Space Shuttle Program

MSC-03321

FINAL SUBMITTAL

(NASA-CR-128663) EXPENDABLE SECOND STAGE
REUSABLE SPACE SHUTTLE BOOSTER. VOLUME
8: PRELIMINARY CEI SPECIFICATION, PART
1 Final (North American Rockwell Corp.)
25 Jun. 1971 99 p CSCL 22B

N73-14874

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Phase B Final Report
Expendable Second Stage
Reusable Space Shuttle Booster
Volume VIII. Preliminary CEI Specification — Part 1

Contract NAS9-10960, Exhibit B
DRL MSFC-DRL-221, DRL Line Item 6
DRD MA-078-U2
SD 71-140-8
25 June 1971

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

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Approved by

fn B. Hello
Vice President and General Manager
Space Shuttle Program

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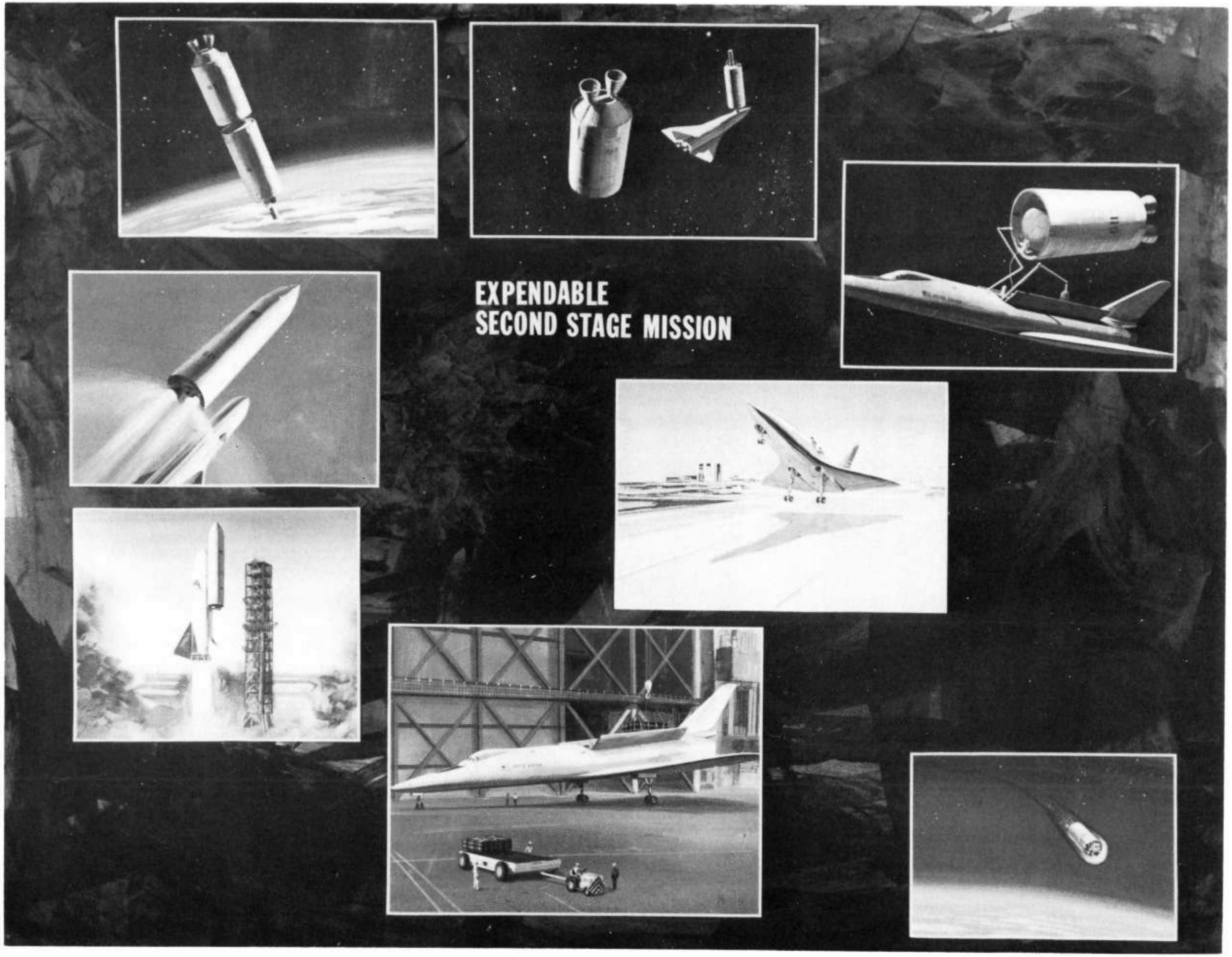
EXPENDABLE
SECOND STAGE MISSION

