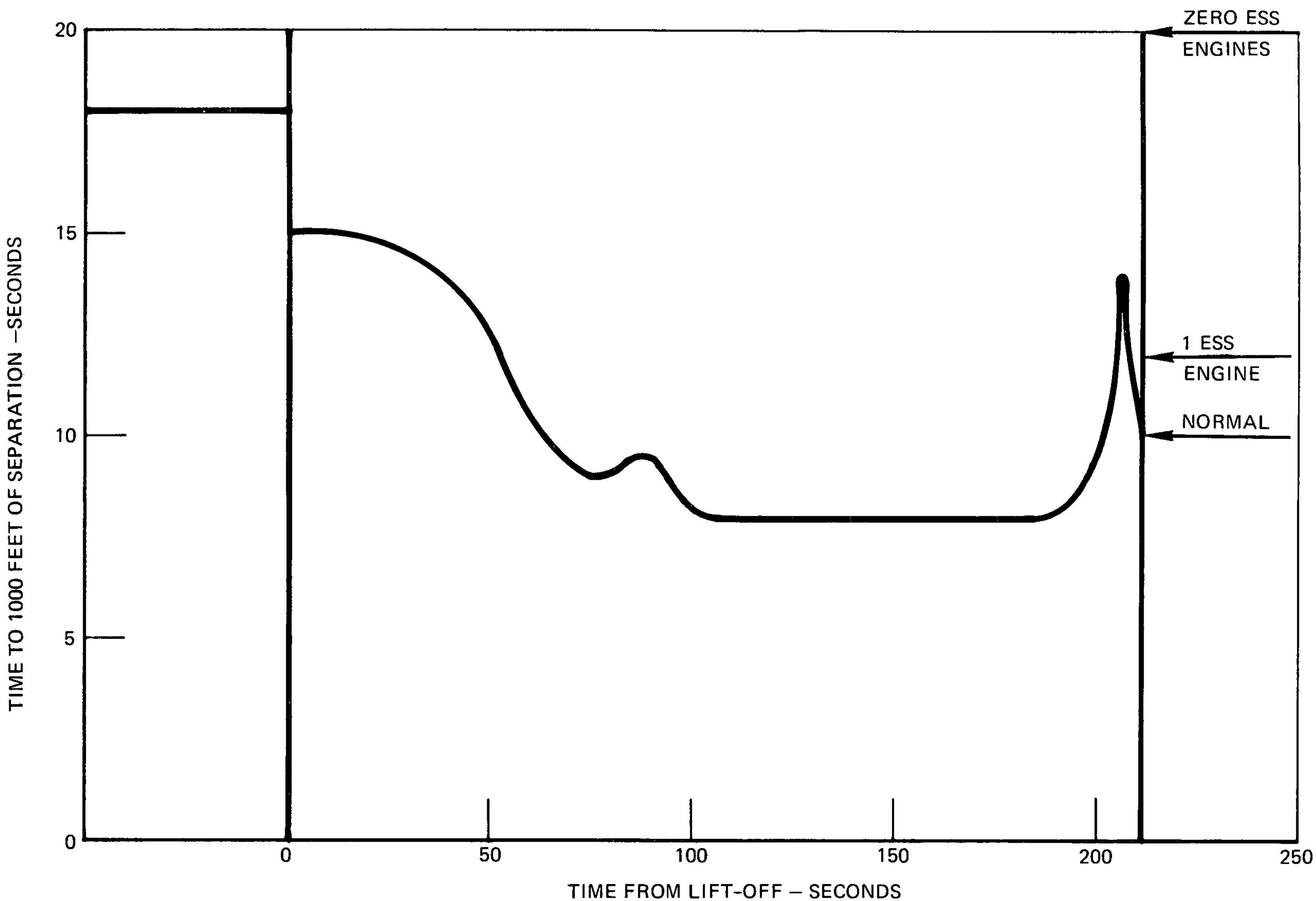


Figure A-6. Envelope of Time to 1000 Feet of Separation

4.5.3 Booster Separation Environment

Figure(s) of the ESS main propulsion engine plume characteristics (TBD).

4.5.4 Separation Sequence

Normal separation shall be accomplished to the timeline shown in Figures A-7 and A-8. A separation signal from the SSB shall initiate throttling of the SSB engines to 50 percent thrust and concurrently start the ESS engines. When the ESS engines are at 50 percent thrust, the explosive bolts in the four vertical links shall be fired, releasing the vertical restraint on the ESS. At the same time, the expansion compensator in the forward rotating frame shall be locked and 0.10 second later the SSB engines cutoff shall occur. With the vertical links broken, the SSB shall accelerate longitudinally relative to the ESS, and after a 1.1 second delay, the explosive bolts restraining the ESS to the rotating links shall be fired, freeing the ESS from the SSB.

4.5.5 Separation Clearance

See Figres A-9 and A-10.

4.5.6 Abort Requirements

The SSB computer shall be the command center for abort during mated ascent. The SSB computer shall monitor SSB and ESS subsystem failures, generate automatic and manual abort signals, display abort conditions to the SSB crew, and control automatic abort initiation commands. The SSB computer shall establish vehicle capabilities and the required abort separation sequence timing to remain within these capabilities. Automatic abort initiation shall be provided for those failure situations in which manual response time is not adequate to provide a safe abort separation; the use of automatic abort initiation is a function of the nature of the failure and the time from liftoff at which the failure occurs. Abort initiation shall be provided for the following conditions:

(a) Manual abort for loss of critical subsystem to fail-safe level, if time permits; otherwise, the computer shall provide an automatic (back-up) abort.

(b) Manual abort for incapacitated crew

(c) Manual abort for leaks/fire/explosions in the (TBD) areas, if time permits; otherwise, the computer shall provide an automatic (back-up)abort.

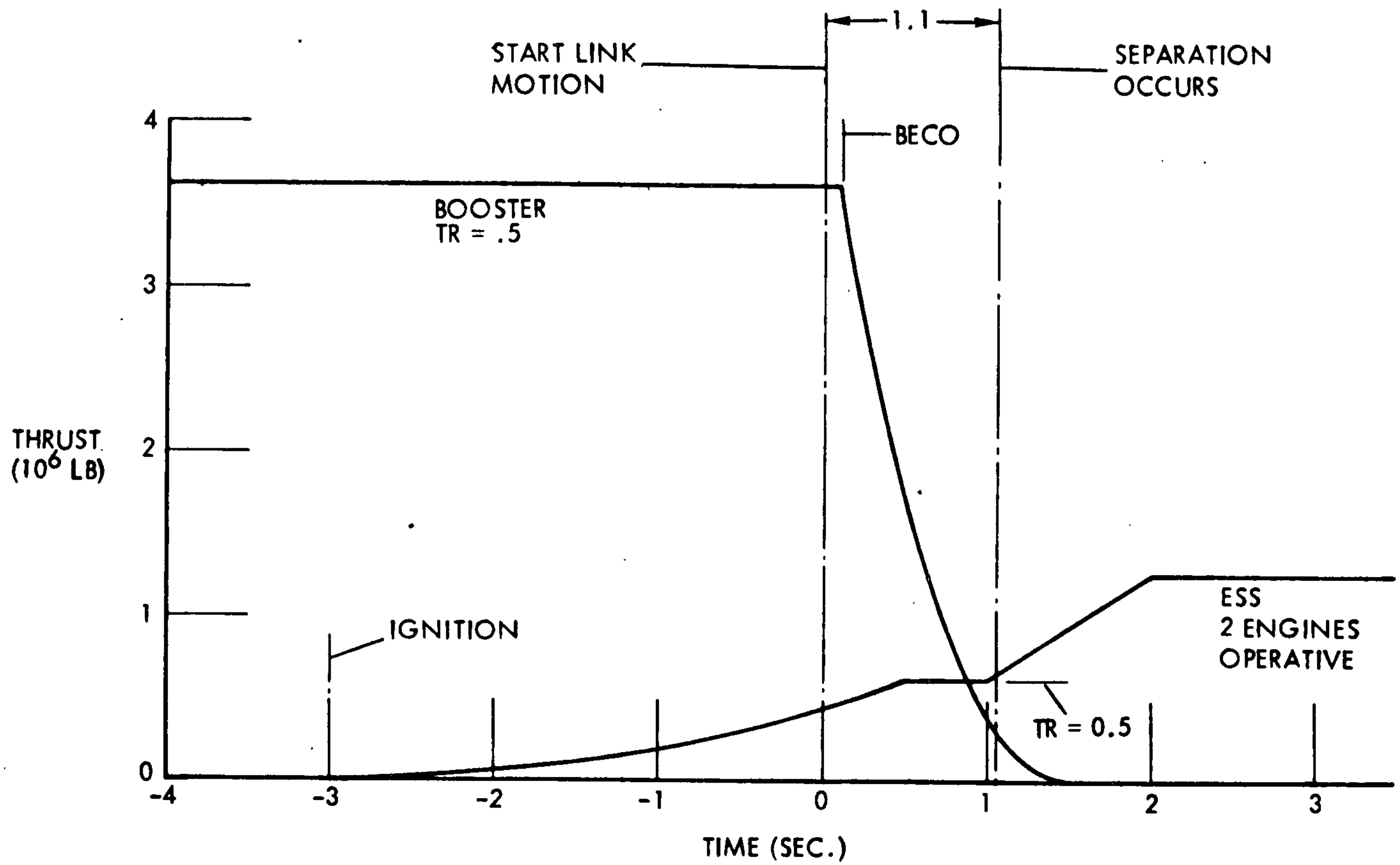


Figure A-7. Thrust Scheduling, Normal Staging of ESS/Booster

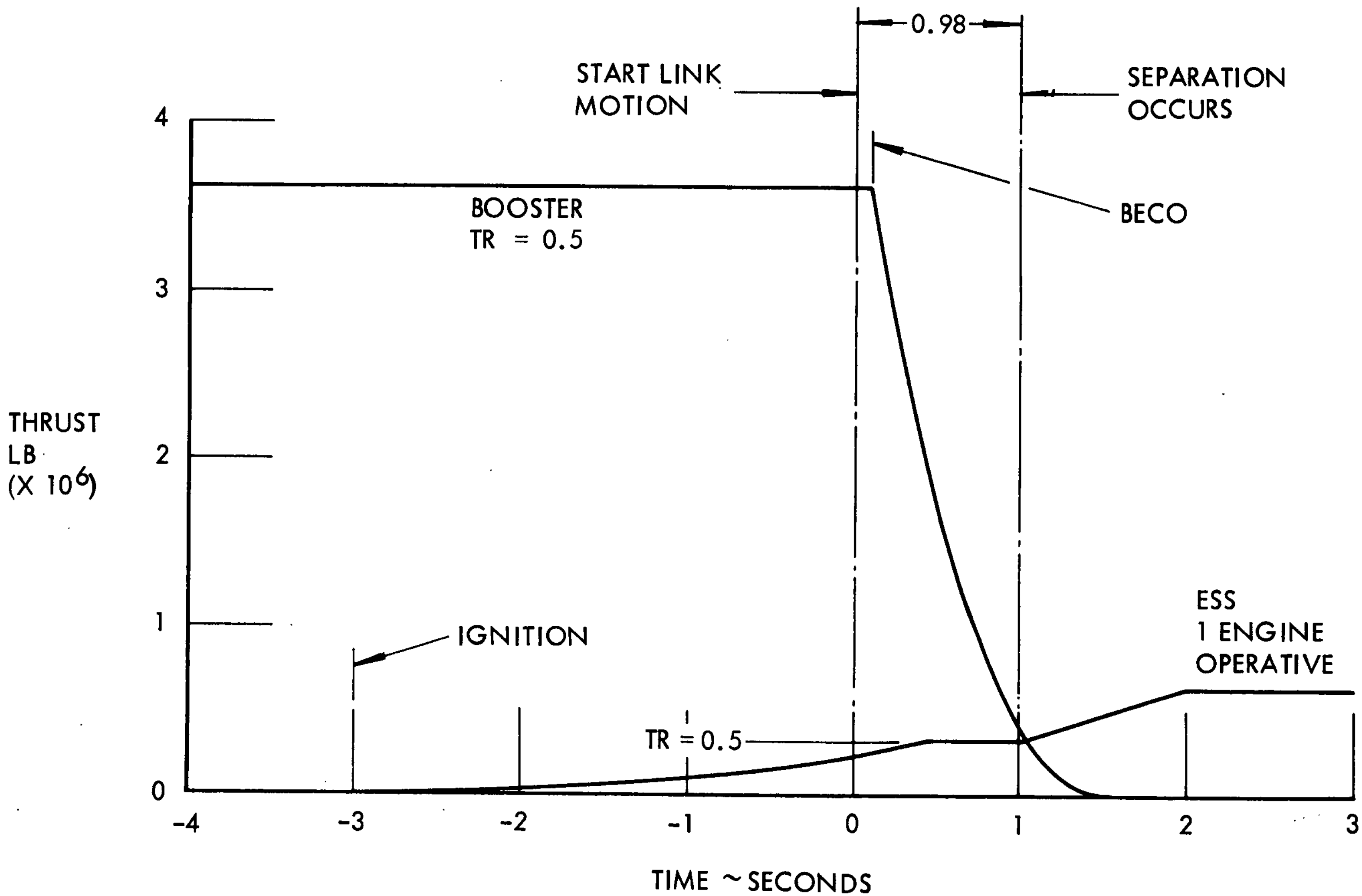


Figure A-8. Thrust Scheduling ESS With RNS Payload (One Engine Operative)

PITCH RATES (INERTIAL)
(DEG/SEC)

TIME (SEC.)	BOOSTER	ESS
-2	+1.65	+1.65
-1	+0.94	+0.94
0	+1.82	+1.82
1	-1.44	+0.08
2	-1.53*	+1.87
3	-1.58*	+1.71
4	-1.62*	+ .87

*BOOSTER ACPS NOT USED IN SIMULATION

BOOSTER ACPS CAPABILITY
0.73 DEG./SEC./SEC.

CONCLUSION: STABILIZATION TIME ≈ 2 SEC.