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.

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1.0 INTRODUCTION

This volume contains the Contract End Item (CEI) Part 1 specifications necessary to define hardware end items required by the expendable second stage on a reusable shuttle booster system (Specification No. SS613M0002). Appendixes A through C provide:

Appendix A—Expendable Second Stage, Part 1 CEI Specification, for Specification No. CP613M0003

Appendix B—Space Shuttle Booster, Part 1 CEI Specification, for Addendum A, Specification No. 76Z0500

Appendix C—Space Shuttle Ground Support System, Part 1 CEI Specification, for Addendum A, Specification No. 76Z0501

2.0 CEI SPECIFICATION REQUIREMENTS

Data Requirements Description (DRD) CM-007M, dated November 10, 1969, establishes the requirements for the preparation and submittal of Specification, CEI, Part 1 in accordance with MIL-STD-490, Appendix II, for prime equipment items. Volume IX, Preliminary System Specification, Expendable Second Stage, Reusable Space Shuttle Booster (Specification No. SS613M0002), contains Figure 4, which requires the CEI specifications contained in this volume.

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3.0 PREPARATION OF CEI SPECIFICATION

The primary CEI specification for the ESS/RSB system is that for the expendable second stage, and it appears in its entirety in Appendix A.

The CEI specifications for the booster and ground support system are presented as addenda to the basic specifications of the space shuttle system. These addenda have been prepared not for end items that are separate and distinct from the basic items, but so the basic specifications could be changed to provide for both the basic space shuttle and the expendable second stage on a reusable shuttle booster system. The changes made by these addenda are very minor modifications to the basic space shuttle end items.

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3.1.1.2.5	Propellant Tank Pressurization and Venting. Deleted specific ullage pressure limits and referred to figures for tank pressure limits. Replaced J-2 engine heat exchanger and re-pressurant performance data with comparable orbiter engine pressurant-gas conditions specified in the orbiter engine ICD.	A-32
3.1.1.2.6	Compartment and Component Conditioning. Revised to reflect absence of interstage and modified engine compartment configuration.	A-35
3.1.1.2.7	Flight Control. Retitled Thrust Vector Control and completely revised to reflect independent TVC systems for each main and OMS engine, including electric motor-driven pump requirement for orbiter engine hydraulic-power usage and hydraulic power for OMS engine gimbaling. The requirement is specified for an orbiter engine power takeoff for main engine TVC power, which is not currently specified in the orbiter engine ICD. Detailed S-II flight control criteria including propellant slosh data and second-stage bending data is deleted.	A-36
3.1.1.2.8	Electrical and Electronic Systems. Retitled Avionics and expanded to include the additional requirements of GN&C and data and control management formerly accomplished by the IU. Electrical power and communication requirements are revised to reflect the ESS power loads and communication system characteristics. The emergency detection requirements are not yet defined and the range safety command requirements remain the same as on S-II.	A-38
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	f. Excluded detailed listing of design, method, and material documents	
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5.0	PREPARATION FOR DELIVERY — No change.	A-82

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INTRODUCTION

1.0 SCOPE

1.1 This specification establishes the requirements for the performance, design, development and test of the Expendable Second Stage Contract End Item. The requirements specified herein are based on the mission requirements and three baseline payload configurations specified in the Statement of Work and the ESS Study Control Document, revised May 5, 1971 except that requirements associated with the rendezvous option are also included. This specification does not include specific requirements associated with 11 other candidate payloads; however, in general, these candidates are believed to lie within the allowable envelope of this specification.

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2.0 APPLICABLE DOCUMENTS

2.1 TBD. The definition of all applicable documents is contingent upon further development of the ESS design. Refer to Paragraph 2.0 of S-II CEI Specification CP621M0014A for a representative listing of documents which will be applicable to the ESS.

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Characteristics. The ESS shall be designed to provide controlled boost, orbit insertion, orbit circulization and orbit transfer (as required) of the payloads defined in Figure 3-1. The ESS shall be

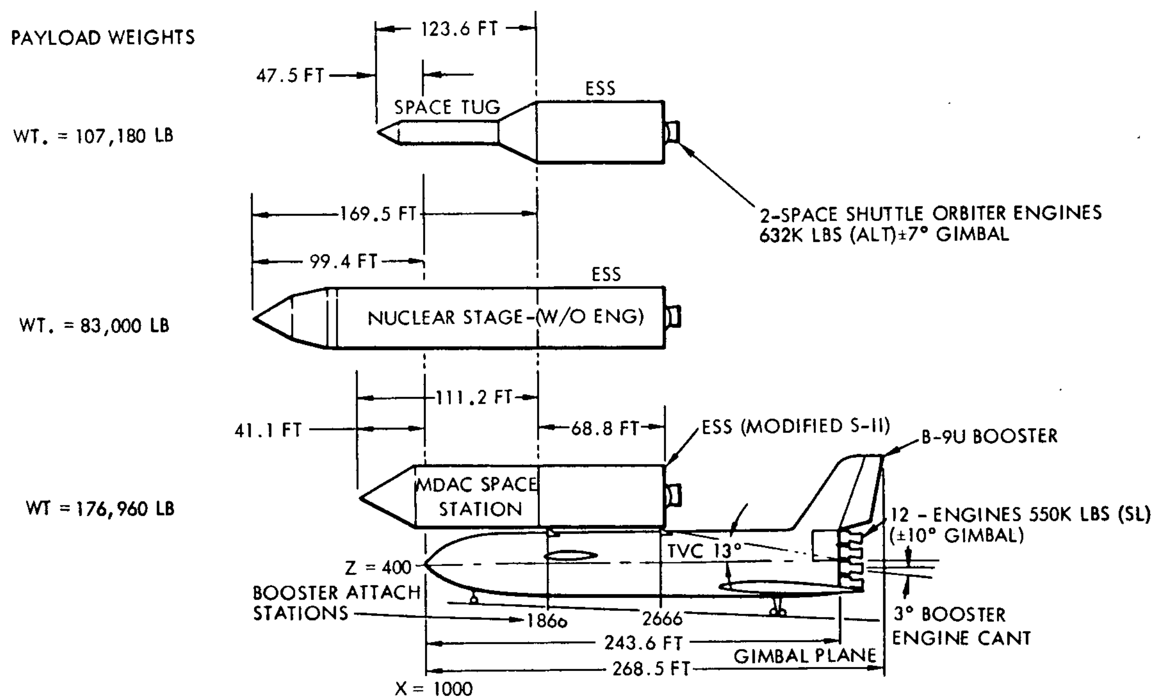

Figure 3-1. Booster/ESS Configuration With Specified Payloads

designed to interface with other parts of the Space Shuttle Transportation System as defined in Figure 3-1. The ESS shall accomplish its missions utilizing government-furnished, shuttle-orbiter engines for main propulsion and shuttle developed components and engines for auxiliary propulsion. The ESS shall be capable of receiving, storing, and distributing liquid hydrogen and liquid oxygen required as propellants for the propulsion systems. The ESS shall provide all vehicle guidance, navigation, and control subsequent to separation from the shuttle booster. The ESS shall be designed to transmit by RF link, data for flight system evaluation. The ESS shall be designed for an on-orbit life of 24 hours and shall provide the capability for stage safing, orbit rendezvous (as required)*, and the recovery and deorbit of the main propulsion engine and avionics.