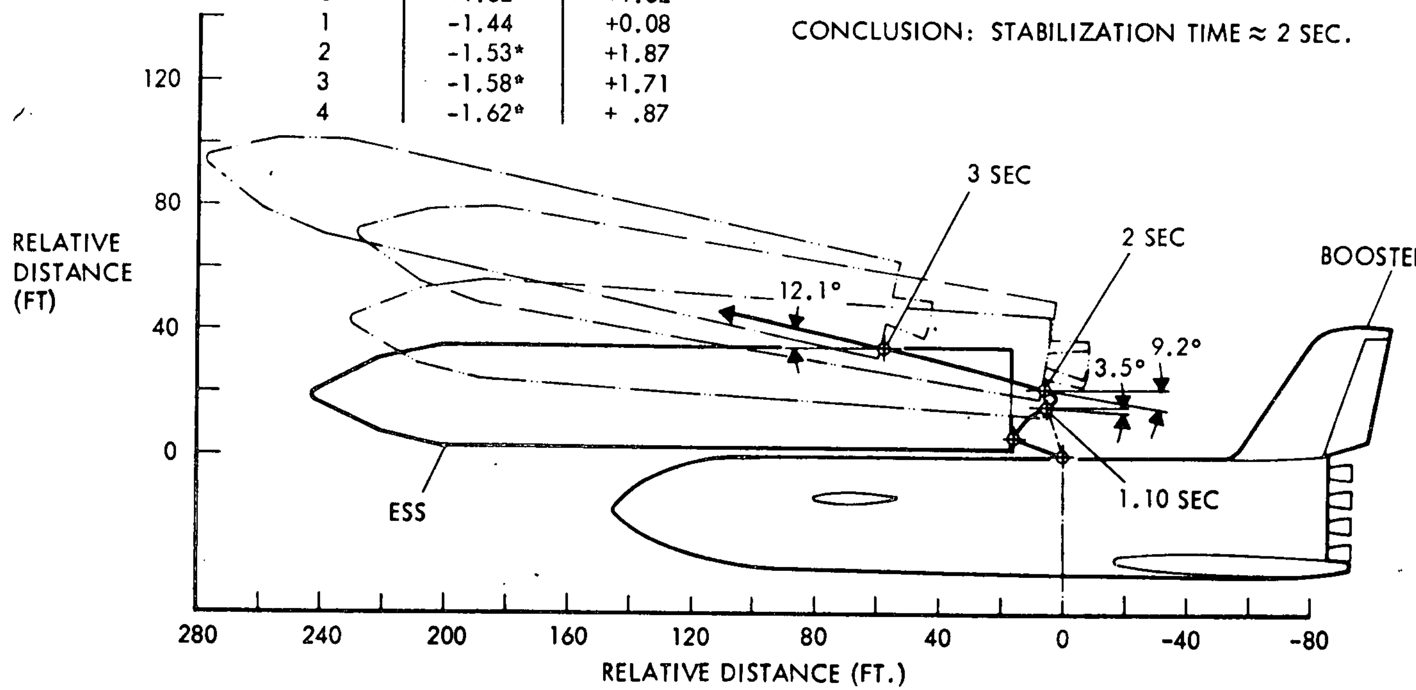


Figure A-9. Separation Trajectory, Normal Staging of ESS With RNS Payload (Two ESS Engines Operative)

PITCH RATES (INERTIAL)
DEG/SEC

TIME (SEC.)	BOOSTER	ESS
-2	+1.67	+1.67
-1	+1.06	+1.06
0	+2.08	+2.08
1	-1.93*	+0.39
2	-2.08*	+0.83
3	-2.13*	+1.57
4	-2.18*	-0.61

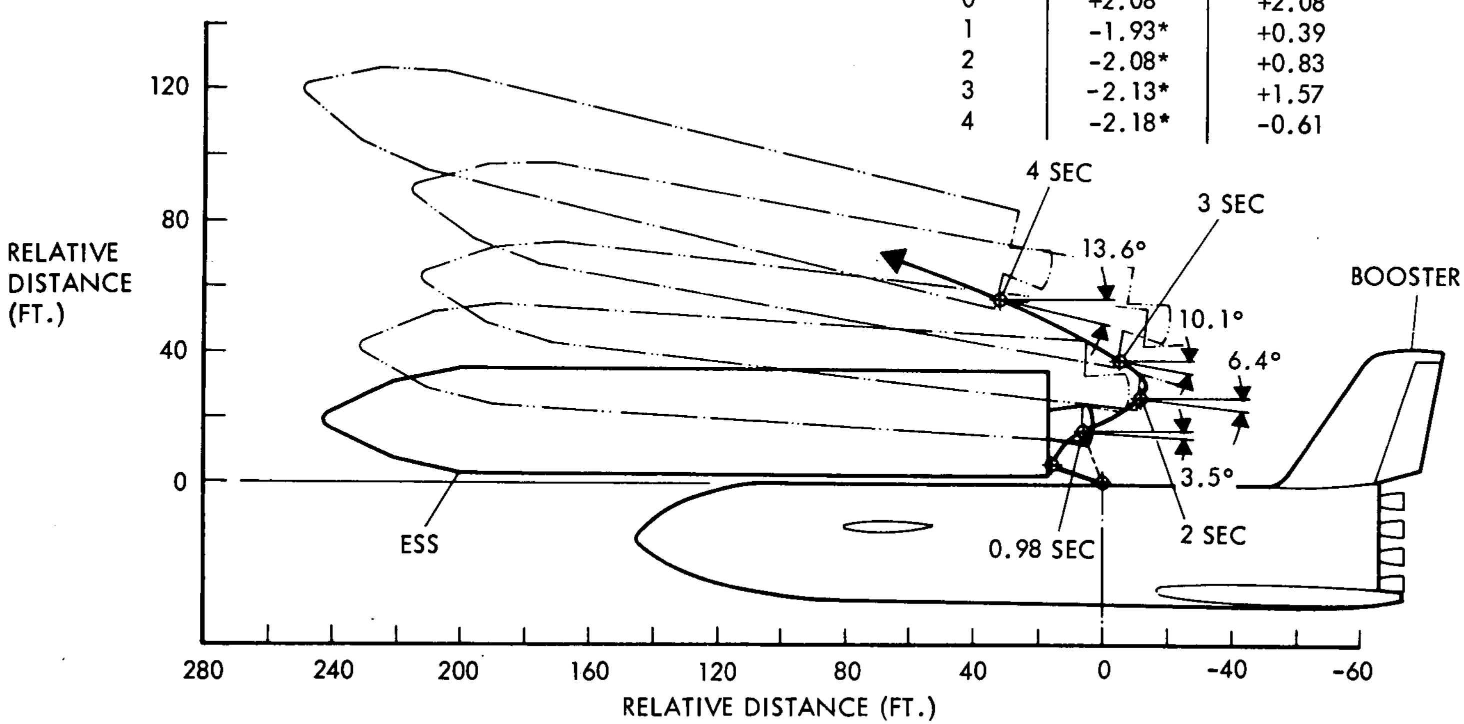


Figure A-10. Separation Trajectory, Staging of ESS With RNS Payload
(One ESS Engine Operative)

4.5.6.1 Control

Following the separation sequence, the SSB control systems shall maintain control during an abort separation maneuver to prevent recontact of the SSB/ESS stages and to allow a safe recovery. The control system shall be capable of operating within the baseline design flight envelope for abort which is (TBD).

4.5.6.2 Loads

For abort conditions, the SSB and ESS design ultimate structural loads shall not be exceeded either during or subsequent to the separation maneuver as a result of the separation maneuver or sequencing. In an abort, the SSB/ESS vehicle may operate at a reduced structural safety margin of (TBD).

4.6 AERODYNAMIC CHARACTERISTICS

4.6.1 Post-Separation Interference Airloads

The airload sustained by each vehicle shall account for interference effects.

4.6.2 Acoustics and Buffeting

The SSB and ESS shall be designed to withstand the acoustic environments on the launch pad and during mated ascent as shown in Figures A-11, A-12, and A-13. Noise sources include the rocket engines and various aerodynamic sources such as boundary layer turbulance, oscillating shocks, boundary layer shock and separated flow.

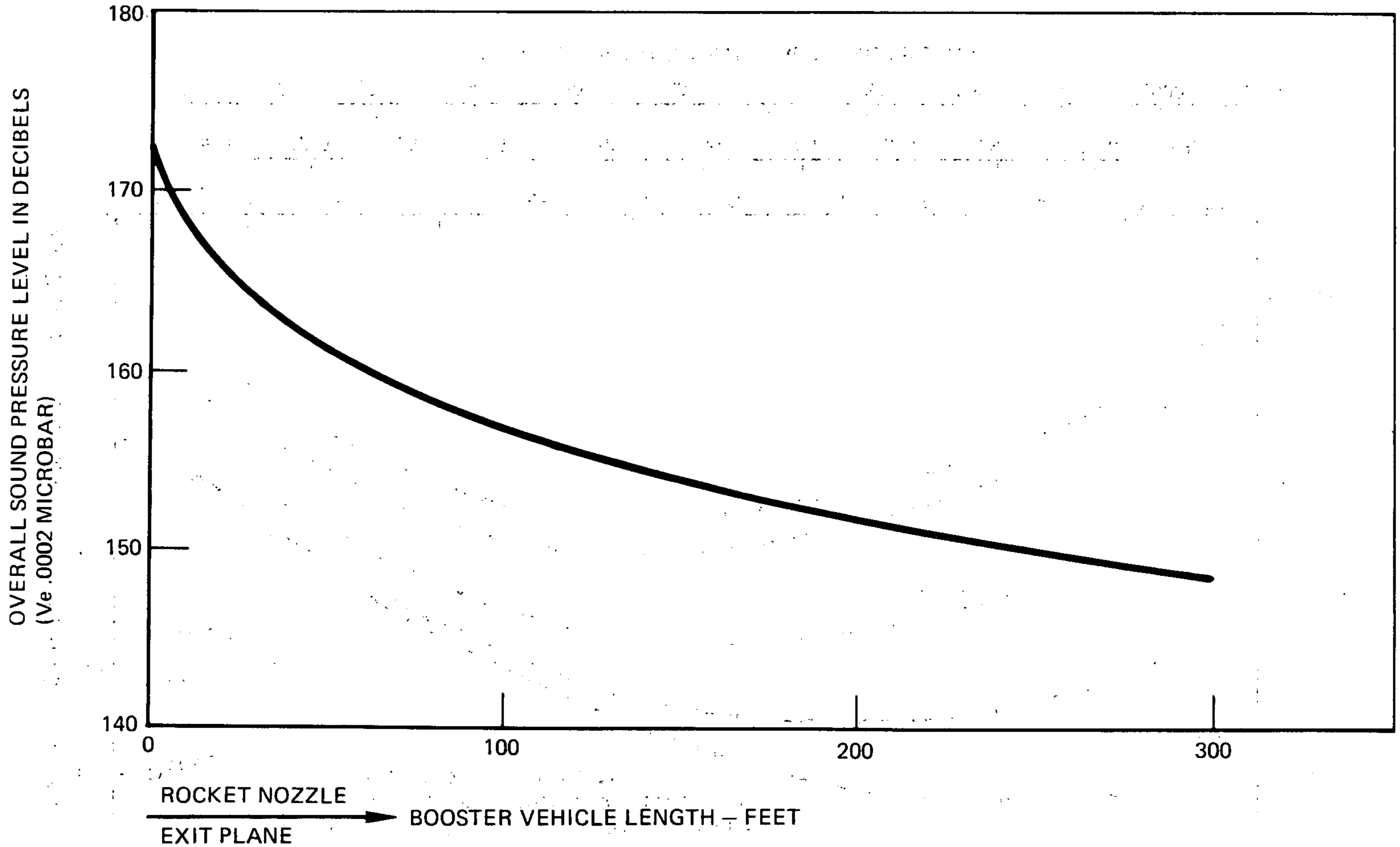


Figure A-11. Launch Acoustic Environment (On Pad) Per Booster Vehicle Length

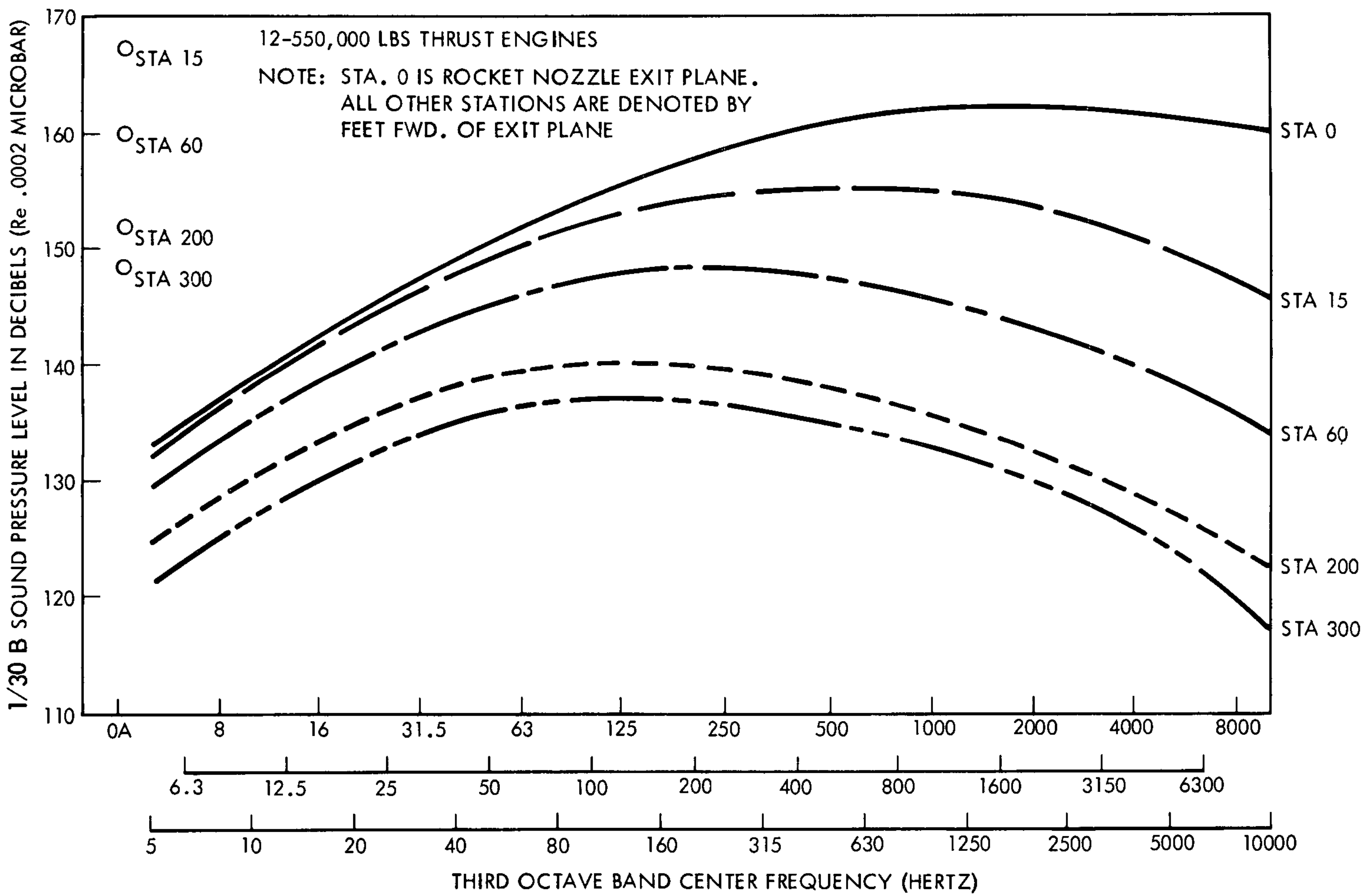


Figure A-12. Launch Acoustic Environment (On Pad) Per Distance Forward of Exit Plane