3.1.1.1 Primary Performance Characteristics

3.1.1.1.1 Structures. The ESS shall be designed with a structure that will support the loads as defined in Paragraph 3.1.1.2.1.

3.1.1.1.2 Separation Systems

3.1.1.1.2.1 Separation Criteria. The ESS shall be capable of in-flight separation from the Space Shuttle Booster as specified in Paragraph 3.1.1.2.2.

3.1.1.1.3 Main Propulsion Propellant Control Systems. The ESS shall be designed to control propellants as a function of the following:

3.1.1.1.3.1 Propellant Management. The propellant management system design shall incorporate capacitance probes and associated electronics to provide signals for main-tank propellant mass indication. The propellant management system design shall provide for a subsystem consisting of discrete sensors and associated electronics for initiating engine cutoff when either main propellant tank reaches depletion level. The propellant management system design shall incorporate point sensors to provide backup control signals for propellant loading.

3.1.1.1.3.2 Propellant Feed, Fill and Drain. The ESS shall be designed to supply liquid oxygen and liquid hydrogen to the two main propulsion engines. The ESS shall be designed for propellant tank filling and draining within the design fill and drain rates listed in Table 3-1.

3.1.1.1.3.3 Slosh and Vortex. The ESS shall provide a suitable method for damping of liquid oxygen tank propellant sloshing during shuttle boost for the range of oxidizer loadings between (TBD) to 587,322 pounds. The ESS shall provide a suitable method to control vortex action in the liquid oxygen tank to assure minimum residuals at engine cutoff under static firing or flight conditions.

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* Rendezvous is an optional capability per NASA MSFC Technical Directive No. 506, dated May 10, 1971, and is included throughout this specification for completeness.

Table 3-1. Propellant Servicing Requirements

Propellant	Servicing Mode	Servicing Rates (gallons/min)	Pressure Req'd at GSE Interface* (psig)
LO_2	Slow fill	475 to 525	TBD
	Fast fill	4850 to 5150	TBD
	Replenish	0 to 100	TBD
	Drain	3300 to 3360	10**
LH_2	Slow fill	950 to 1050	TBD
	Fast fill	9700 to 10,300	TBD
	Replenish	0 to 500	TBD
	Drain	6600 to 6740	11.4**

*The GSE interface is the inlet to the GSE part of the propellant fill disconnect coupling.

**Back pressure at the drainage flow rate shall be less than the values shown.

3.1.1.1.4 Engines. The ESS shall be designed to use two government-furnished space shuttle orbiter engines for the main propulsion system. Main propulsion engine system stage requirements are defined in Paragraph 3.1.1.2.4.

3.1.1.1.5 Pressurization. The ESS shall be designed to include pressurization for the main propellant tanks, for propellant and vent valve actuation, and for hydrogen pressurant-line purging. The system shall have the capability of prepressurizing the main propellant tanks using a ground source. Propellant tank pressure switches shall be of the calips type.

3.1.1.1.6 Compartment and Component Conditioning

3.1.1.1.6.1 Engine Compartment Conditioning. The engine compartment of the ESS is defined as the volume enclosed by the aft LO_2 tank bulkhead and the heat shield. The ESS shall be designed to provide engine compartment conditioning by maintaining an explosively inert and thermally controlled atmosphere with ground-supplied and controlled purge gas.