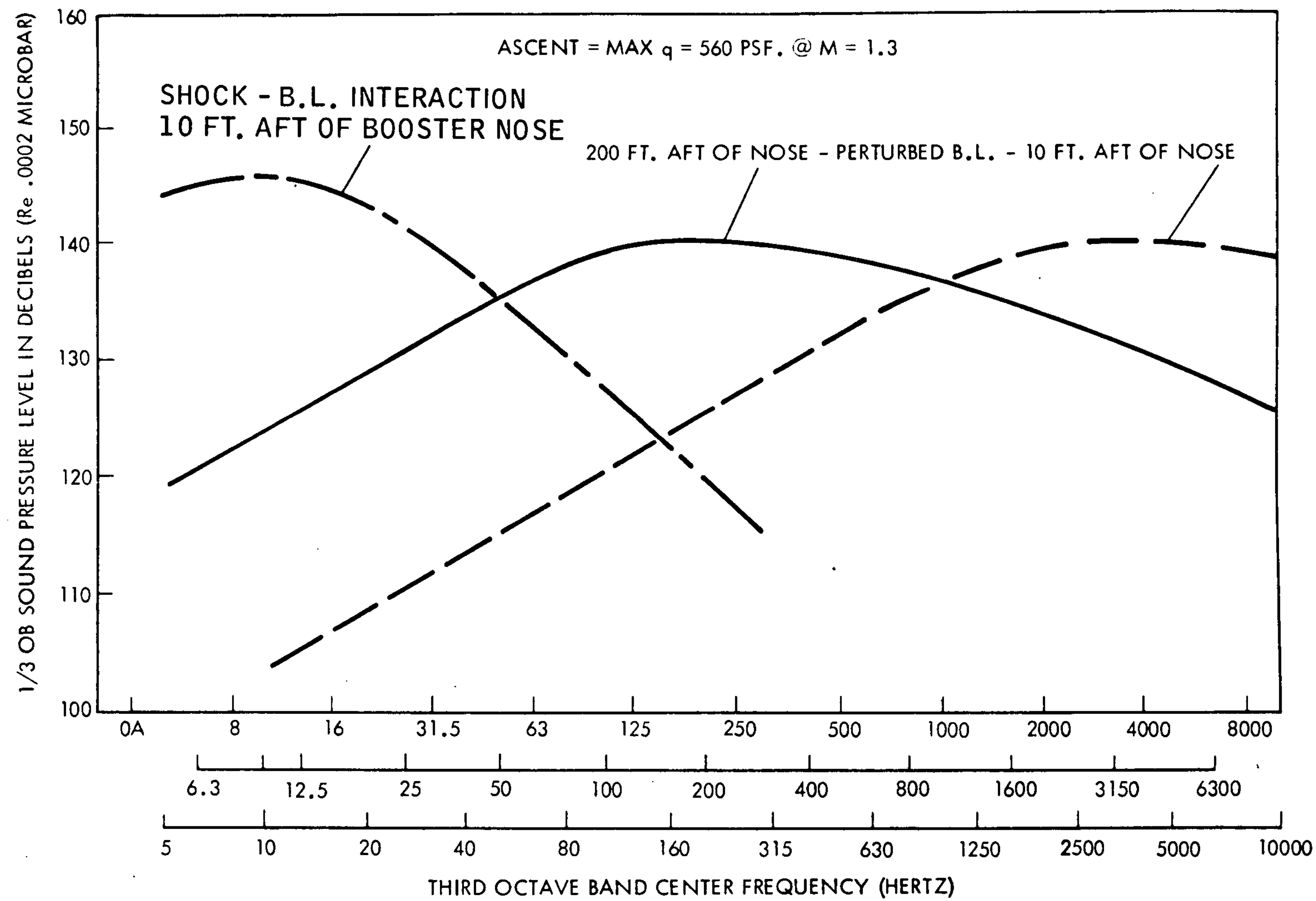


Figure A-13. Aerodynamic Pseudo-Noise

5.0 PHYSICAL REQUIREMENTS

The SSB/ESS physical interface shall be as specified in the following paragraphs.

5.1 CONFIGURATION

The SSB/ESS physical interface shall be in accordance with Figures A-14 through A-17.

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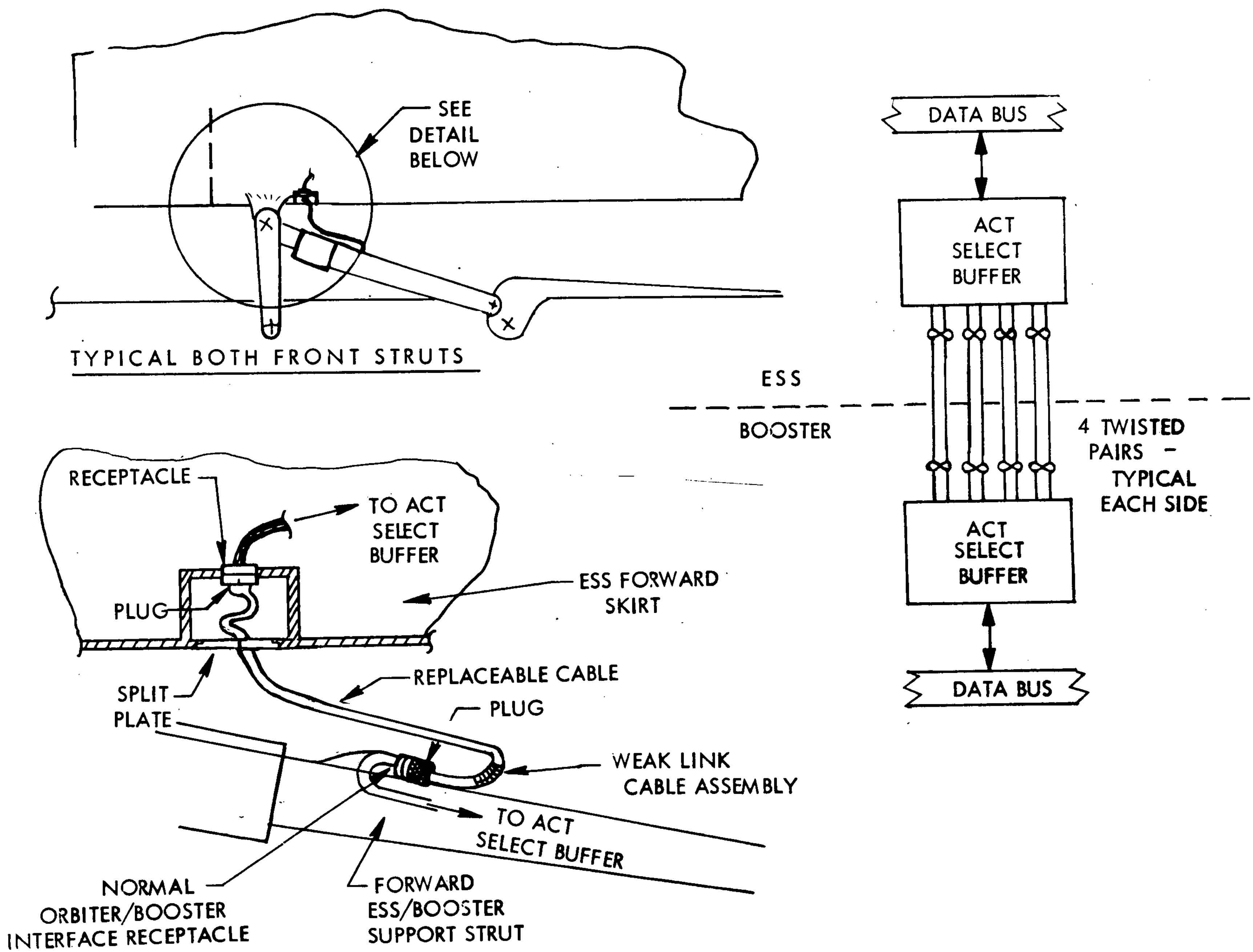

Figure A-16. ESS/Booster Avionics Interface

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6.0 PROCEDURAL REQUIREMENTS

6.1 ACCESSIBILITY

Access equipment provided for the Booster and the ESS attachment area shall be designed to support operations in the SSB/ESS mating area involving a procedural interface. The access provisions shall be compatible with the following interface operations.

6.1.1 Booster/ESS Mating (VAB)

The Booster shall be erected and mated to Launch Umbilical Tower (LUT) prior to receiving the ESS. The ESS shall be transported horizontally on transfer dollys to the transfer aisle. Existing VAB equipment shall be used for hoisting, handling and safety retention. The ESS shall be hoisted by crane to the vertical position and transported to the mating bay where all mating surfaces shall be inspected and verified. The ESS shall be lowered and mated to the SSB. Payload mating shall then be accomplished. During SSB/ESS mating operation, the contact force between SSB and ESS shall not exceed TBD pounds.

6.2 SSB PROTECTION

(Protective measures to be observed/taken for SSB protection such as loose equipment removal, installation of protective platforms, and any special precautions that are required shall be included) TBD.

6.3 DE-MATING REQUIREMENTS

De-mating of the ESS from the Booster shall be required in order to permit the following operations:

(Describe the operations that would require the de-mating of the ESS from the Booster)

(None Identified).

6.4 ASSEMBLY AND DISASSEMBLY

6.4.1 Interface Alignment

Booster/ESS interface alignment procedure (TBD).

6.5 ORDNANCE MATING

TBD

6.6 ELECTRICAL MATING

The SSB/ESS electrical interface harness and connectors shall be transferred from their stowed position in the Booster (attachment area) and connected subsequent to completion of Booster/ESS structural mating.

Volume 6
Appendix B

SPACE SHUTTLE ENGINE (SSE)/EXPENDABLE SECOND STAGE (ESS)

INTERFACE REQUIREMENTS

S080-1002

SPACE DIVISION

NORTH AMERICAN ROCKWELL CORPORATION

Interface Control Drawing

Contents

1.0 SCOPE

This document specifies the Space Shuttle Engine/Expendable Second Stage (ESS) functional and physical interface criteria. It specifies the requirements to be observed in the design of interfacing equipments.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

CP613M0003 Expendable Second Stage, Preliminary CEI Part I Specification

2.2 INTERFACE CONTROL DOCUMENTS

13M15000B Space Shuttle Vehicle/Engine 550K(SL) Interface Control Document

2.3 MANUALS AND HANDBOOKS

TBD

2.4 DRAWINGS

TBD

3.0 ABBREVIATIONS AND SYMBOLS

3.1 ABBREVIATIONS

c/o	cutoff
DNA	does not apply
EPL	emergency power level
FHP	fuel high pressure
Fx	force, x-axis
Fy	force, y-axis
g	gravitational constant
GH_2	gaseous hydrogen
GN_2	gaseous nitorgen
GO_2	gaseous oxygen
He	helium
Hz	Hertz
in.-lb	inch-pounds
lb/sec	pounds per second
LH2	liquid hydrogen
LO_2	liquid oxygen
max	maximum
min	minimum
MPL	minimum power level
Mx	moment, x-axis
My	moment, y-axis
Mz	moment, z-axis
No.	number
nom	nominal
NPL	normal power level
NPSP	net positive suction pressure
ppm	parts per million
ESS	Expendable Second Stage
SSE	Space Shuttle Engine
psia	pounds per square inch, absolute
psig	pounds per square inch, gauge
R	Rankine
rad	radians
ref	reference
rms	root mean square
sec	seconds
TBD	to be determined
VDC	volts, direct current
VAC	volts, alternating current
l	length
σ	standard deviation

3.2 SYMBOLS

Symbols used in the tabular data of this document are as follows:

○	Interface number as shown on the applicable drawing.
[ ]	Notes applicable to specific items.

4.0 FUNCTIONAL REQUIREMENTS

The functional requirements of the Space Shuttle Engine/ESS interfaces shall be as defined in the following paragraphs.

4.1 ELECTRICAL REQUIREMENTS

4.1.1 Connectors Definition

The electrical interface connectors for the SSE engine to the ESS shall be as defined in Table B-1.

4.1.1.1 Detailed Characteristics

The characteristics of each interface connector should be defined as engine requirements are finalized. These characteristics should include the following:

(a) Connector Type

(b) Pin Assignments

(c) Signal Functions (Commands/Measurements)

(d) Signal Characteristics (Analog/Discrete/Voltage/Waveforms/Load)

4.1.2 Power Requirements

The interface electrical power requirements shall be as defined in Table B-2. The values given are the maximum operating power requirements of the engine and the minimum power requirements to the supplying stage.

4.1.3 Shield Terminations

All shields shall terminate in the ESS.

Table B-1 SSE/ESS Electrical Connector Reference Designations

ENGINE CONNECTOR NUMBER	STAGE CONNECTOR REFERENCE DESIGNATION NUMBERS	
	ENGINE NO. 1	ENGINE NO. 2

Table B-2 Engine Electrical Requirements

ELECTRICAL POWER REQUIREMENTS		
FUNCTION	REQUIREMENTS	REMARKS
CONTROL	(1)	
IGNITION	(1)	
INSTRUMENTATION	(1)	

(1) See Figures B-1 and B-2.