3.1.1.1.6.2 Thermal Control. The ESS shall be designed to provide thermal protection for thermally sensitive systems, subsystems, assemblies, and subassemblies during ESS ground and flight operations.

3.1.1.1.7 Thrust Vector Control. The ESS shall be designed to provide and maintain directional control during flight by gimbaling the two main propulsion engines or the two orbit maneuvering engines as commanded by the guidance, navigation, and control subsystem.

3.1.1.1.8 Avionics Systems

3.1.1.1.8.1 Electrical Control. The ESS shall be designed to provide electrical control for each of the stage subsystems.

3.1.1.1.8.2 Electrical Power. The ESS shall be designed to provide electrical power from battery sources to using subsystems for flight operations. The ESS shall be capable of operation with power from an external source for ground operations.

3.1.1.1.8.3 Emergency Detection. (TBD)

3.1.1.1.8.4 Communications. The ESS shall be designed to acquire data by use of various measuring devices which provide outputs proportional to parameters measured. Data shall be transmitted to the ground by telemetry. The communications subsystem shall also include a dual secure range safety command system. The communications subsystem design shall include an antenna installation for transmission of radio frequency signals and for reception of radio command signals.

3.1.1.1.8.5 Static Firing Instrumentation. The ESS shall include installation provision for hardwire transmission during static firing and ground checkout.

3.1.1.1.8.6 Data and Control Management. The ESS shall be designed to provide a computerized means of integrating, managing, and controlling the ESS vehicle.

3.1.1.1.8.7 Guidance, Navigation, and Control. The ESS shall be designed to accomplish vehicle guidance, navigation, and control following booster separation and through stage de-orbit.

3.1.1.1.9 Propellant Dispersion. The ESS shall have the capability of accomplishing dispersion of liquid hydrogen and liquid oxygen on opposite sides of the vehicle. This function shall be accomplished in accordance with AFETRM 127-1.

3.1.1.1.10 Structure and Insulation Purge. The ESS shall be designed to have provisions for purging of hydrogen and/or oxygen leakage in the insulation or structural areas where propellant leakage or air liquefaction could create a hazardous condition.

3.1.1.1.11 Standby Time. The ESS shall be capable of successful operation, as part of the Space Shuttle launch vehicle, after a standby time of TBD hours. Standby time shall be defined as that period of time from initial completion of ESS propellant tanking to liftoff.

3.1.1.1.12 Orbital Safing. The ESS shall incorporate auxiliary tank venting systems to safe the main LH_2 tank and LO_2 tank after orbital insertion. The main LH_2 and LO_2 tanks shall be vented through a non-propulsive vent system.

3.1.1.1.13 Auxiliary Propulsion System (APS). The ESS shall contain an auxiliary propulsion system to provide the dual function of orbit maneuvering and attitude control. In the orbit maneuvering mode, the system shall provide the velocity increments necessary for orbit circularization, transfer, rendezvous (if required) and de-orbit. The requirements of the APS orbital maneuvering mode are:

On-orbit Delta V (including rendezvous)	670 fps (ESS plus Payload)
De-orbit Delta V	550 fps (ESS only)

The attitude control operating mode shall provide the required capability to establish and maintain a desired vehicle orientation during all mission phases from orbit insertion through de-orbit. In addition, the attitude control function shall provide braking thrust for rendezvous and shall provide the capability for roll control during mainstage boost with one engine out. The functional requirements of the APS attitude control mode are as shown in Table 3-2.