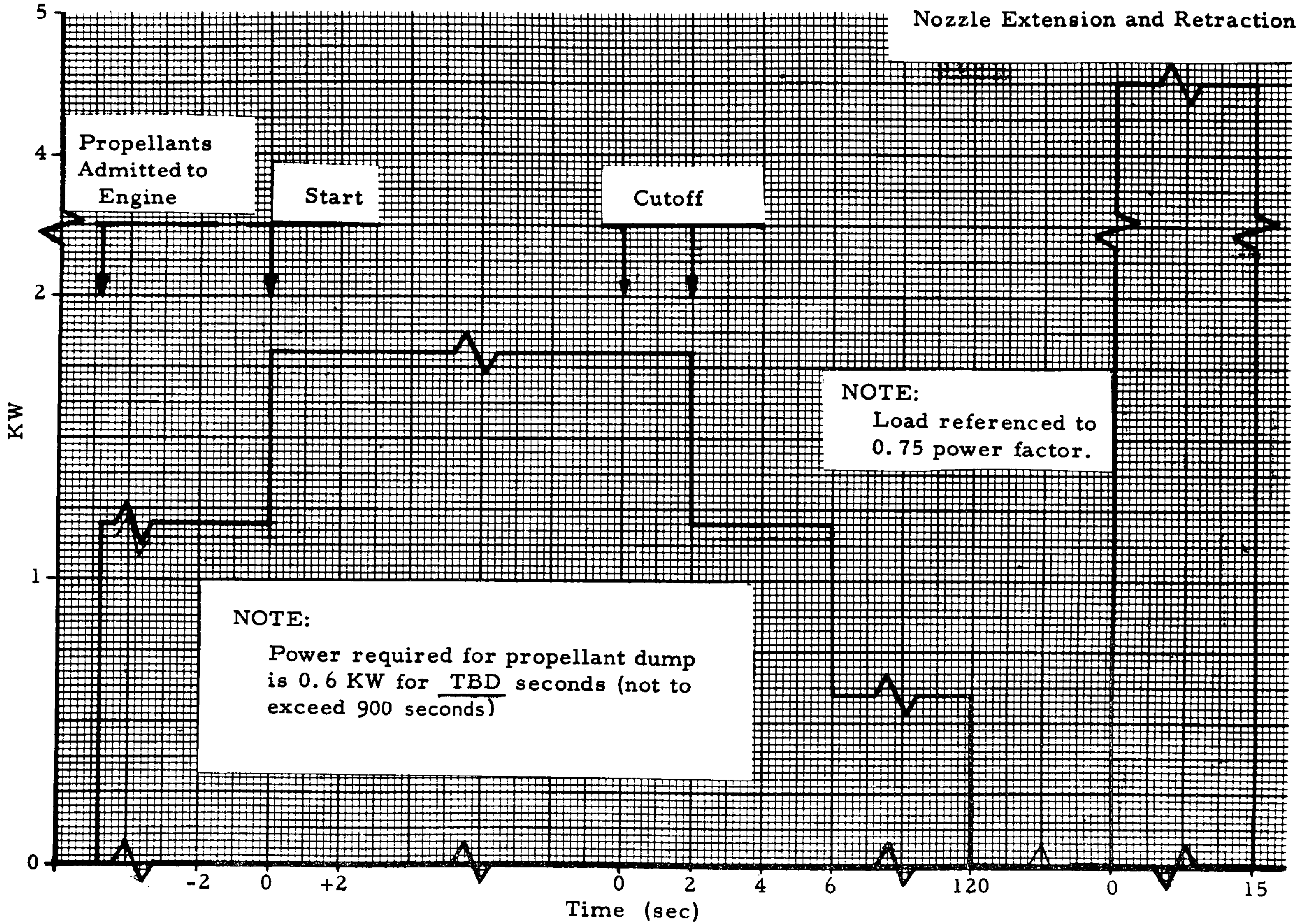


Figure B-1. AC Engine Electrical Power Profile

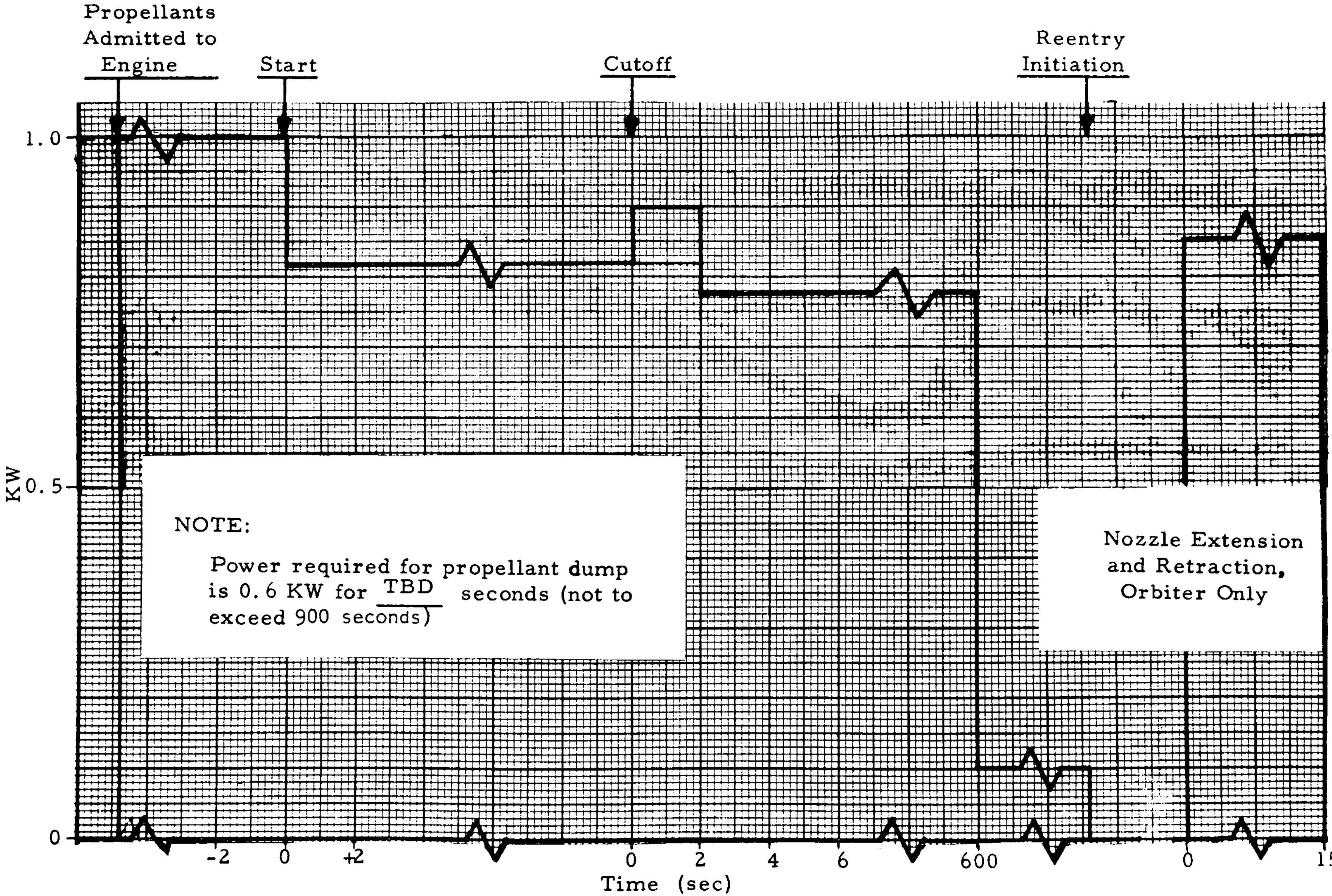


Figure B-2. DC Engine Electrical Power Profile

4.2 LOAD REQUIREMENTS

4.2.1 Loads and Moments

The maximum allowable loads and moments for the specified interface areas are shown in Tables B-3 and B-4.

Fx, Fy and Fz loads are along axes coincident or parallel to the corresponding engine axes of the engine coordinate system. Mx, My, and Mz bending moments are with respect to axes of the engine coordinate system. For positive moments, the right hand rule applies (i.e., when sighting along an axis in the positive direction, clockwise moments about the axis are positive). See Figure B-3 for definition of the coordinate system.

4.3 FLUID REQUIREMENTS

The functional fluid requirements shall be as specified in Table B-5 for each interface. Each interface shall include the following categories: Media, Pressure, Temperature, and Flowrate.

Table B-3 Allowable Vehicle Structural Characteristics

	Axis	Gimbal Joint	Oxidizer Pump Inlet	Fuel Pump Inlet	Actuator No. 1	Actuator No. 2
Deflection (along axis shown)	X		(+ 0.20 in. (- 0.30	(+ 0.20 in. (- 0.30		
	Y	TBD	$\pm$ 0.10 in.	$\pm$ 0.10 in.		
	Z		$\pm$ 0.10 in.	$\pm$ 0.10 in.		
Rotation (about axis shown)	X		$\pm$ 0.25°	$\pm$ 0.25°		
	Y		$\pm$ 0.25°	$\pm$ 0.25°		
	Z		$\pm$ 0.25°	$\pm$ 0.25°		
Spring Rate (lb/in.)		TBD	TBD	TBD	800K +150K -350K	800K +150K -350K

Table B-4

Space Shuttle Engine Allowable Interface Loads

Maximum Allowable Loads at Gimbal Interface	Fx Fy Fz Mx My Mz	TBD TBD TBD TBD TBD TBD
Maximum Allowable Loads at Actuator #1 Vehicle Interface	Fx Fy Fz Mx My Mz	TBD TBD TBD TBD TBD TBD
Maximum Allowable Loads at Actuator #2 Vehicle Interface	Fx Fy Fz Mx My Mz	TBD TBD TBD TBD TBD TBD
Maximum Allowable Loads at Low Pressure Fuel Turbopump Inlet Interface	Fx Fy Fz Mx My Mz	(+ 15000 (- 34000 ± 12,000 ± 12,000 ± 70,000 ±225,000 ±225,000
Maximum Allowable Loads at Low Pressure Oxidizer Turbopump Inlet Interface	Fx Fy Fz Mx My Mz	(+ 15000 (- 68000 ± 12,000 ± 12,000 ±110,000 ±225,000 ±225,000

Each force and/or moment is a maximum allowable value. This tabulation does not constitute a compatible set of forces and moments. Compatible component loads to accompany the above maximum load components will be supplied later.

NOTE: (1) Forces are in pounds.
(2) Moment are in inch-pounds.

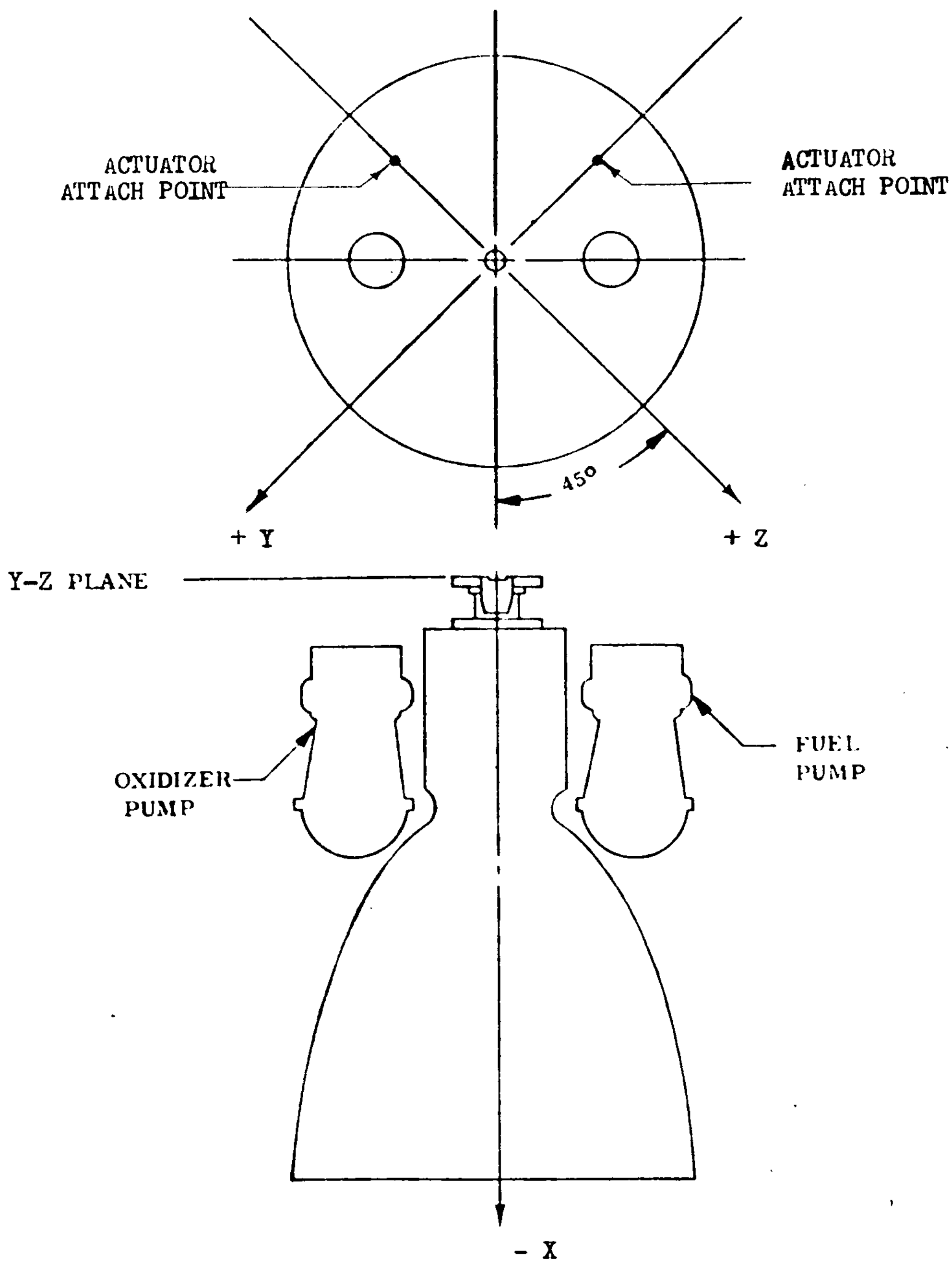


Figure B-3. Coordinate Axis Diagram

Table B-5
Engine/Stage Fluid Connection Nominal Input and Output Design Criteria and Limits

Interface Number	Description	Fluid Type	System Operating Pressure PSIA			Nominal Flowrate	Fluid Temperature Limits, °R	
			Minimum	Nominal	Maximum		Minimum	Maximum
4	Engine LO_2 Inlet	LO_2	Fig B-4			1175lb/sec	Fig B-4	
5	Engine FUEL Inlet	LH_2	Fig B-4			195lb/sec	Fig B-4	
6	Hydrogen Tank Pressurant Outlet	GH_2	Table B-6					
7	Oxidizer Tank Pressurant Outlet	GO_2	Table B-6					
8	Fuel Drain	GH_2			TBD			
9	Engine GN_2 Supply	GN_2	TBD	600	1000	0.5 lb/sec	510	660
10	Engine Helium Supply	Helium	Fig B-5					
20	Fuel Recirculation	LH_2	DNA	TBD	50	1.7 lb/sec	36	42
21	LO_2 Recirculation [1]	LO_2	DNA	TBD	300	4.0 lb/sec	162	171
25	Hydraulic Supply	MIL-H-5606	See Fig B-6					
26	Hydraulic Return	MIL-H-5606	See Fig B-6					

NOTE:
[1] At engine cutoff, maximum total pressure will be 1080 psia at a surge flowrate of 170 lb/sec and a total flow of 120 pounds over a two-second period of time.

NOTE:
Values referenced to Y-Z plane.

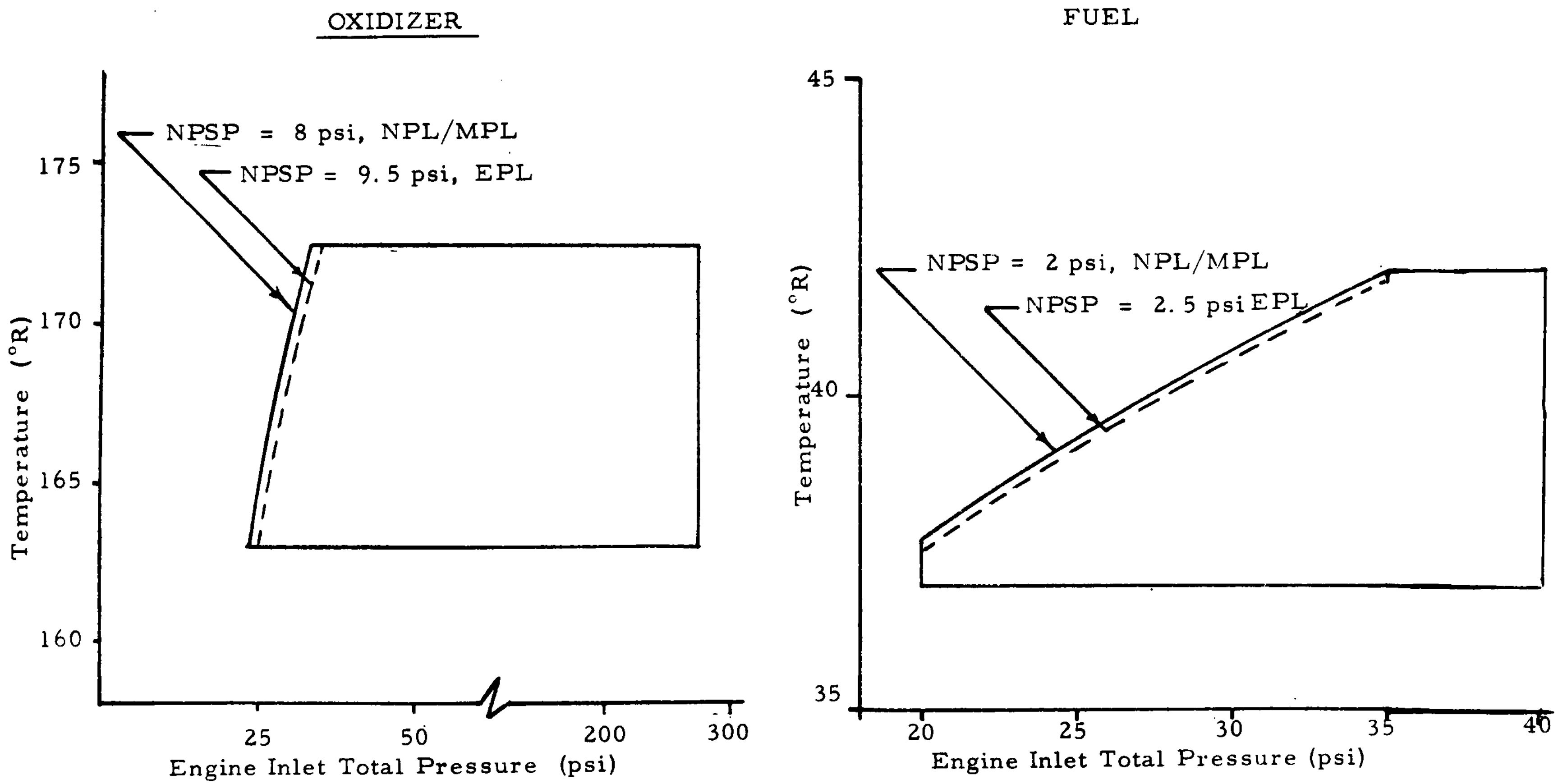


Figure B-4. Engine Propellant Inlet Conditions (Mainstage Operation)

Table B-6

Tank Pressurant/Heat Exchanger Design Requirements

SYSTEM	GOX	GH_2
Flowrate (lb/sec/engine)		
NPL*	2.55	0.50
Design Range	2.0 to 4.0	0.4 to 1.0
Temperature (°R)		
NPL*	800 $\pm$ 50	530 $\pm$ 130
Heat Exchanger Control Characteristic: $(\partial T/\partial W)$ $\left(\frac{°R\text{-Sec}}{lb}\right)$		
Design Range	0 to -200	0 to -200
Pressure (psia)		
Maximum	1000	1000
Minimum	200	200

[1] Flowrate is to be controlled by engine - mounted orifices.

[2] Interface Pressure is to be determined by stage flow resistance.

[3] Heat Exchangers shall not contain liquids prior to engine start.

[4] Heat Exchangers shall be capable of accepting zero pressurant flow.

* At mixture ratio (O/F)= 6.0

NOTES:

MAXIMUM HELIUM CONSUMPTION PER ENGINE PER FLIGHT IS 17 LBS BASED ON 500 SEC RUN

PRESS. MIN: 1400 PSIA

MAX: 1800 PSIA

TEMP. MIN: 490°R

MAX: 660°R

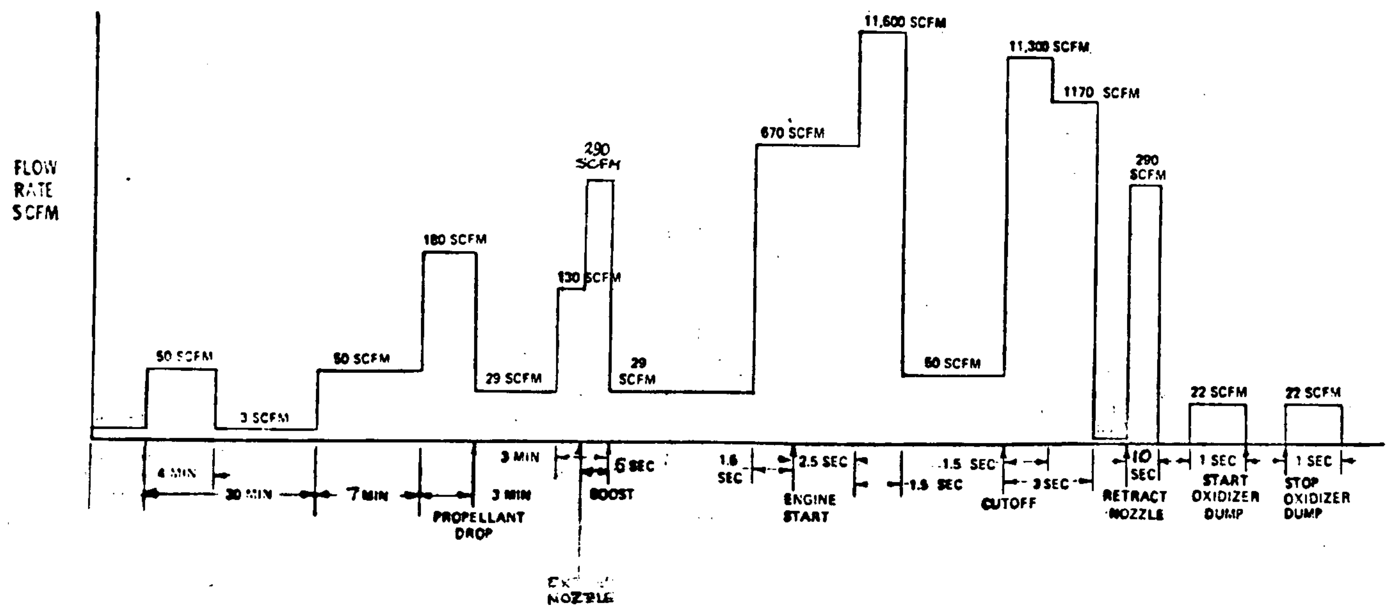


Figure B-5. Space Shuttle Engine Helium Requirements

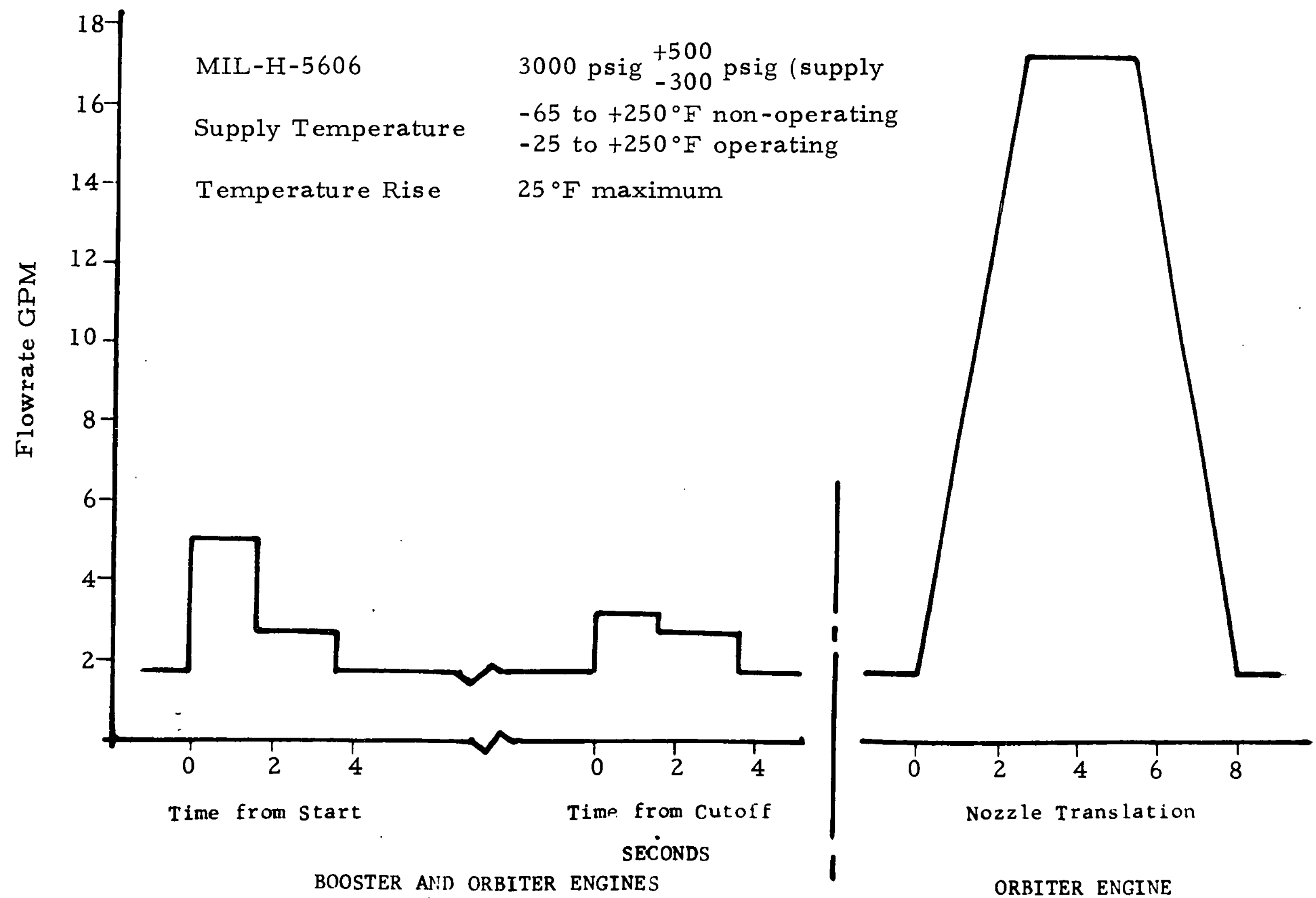


Figure B-6. Space Shuttle Engine Hydraulic Requirements

4.3.1 Media

The media that flow through the interfaces shall be as specified in Table B-7.

4.3.2 Operating Pressure

This specifies the minimum and/or maximum pressure of the media at the interface. These values define the allowable pressure range within which the media must be supplied to satisfactorily perform the related operations. Any pressure within this range unless otherwise specified will satisfy the interface requirements.

4.3.3 Operating Temperature

This specifies the minimum and/or maximum temperature of the media at the interface. These values define the allowable temperature range within which the media must be supplied to satisfactorily perform the related operations. Any temperature within this range unless otherwise specified will satisfy the interface requirements.

4.3.4 Operating Flow Rate

This specifies the nomonal, minimum and/or maximum flow rate of the media flowing through the interface. Operating curves shall be given for applicable functions.

4.4 ENGINE GIMBALING CHARACTERISTICS

4.4.1 Gimbal Capability

The engine gimbaling capability will permit locating the thrust chamber centerline ± 8.0 degrees (including 0.5 degree for snubbing and overtravel and 0.5 degree for engine misalignment) from the engine centerline as depicted in Figure B-7. The engine is capabable of being gimbaled at a maximum angular velocity of 20 degrees per second with the extendable nozzle in the retracted or extended position during firing and non-firing conditions. Excluding engine and vehicle induced forces, the maximum angular acceleration shall not exceed 30 radians per second squared.

4.4.2 Accessory Drive

An accessory drive shall be provided by each engine capable of delivering 60 (shaft) horsepower when the engine is operated at 50 percent of rated thrust. At maximum rated thrust, the drive shall be capable of developing the same torque as at the 50 percent thrust condition. The maximum drive speed shall not exceed 12,000 RPM.

Table B-7. Engine Operating Fluid Cleanliness Limits

Type	Maximum Particle Size, or Requirement [1]		Remarks
	Particle Size (x), Microns	Particles Allowable (No.)	
GN_2, MIL-P-27401 [2]	$x \leq 30$ $30 < x \leq 100$ $x > 100$	No limit 25 0	
Helium, MSFC-SPEC-364 or MIL-P-27407 [2]	$x \leq 30$ $30 < x \leq 100$ $x > 100$	No limit 25 0	
Liquid Oxygen, MIL-P-25508 [3]	$x \leq 100$ $100 < x \leq 200$ $200 < x \leq 250$ $x > 250$	No limit 1000 500 0	Acetylene content shall be no larger than 1.55 ppm, soluble hydrocarbon shall not exceed 75 ppm, the purity not to be less than 99.2 percent, and the particulate content of the oxygen must not be limited by the total weight.
Liquid Hydrogen, MIL-P-27201 [3]	$x \leq 100$ $100 < x \leq 200$ $200 < x \leq 250$ $x > 250$	No limit 1000 500 0	
Hydraulic Fluid MIL-H-5606	Values specified in MSFC-PROC-166	Values specified in MSFC-PROC-166	
GH_2	TBD	TBD	

NOTES:

[1] Cleanliness limits specified are the maximum allowable at the engine-to-vehicle interface.

[2] Maximum number of particles based on a 30 standard cubic foot sample.

[3] Maximum number of particles based on a 100 ml sample.

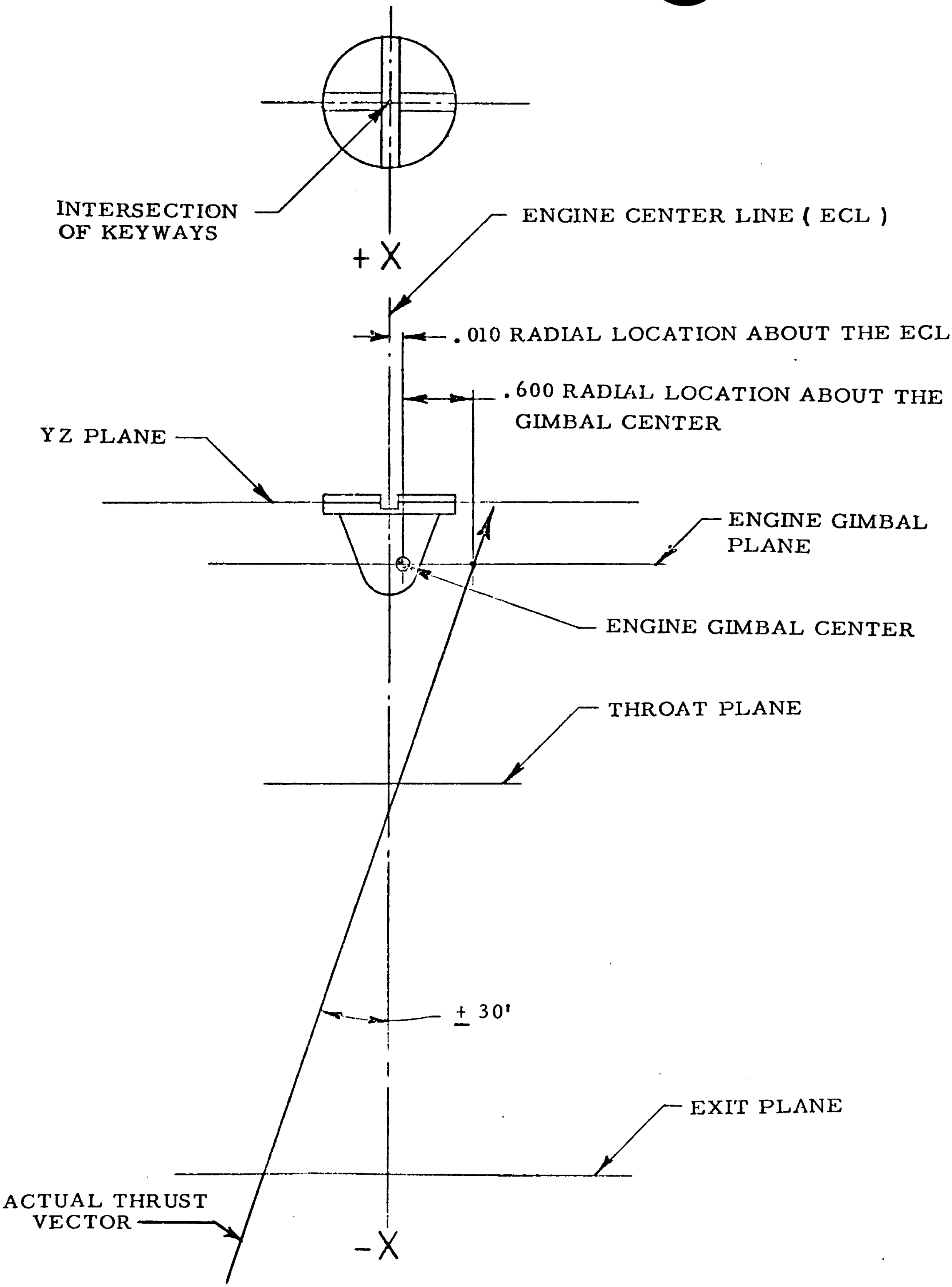


Figure B-7. Actual Thrust Vector Description

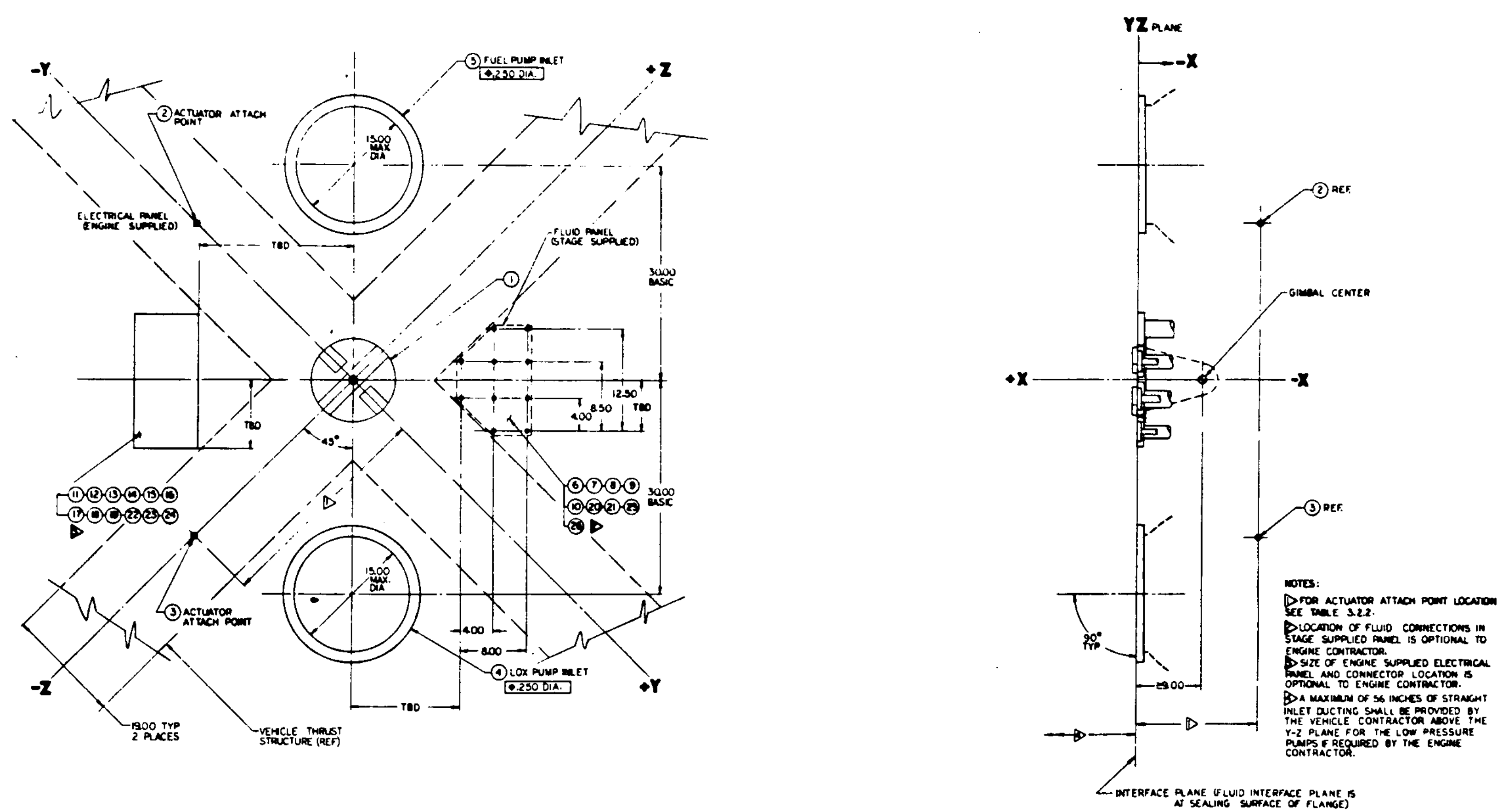


Figure B-8. Space Shuttle Engine Interface

VEHICLE CONNECTION – INTERFACE POINTS			
Interface No. [1]	Zone	Description	End Configuration
1	4C	Gimbal Bearing	Machined Flange
2	5C	Gimbal Actuator Attach Point	Clevis
3	5B	Gimbal Actuator Attach Point	Clevis
4	4B	LOX Engine Inlet	Fixed Flange
5	4D	Fuel Engine Inlet	Fixed Flange
6	4C	Hydrogen Tank Pressurant Outlet	Swivel Flange
7	4C	Oxidizer Tank Pressurant Outlet	Swivel Flange
8	4C	Fuel Drain [2]	Swivel Flange
9	4C	Engine GN_2 Purge Supply [2]	Swivel Flange
10	4C	Engine Helium Control/Purge Supply [2]	Swivel Flange
11	5C	Power, D. C. [2] – Group A	
12	5C	Power, D. C. [2] – Group A	
13	5C	Power, D. C. [2] – Group A	
14	5C	Data Bus [2] – Group B	
15	5C	Data Bus [2] – Group B	
16	5C	Instrumentation [2] – Group B	
17	5C	Instrumentation [2] – Group B	
18	5C	Data Bus [2] – Group B	
19	5C	Data Bus [2] – Group B	
20	4C	Fuel Recirculation [2]	Swivel Flange
21	4C	LOX Recirculation [2]	Swivel Flange
22	5C	Power, A. C. [2] – Group C	
23	5C	Power, A. C. [2] – Group C	
24	5C	Power, A. C. [2] – Group C	
25	4C	Hydraulic Supply [2]	Swivel Flange
26	4C	Hydraulic Return [2]	Swivel Flange

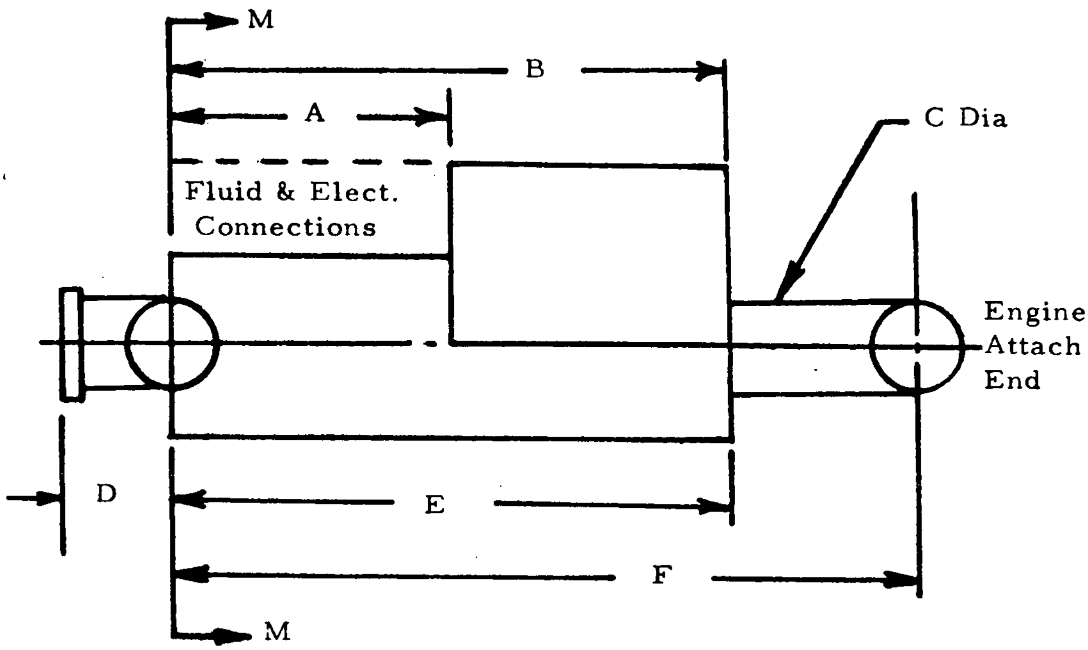
[1] Interface numbers are as shown on Drawing 3.2.2.

[2] Optional to engine contractor only. There will be at least six inches separation between groups A, B, and C.

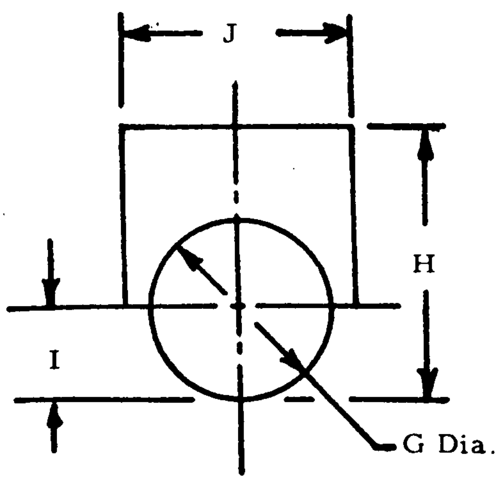
Figure B-9. Space Shuttle Engine Interface Drawing

Engine Configuration	Engine Aft Attach Point (in.) 2 & 3		Engine Envelope Forward Pierce Point (in.)	
	Y & Z	X	Y & Z	X
A	- 19.3	- 48.4	- 41.4	0.0
B	- 25.0	- 47.0	- 32.0	0.0
C	- 22.0	- 47.2	- 22.0	0.0
*For actuator envelope see Figure B-11				

Figure B-10. Actuator Envelope and Aft Engine Attach Point



NOTE:
Actuator shown in null position.



SECTION M-M

Dimension	ENGINES		
	P	R	A
A	19.0	18.5	14.5
B	36.0	35.5	28.0
C	3.0	3.0	3.5
D	4.5	4.5	4.5
E	36.0	35.5	28.0
F	46.2	43.0	42.1
G	8.0	8.0	10.0
H	14.0	14.0	16.0
I	4.0	4.0	5.0
J	9.0	9.0	10.0

Figure B-11. Actuator Envelope

5.0 PHYSICAL REQUIREMENTS

The SS engine to the ESS physical interface shall be in accordance with Figures B-8 through B-11.

APPENDIX C

EXPENDABLE SECOND STAGE (ESS)/GSE

INTERFACE REQUIREMENTS

(Drawing S080-1003)

SPACE DIVISION

NORTH AMERICAN ROCKWELL CORPORATION

INTERFACE CONTROL DRAWING

Contents

1.0 SCOPE

This document specifies the functional and physical interfaces of the Expendable Second Stage (ESS)/Ground Support Equipment (GSE). It defines the requirements and criteria to be observed in the design of interfacing equipment.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

MSFC-SPEC-364	Helium
MIL-P-27407	Propellant Pressurizing Agent, Helium
MIL-P-27201	Propellant, Hydrogen
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen
MIL-P-25508	Propellant, Oxygen, Type II
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance
CP613M0003	Expendable Second Stage, Preliminary CEI Part I Specification

2.2 DRAWINGS
TBD

2.3 INTERFACE CONTROL DOCUMENTS
TBD

2.4 MANUALS AND HANDBOOKS
TBD

3.0 ABBREVIATIONS AND SYMBOLS

NA	Not Applicable
TBD	To be Determined
LH_2	Liquid Hydrogen
HE	Helium
GN_2	Gaseous Nitrogen
GH_2	Gaseous Hydrogen
FWD	Forward
C/O	Checkout
ESS	Expendable Second Stage
LO_2	Liquid Oxygen
GO_2	Gaseous Oxygen
MIN	Minimum, Minute
MAX	Maximum
GSE	Ground Support Equipment
DC	Direct Current

4.0 FUNCTIONAL REQUIREMENTS

The functional requirements of the ESS/GSE interface shall be as defined in the following paragraphs.

4.1 ELECTRICAL REQUIREMENTS

4.1.1 Connector Definition

The electrical interface of the ESS/GSE consists of the following functions:

a. Umbilical Connectors

(1) Ground Electrical Power

(2) Data and Communication

b. Special Test Connector

(1) On-Board Computer Checkout

4.1.2 Wire Size

The minimum wire size to be used shall be AWG No. TBD . Connector pins may be bussed together when current exceeds the capacity of a single pin is required.

4.1.3 Voltage Levels

Unless otherwise noted, the voltage level used in this document shall be TBD volts DC.

4.1.4 Shield Termination

Unless otherwise noted, all shields shall terminate in the GSE. Shields shall be isolated from other shields by systems and functions within systems.

4.1.5 Power Requirements

The interface electrical power requirements shall be as defined in Table TBD. The values given are the maximum operating power requirements of the ESS and the minimum power requirements to the supplying GSE.

4.2 FLUID REQUIREMENTS

This section establishes the fluid requirements of the ESS at the interfaces of the umbilical disconnects. These requirements include all functions requiring transfer of fluids between the stage and GSE during vehicle checkout, static firing, and launch.

4.2.1 Detailed Fluid Requirements

4.2.1.1 Propellants and Gases

Table C-1 defines the requirements for propellants and gases and the definitions of the heading are as follows:

- Item - A number assigned to each functional operation for reference.
- Functional Operation - The task being performed across the interface between the stage and the GSE.
- Media - The fluid being transferred during functional operation.
- Pressure - The nominal pressure and its tolerance or pressure range required at the interface.
- Temperature - The temperature and its tolerance at the interface.
- Flow Rate - The flow rate of fluid at the interface.
- Time Required - The approximate total time required to perform the functional operation.
- Quantity - In purging operations, it is the total quantity of fluid to be transferred across the interface. In loading operations, it is the total quantity of fluid required on board the stage at liftoff.
- Umbilical Requirements - The number, size and location of GSE interface disconnect(s) necessary for performing the functional operations.

Table C-1. Propellants and Gases

Item	Functional Operation	Functional Requirements							
		Media	Press. (PSIG)	Temp. (°F)	Flow (lb/min)	Time (min)	Quantity (lb)	Umb. Reqts. Size	Function
1.0	Fuel Transfer	LH_2					99,582	Aft,8"	Fill & Drain
2.0	Oxidizer Transfer	LO_2					604,302	Aft,8"	Fill & Drain
3.0	Main Engine Helium Supply Fill	HE	4500 $\pm$ 200	30-200	12	2	23	Aft,1"	Fill
3.1	Main Engine Helium Supply Purge	HE	1600 $\pm$ 200	30-200	.06-58	.1-75	0.6-45		Purge
4.0	Main Engine Purge Supply	GN_2	1250 $\pm$ 100	50-200	60	30	1800	Aft,1"	Purge
5.0	Main Engine Fuel Drain	GH_2	50	-400	TBD	TBD	TBD	Aft,½"	Drain
6.0	Fuel Recirc. Line Purge	HE	20 max	AMB	.40	3	TBD	Aft,1"	Purge
7.0	LH_2 Press. Purge Supply	HE	750	70 $\pm$ 30	0.2	30	6	Aft,½"	Purge
8.0	Stage Valve Actuation Supply	HE	2800 - 3100	AMB	3	1.34	4.32	Aft,1"	Press
9.0	LO_2 Fill Line Drain	LO_2 & HE	30	NA	NA	2.1	NA	Aft,1"	Drain
*10.0	Hazardous Gas Detection, Aft.& Fwd. Compartments	NA		AMB	0.02	Contin-ous	NA	Aft,¼" Fwd.¼"	Sensing

* Initiated prior to any propellant transfer until liftoff.

Table C-1. Propellants and Gases (continued)

Item	Functional Operation	Functional Requirements							
		Media	Press. (PSIG)	Temp. (°F)	Flow (lb/min)	Time (min)	Quantity (lb)	Umb. Size	Reqts. Function
11.0	Common Bulkhead Purge Inlet, (Outlet for Evacuation)	HE	8.0 max	AMB	TBD	TBD	NA	Aft, 1"	Purge & Bulkhead Evacuation
12.0	J-Ring Area Purge Inlet	HE	2.3-2.7	AMB	.054-.075	Continuous	NA	Aft, ½"	Purge
13.0	J-Ring Area Purge Outlet	NA	0.15 min	NA	0.054-.075	Continuous	NA	Aft, ½"	Sensing
14.0	Fwd. Bulkhead Uninsulated Area Purge Inlet	HE	1.0-1.5	AMB	.031-.056	Continuous	NA	Fwd, ½"	Purge
15.0	LH_2 Fill Valve Actuation Supply	HE	750	AMB	Static	NA	NA	Aft, ½"	Act. Press.
16.0	LH_2 Tank Prepressurization	HE	1500 max	AMB	100±20	1 max	120 max	Fwd. 1"	Press.
17.0	LH_2 Tank Aux. Press.								
18.0	LH_2 Vent Valve No.1 Sensing	AMB							Sensing
19.0	LH_2 Vent Valve No.2 Sensing	AMB							Sensing
20.0	LH_2 Tank Press. C/O Supply	HE	6-35.5	AMB	Static	5	NA	Fwd. ½"	C/O
21.0	LH_2 Tank Sensing								Sensing

Table C-1. Propellants and Gases (continued)

Item	Functional Operation	Functional Requirements: Media	Press. (PSIG)	Temp. (°F)	Flow (lb/min)	Time (min)	Quantity (lb)	Umb. Size	Reqts. Function
22.0	LH_2 Vent Valve No.1 and No. 2	GH_2	TBD	AMB to -423	TBD	TBD	TBD	Fwd.7"(2)	Venting
23.0	Helium Injection Supply	HE	2800-3100	AMB	3.0	1	TBD	Aft.½"	Press.
24.0	Engine Compartment Conditioning Preflt. Purge	GN_2	1.5 max	60-215	500±25	TBD	TBD	TBD	Purge & Temp. Control
25.0	LO_2 Tank Prepressurization	HE	1500 max	AMB	100±20	3.5 max	420 max	Aft.1"	Press & Purge
26.0	LO_2 Tank Aux. Press.	HE							
27.0	LO_2 Tank Component Actuation Supply	HE	750±50	AMB	Static	NA	NA	Aft.½"	Control Press.
28.0	LO_2 Vent Valve No. 1 Ambient Sensing								Sensing
29.0	LO_2 Vent Valve No. 2 Ambient Sensing								Sensing
30.0	LO_2 Vent Valve No. 1 and No. 2	GO_2							Venting
31.0	LO_2 Press. Sys. C/O Supply	HE	6-35.5	AMB	Static	5	NA	Aft.½"	Checkout
32.0	AFT Compartment Thermal Control	AIR, GN_2	TBD	TBD	TBD	TBD	TBD	TBD	

Table C-1. Propellants and Gases (continued)

Item	Functional Operation	Functional Requirements							
		Media	Press (PSIG)	Temp. (°F)	Flow (lb/min)	Time (min)	Quantity (lb)	Umb. Size	Reqts. Function
33.0	FWD.Compartment Thermal Control	AIR, GN_2	TBD	TBD	TBD	TBD	TBD	TBD	
34.0	Aux. Propulsion Sys. LH_2 Fill and Drain	LH_2	15	-423	325	10	3200	Aft.2"	Fill & Drain
35.0	Aux. Propulsion Sys. H_2 Vent	GH_2	15	-400	TBD	120	NA	Aft.3/4"	Venting
36.0	Aux. Propulsion Sys. GH_2 Charge, Fill	GH_2	1100 ± 100	AMB	5	3	30	Aft.$\frac{1}{2}$"	Fill
36.1	Aux. Propulsion Sys. GH_2 Charge, Purge	GN_2	TBD	AMB	15	TBD	TBD		Purge
37.0	Aux. Propulsion Sys. GOX Charge, Fill	GO_2	1100 ± 100	AMB	25	3	75	Aft.$\frac{1}{2}$"	Fill
37.1	Aux. Propulsion Sys. GOX Charge, Purge	GN_2	TBD	AMB	45	TBD	TBD		Purge

5.0 PHYSICAL INTERFACE REQUIREMENTS

The ESS/GSE physical interface shall be as specified in the following paragraphs.

5.1 CONFIGURATION

The ESS/GSE physical interface shall be in accordance with Figure C-1.

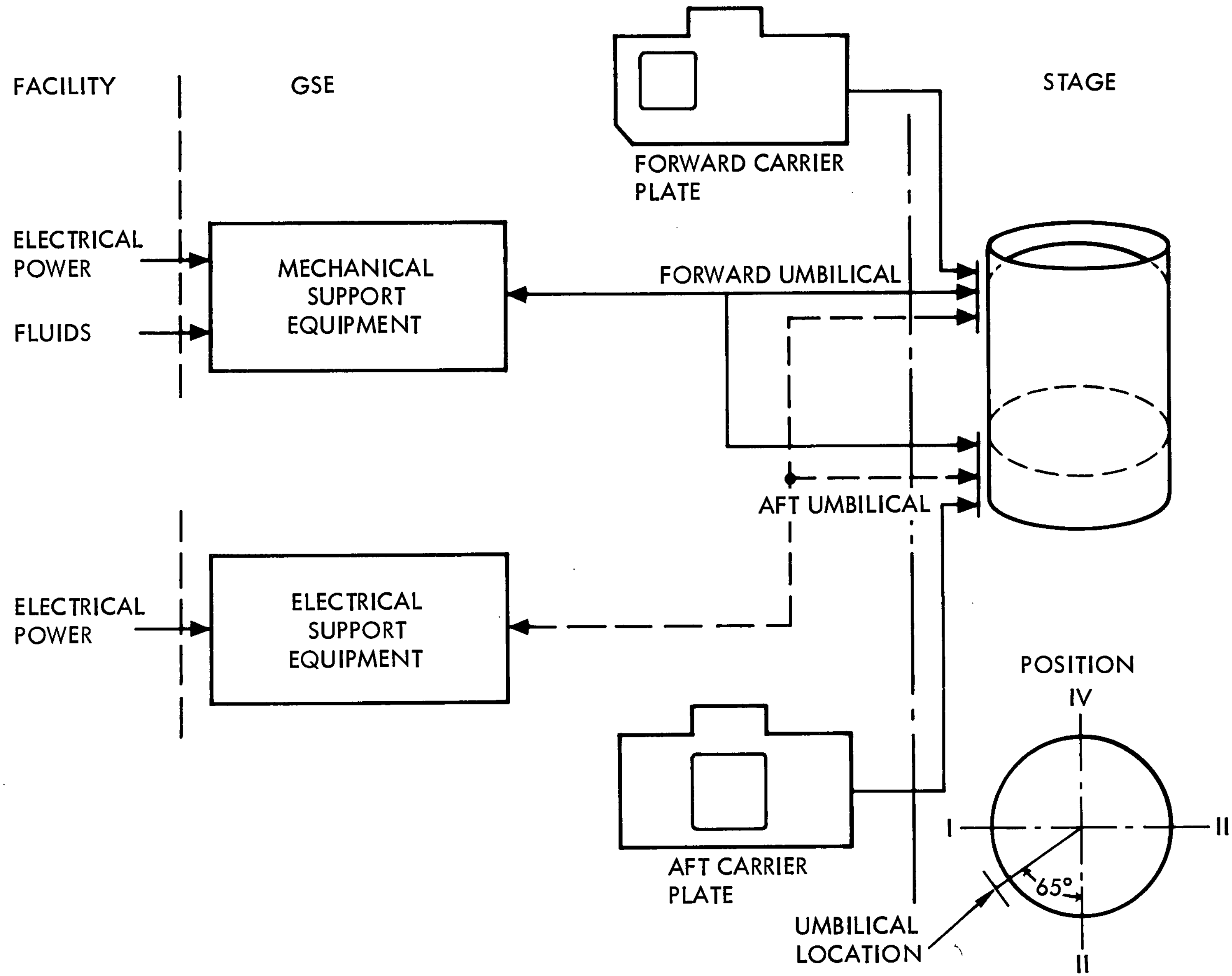


Figure C-1. Umbilical Locations

EXPENDABLE SECOND STAGE (ESS)/PAYLOAD INTERFACE REQUIREMENTS

(Drawing S080-1004)

SPACE DIVISION

NORTH AMERICAN ROCKWELL CORPORATION

INTERFACE CONTROL DRAWING

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1.0 SCOPE

This document specifies the functional, physical and procedural interfaces of the Expendable Second Stage (ESS) to the Payload of the Space Shuttle Booster/ESS Vehicle. It defines the requirements and criteria to be observed in the design of interfacing equipment.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

TBD

2.2 INTERFACE CONTROL DOCUMENTS

TBD

2.3 DRAWINGS

TBD

2.4 MANUALS AND HANDBOOKS

TBD

3.0 ABBREVIATIONS AND SYMBOLS

ESS	Expendable Second Stage
ICD	Interface Control Document/Drawings
NG and C	Navigation, Guidance and Control
SSB	Space Shuttle Booster
TBD	To Be Determined
VAB	Vertical Assembly Building
LUT	Launch Umbilical Tower

4.0 FUNCTIONAL REQUIREMENTS

The ESS/Payload functional interface defines the limits of fluid transfer, environmental and separation criteria as indicated by the following paragraphs.

4.1 ELECTRICAL REQUIREMENTS (None Identified)

4.2 STRUCTURAL REQUIREMENTS

4.2.1 Structure

The structural members of the ESS/Payload interface shall be capable of transferring the structural loads through the interface and shall be designed to meet or exceed the limit loads given in the following paragraphs using the permissible structural margins of safety.

4.2.2 ESS/Payload Interface Limit Loads (TBD)

Condition	Shear Bending Moment (KIPS)(IN-KIPS)	Longitudinal Compression (KIPS)	Longitudinal Tension (KIPS)
Max q and/or			
Period of max. load			

4.2.3 Venting, Structural Leakage, Drainage

4.2.3.1 Venting

The venting of the area shall be accomplished by TBD square inches maximum opening(s) on the Payload aft interstage.

4.2.3.2 Structural Leakage

Structural leakage in the ESS/Payload interface area, in excess of that listed in paragraph 4.2.3.1, shall be designed not to exceed the following:

a. In the ESS Forward Skirt area TBD square inches (equivalent)

b. In the Payload Aft Skirt are TBD square inches (equivalent)

4.2.3.3 Drainage

Drain holes in the ESS Forward Skirt area shall be plugged prior to launch.

4.3 CRITICAL ENVIRONMENTAL PARAMETERS

4.3.1 Temperature

Heating effects from protuberances as defined in ICD TBD shall be considered for ESS thermal design.

4.3.2 Pressure

The ESS/Payload interstage pressure shall not exceed the ESS LH_2 tank ullage pressure by more than 0.05 psi during all operations. The minimum ESS LH_2 tank ullage pressure occurs when the LH_2 vent valves are open (from start of LH_2 loading). The ullage pressure at this time will be TBD psi above atmosphere pressure.

4.3.2.1 Pressurization During Orbital Period

TBD (If Applicable)

4.4. SEPARATION PARAMETERS

4.4.1 General

The single plane mode of separation shall be used for the ESS/ Payload separation. The separation shall occur at the ESS/Payload station 856 plus 5 inches upon command from the ESS onboard computers after inserting the payload into its proper orbit.

4.4.1.1. Dynamic Separation Criteria

Initial conditions at physical separation:

1. Angle of attack = TBD degrees (max.) (If applicable)
2. Attitude error = TBD degrees (deviation from nominal vehicle attitude)
3. Attitude rate = TBD degrees/sec. (max.)

4.4.2 Separation Altitude

Separation altitudes shall be as defined in documents TBD.

4.4.3 ESS Venting During Separation

Disturbance caused by venting of the ESS propellant tanks during the ESS/Payload separation sequence shall be a maximum of TBD pounds.

4.4.4 Separation System Criteria

The separation system shall be redundant in ordnance initiation and shall be supplied 28 VDC power.

a. Live ordnance items shall be capable of being installed after vehicle assembly into final launch configuration on the launch pad.

b. The separation system design shall provide for verification of proper electrical function with or without live ordnance items installed.

c. The separation system shall be designed to receive signals from the ESS onboard computers for the separation sequence initiation.

d. Physical separation shall be accomplished by detonating linear shape charges using exploding bridgewire ordnance initiation techniques.

e. The EBW firing units shall be mounted in the forward skirt area.

4.5 FLUID REQUIREMENTS

4.5.1 GN_2 Purges

In order to inert the ESS/Payload interstage atmosphere and reduce the hazardous gas concentration, a GN_2 purge shall be required. The purge shall begin a minimum of 30 minutes prior to ESS propellant loading and shall terminate at liftoff. This purge shall meet the following requirements:

GN_2 shall be provided to the interstage area under the following conditions:

a. Inlet temperature TBD

b. Inlet pressure TBD

c. Flowrate TBD

A GN_2 purge of the ESS forward compartment electrical containers shall be initiated a minimum of 30 minutes prior to cryogenic conditioning and continued to liftoff, or continued for 30 minutes minimum after detanking.

4.5.2 Thermal Conditioning System

Cooling requirements of the NG and C systems to be established (if required).

5.0 PHYSICAL INTERFACE REQUIREMENTS

The ESS/Payload physical interface shall be in accordance with Figure D-1.

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6.0 PROCEDURAL REQUIREMENTS

6.1 ACCESSIBILITY

Access equipment provided for the ESS/Payload interstage area shall be designed to support the required operations in the interstage area involving a procedural interface. The access provisions shall be compatible with the following interface operations:

6.1.1 <u>ESS/Payload Mating</u>

After the ESS is mated to the Space Shuttle Booster, the payload required will then be transported to the transfer aisle, hoisted to vertical position, and transferred to the mating bay. The ESS and payload mating surfaces are inspected and verified prior to final positioning and mating. When performing ESS/Payload mating, a continuous internal access (TBD) is necessary.

6.1.2 <u>Platform Installations</u>

(Description of the access requirements for installation of platforms, the area and which station where platforms are to be installed). (If applicable).

6.1.3 <u>ESS LH_2 Tank Entry in the Stacked Condition</u>

(Description of the equipment and procedures utilized to perform job, and the precautions required shall be stated. Personnel safety procedures and safety equipment shall be listed.) (TBD)

6.2 ILLUMINATION

Lighting provisions shall be available in the interstage area for support of the ESS/Payload procedural operations. The lighting equipment shall be provided by the <u>NASA</u>.

6.3 ESS FORWARD BULKHEAD PROTECTION

(ESS forward bulkhead protection requirements resulting from interface operations. Procedures regarding installation of bulkhead protection devices shall be included).(TBD)

6.4 DE-MATING REQUIREMENTS

(Operations performed on the ESS or Payload that would require de-mating of Payload from the ESS.) (TBD)

6.5 ASSEMBLY AND DISASSEMBLY

6.5.1 <u>Interface Alignment</u>

Alignment procedures. TBD

6.5.2 <u>Ordnance Mating</u>

(Ordnance installation procedures, any special access requirements.) TBD

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Appendix E

SPACE SHUTTLE ORBITER/EXPENDABLE SECOND STAGE (ESS)

INTERFACE REQUIREMENTS
(S080-1005)

SPACE DIVISION

NORTH AMERICAN ROCKWELL CORPORATION

INTERFACE CONTROL DRAWING

TABLE OF CONTENTS

1.0 SCOPE

This document specifies the functional, physical and procedural interfaces of the Space Shuttle Orbiter/Expendable Second Stage (ESS). It defines the interface requirements of the Orbiter docking with the ESS for the removal of ESS main propulsion engines and avionics module by the orbiter manipulators after completion of the ESS boost mission. The criteria specified shall be a consideration in the design of the interfacing equipments.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

CP613M0003 Expendable Second Stage Preliminary CEI Part 1 Specification

2.2 INTERFACE CONTROL DOCUMENTS

TBD

2.3 MANUALS AND HANDBOOKS

TBD

2.4 DRAWINGS

TBD

3.0 ABBREVIATIONS AND SYMBOLS

ESS	Expendable Second Stage
ICD	Interface Control Document/Drawing
SSB	Space Shuttle Booster
LUT	Launch Umbilical Tower
TBD	To Be Determined
VAB	Vertical Assembly Building
n.m.	Nautical Mile
BPS	Bits Per Second
ACPS	Attitude Control Propulsion System
OMS	Orbital Maneuvering System

4.0 FUNCTIONAL REQUIREMENTS

4.1 ELECTRICAL REQUIREMENTS (None)

4.2 STRUCTURAL REQUIREMENTS

4.2.1 Structural Loads

The Orbiter/ESS interface structure shall be designed to withstand the load conditions shown in Table TBD.

4.2.2 Manipulator Arms Loads

The manipulator arms shall be designed to withstand the load conditions as shown in Table TBD.

5.0 PHYSICAL REQUIREMENTS

The physical details of the interface between the Orbiter's docking adapter and the ESS docking area and engine recovery attach points shall be as shown in Figures E-1 through E-4.

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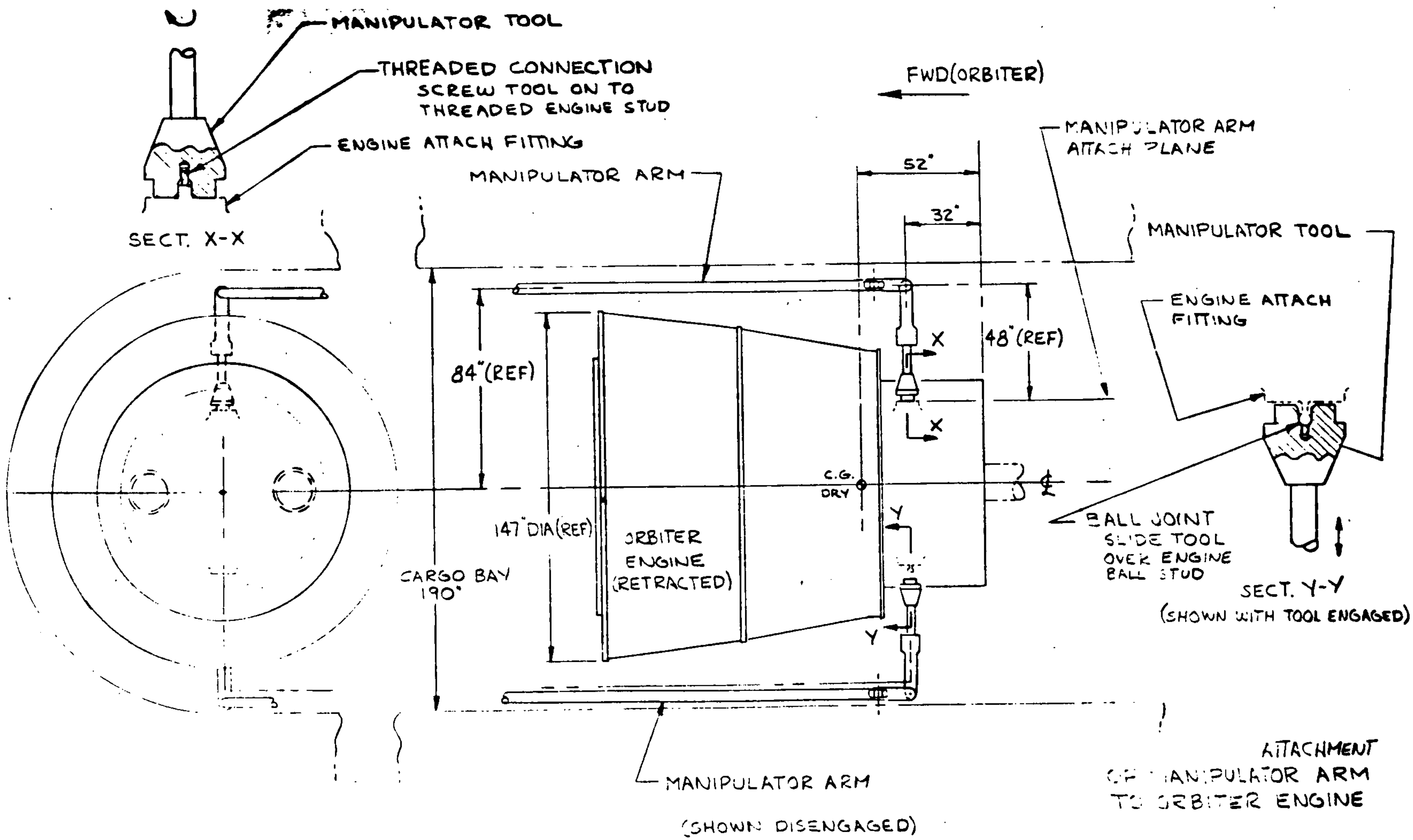

Figure E-2. Manipulator Arm Attachment to Orbiter Engine

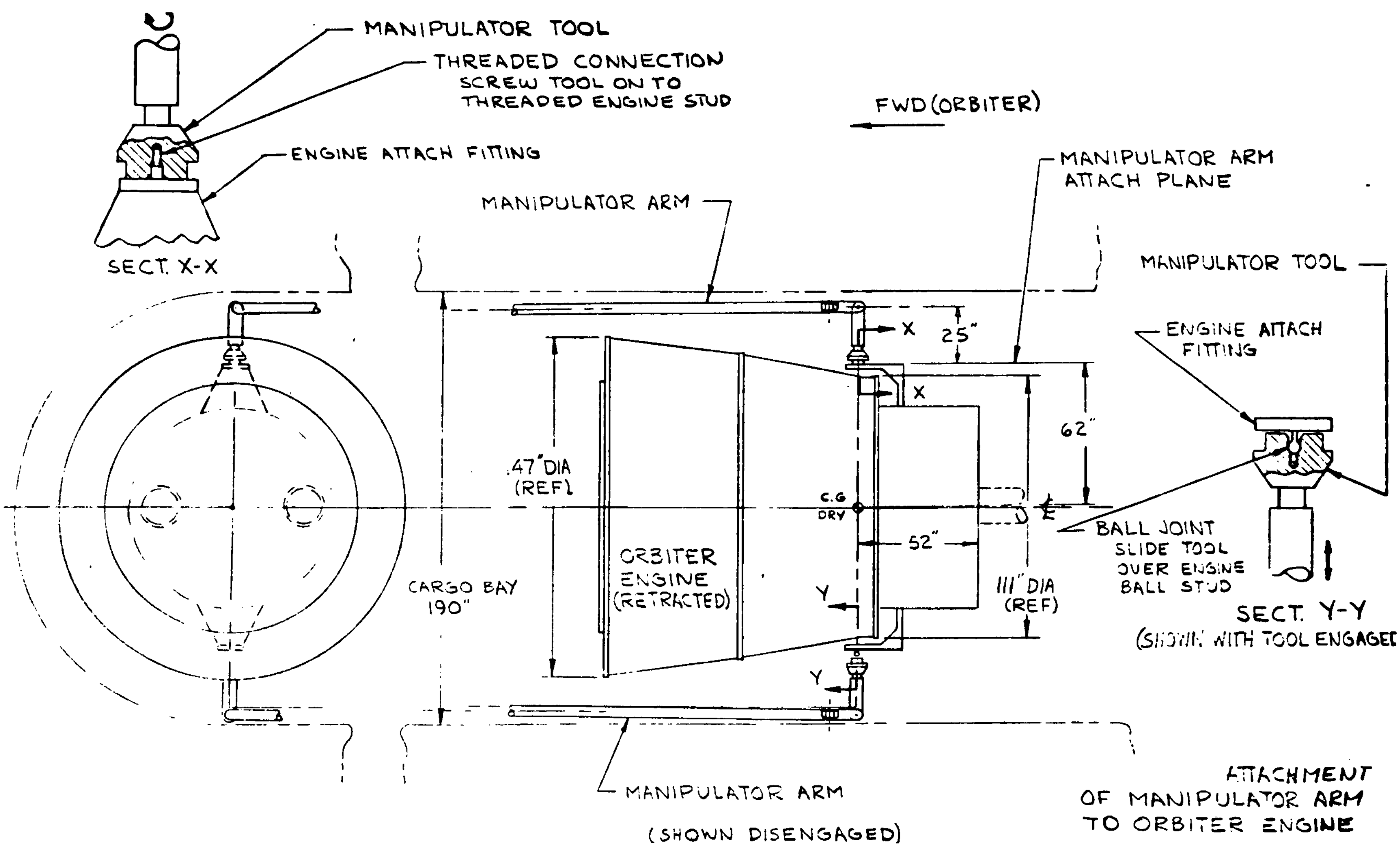

Figure E-3. Manipulator Arm Attachment to Orbiter Engine

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6.0 PROCEDURAL REQUIREMENTS

6.1 RENDEZVOUS

The Orbiter guidance method shall be self targeting and shall be in command during rendezvous. The Orbiter shall perform all translational and attitude maneuvers required to accomplish rendezvous. The maneuver times and steering commands required to achieve rendezvous with the ESS shall be computed on board the Orbiter with only the knowledge of the present state of the Orbiter and the ephemeris of the ESS.

Completion of rendezvous shall be defined as occurring when (1) the Orbiter is TBD feet from the ESS, and (2) there is no greater than TBD feet per second differential velocity between the Orbiter and the ESS.

Until the completion of rendezvous the ESS shall maintain a circular orbit at TBD nm., TBD degrees inclination with accuracies shown in Table TBD . The ESS attitude shall be TBD with accuracies shown in Table TBD . The ESS docking aids and transponder shall be activated by command from the Orbiter.

6.2 STATION KEEPING

The Orbiter shall be in command of ESS station keeping when close rendezvous conditions exist. During station keeping, the ESS shall maintain a circular orbit of TBD nm., TBD inclination with accuracies shown in Table TBD . The ESS attitude shall be TBD with accuracies shown in Table TBD .

6.3 DOCKING

The Orbiter shall be in command during docking operations and shall proceed as follows:

1. The Orbiter shall establish the position and attitude relations shown in Table TBD

2. The Orbiter manipulators shall be activated for removing the docking adapter from the cargo bay and attach it to the ESS docking area.

3. The manipulators shall then draw the ESS and Orbiter together.

4. The docking adapter shall engage the Orbiter's airlock docking port and terminate docking.

Prior to the attachment of the docking adapter to the ESS, the ESS shall be in a circular orbit at TBD nm., TBD inclination, with accuracies shown in Table TBD ; the ESS attitude shall be TBD, with accuracies as shown in Table TBD. There shall be neither translational nor attitude thrusting by the ESS between the attachment of the docking adapter to the ESS and the termination of docking.

At the moment when the docking adapter engages the Orbiter's airlock docking port, the following errors shall not be exceeded:

a. Centerline miss distance: TBD

b. Miss angle: TBD

c. Longitudinal velocity: TBD

d. Lateral velocity: TBD

e. Angular velocity: TBD

6.4 ORBITER/ESS DOCKED

Docking verification shall be performed by the Orbiter, upon verification of docking, the Orbiter shall be in command and provide attitude control of the docked cluster.

The docked cluster shall maintain a circular orbit at TBD nm., TBD inclination with accuracies shown in Table TBD ; the cluster attitude shall be TBD with accuracies shown in Table TBD.

6.5 EQUIPMENT RECOVERY

6.5.1 Main Propulsion Engine Recovery

After the ESS and Orbiter are docked and verified, the ESS main propulsion engine removal sequence shall be as follows:

1. Initiate the discharge of the majority of the engine separation nuts. (Safety considerations may dictate this be accomplished prior to docking.)

2. If required, change the manipulator tool for engine removal.

3. Attach the manipulator arms to the engine attach points and initiate the discharge of the remaining engine separation nuts. With the manipulator arms still attached to the engine, remove engine from the ESS and stow it in Orbiter cargo bay.

4. Repeat procedure for the remaining engine.

6.5.2 Avionics Modules Removal

Upon completion of engine removal, the avionics modules are removed and stored in the Orbiter cargo bay. (Sequence TBD)

6.6 UNDOCKING

The ESS and Orbiter shall remain docked until ESS deorbit preparations are initiated. Final deorbit attitude orientation of the ESS will be maneuvered by the docked Orbiter ACPS.

The Orbiter shall be in command during undocking. Undocking shall proceed in the reverse of the sequence described in Paragraph 6.3. There shall be neither translational nor attitude thrusting by the ESS between initiation of undocking and physical uncoupling of the Orbiter and the ESS. Upon verification of Orbiter/ESS physical separation, the Orbiter shall activate the ESS control system for ESS de-orbiting operations. The Orbiter shall maneuver away from the ESS a minimum of TBD feet before starting its main engines or ESS OMS engines.

6.7 RF COMMUNICATIONS

The ESS shall be capable of transmitting data at a frequency of TBD MH_z to the Orbiter and receiving data from the Orbiter at a frequency of TBD MH_z at a rate of TBD BPS maximum.

The ESS shall be capable of responding to the tracking signals generated by the Orbiter at frequencies defined in the above paragraph.