Table 3-2. APS Attitude Control Function Requirements

Axis	Acceleration
Yaw	TBD (Deg/sec^2)
Pitch	TBD
Roll	TBD
$\bar{X}$	TBD
$\bar{Y}$	TBD
$\bar{Z}$	TBD

3.1.1.1.14 Payload Deployment. The ESS shall provide for the safe deployment of the payloads defined in Figure 3-1.

3.1.1.2 Secondary Performance Characteristics

3.1.1.2.1 Structural Design. The ESS shall be designed as a self-supporting structure and shall support and withstand the following loads:

3.1.1.2.1.1 Propellant and Pressurization Loads. The ESS structure shall be capable of withstanding the tank pressurization and propellant loads presented below. The ultimate maximum internal pressure loads specified herein shall be combined with the appropriate ultimate externally applied loads specified elsewhere in Paragraph 3.1.1.2.1 when the resulting stresses are additive. For tank wall ultimate design compression loading, limit minimum internal pressure loads specified herein shall be combined with the appropriate ultimate externally applied loads specified elsewhere in Paragraph 3.1.1.2.1 when the pressure loads relieve the body loads. The effects of propellant hydrostatic or dynamic head shall be included where applicable. The design of the common bulkhead shall be based on the maximum propellant tank ullage pressure in one tank, defined as the upper limit of the prelaunch pressure switch setting, in combination with the minimum prelaunch pressure in the other propellant tank.

3.1.1.2.1.1.1 Pressurization Loads. The ESS structural design shall be based on the maximum and minimum tank ullage pressures experienced during the following structural loading environments. Ambient atmospheric pressures to be used with these environments shall be based on the design atmosphere of Paragraph 3.1.2.4.1.1.

Prelaunch. The maximum tank ullage pressures shall be 36.0 psia for the liquid oxygen tank and 36.0 psia for the liquid hydrogen tank. The minimum tank ullage pressure for both the liquid oxygen and the liquid hydrogen tank shall be 14.7 psia.

Shuttle Boost and ESS Boost. The maximum and minimum ullage pressures shall be as specified in Figures 3-2 and 3-3 for the liquid hydrogen tank, and Figures 3-4 and 3-5 for the liquid oxygen tank.

On-Orbit and De-Orbit. The ullage pressure for both tanks shall bleed down to the surrounding atmosphere (tanks vented).

3.1.1.2.1.1.2 Propellant Loads. The ESS structure design shall be based on propellant loading consistent with 687,049 pounds of cryogenic propellant. The total liquid oxygen loading in the liquid oxygen propellant tank shall be a maximum of 587,322 pounds. The total liquid hydrogen loading in the liquid hydrogen propellant tank shall be a maximum of 99,727 pounds. The ESS shall be capable of loading the propellant tanks after preconditioning of the liquid hydrogen tank to the requirements of Paragraph 3.2.1.5.3.1 and chilling the aft facing sheet of the common bulkhead to -100°F or lower by filling the liquid oxygen tank to the 40-percent level. The ESS shall be capable of tank pressurization in any sequence after propellant loading is complete.

3.1.1.2.1.2 Prelaunch Loads. The ESS shall be designed to withstand the shuttle/ESS vehicle prelaunch load condition of free standing shear and bending moment distributions resulting from 99-percentile ground winds at Cape Kennedy, Florida for a one-day exposure per NASA TMX-53872, with the vehicle fueled and pressurized. The ESS shall be designed to withstand loads resulting from 99-percentile ground winds for a 14-day exposure with the vehicle unfueled and unpressurized. The ESS fueled or unfueled shall withstand a 0.4-psig peak blast overpressure with the main propellant tanks pressurized and with 99-percentile ground winds (for one day exposure). The 0.4-psig overpressure shall be combined as a uniform circumferential compressive type loading on a panel with the shear and bending moment distributions due to ground winds. The liquid hydrogen tank shall be pressurized to not less than 4 psig, and the liquid oxygen tank shall be pressurized to not less than 4 psig to withstand the 0.4-psig peak blast overpressure. The ESS shall be designed to withstand loads applied at the propellant fill line attach points as indicated in Figures 3-6 and 3-7 and at the umbilical attach point as indicated in Figure 3-8.

3.1.1.2.1.3 Launch Loads. The ESS shall be designed to withstand the steady state launch loads resulting from 99 percentile winds for a one day exposure per NASA TMX-53872 and dynamic launch loads for the

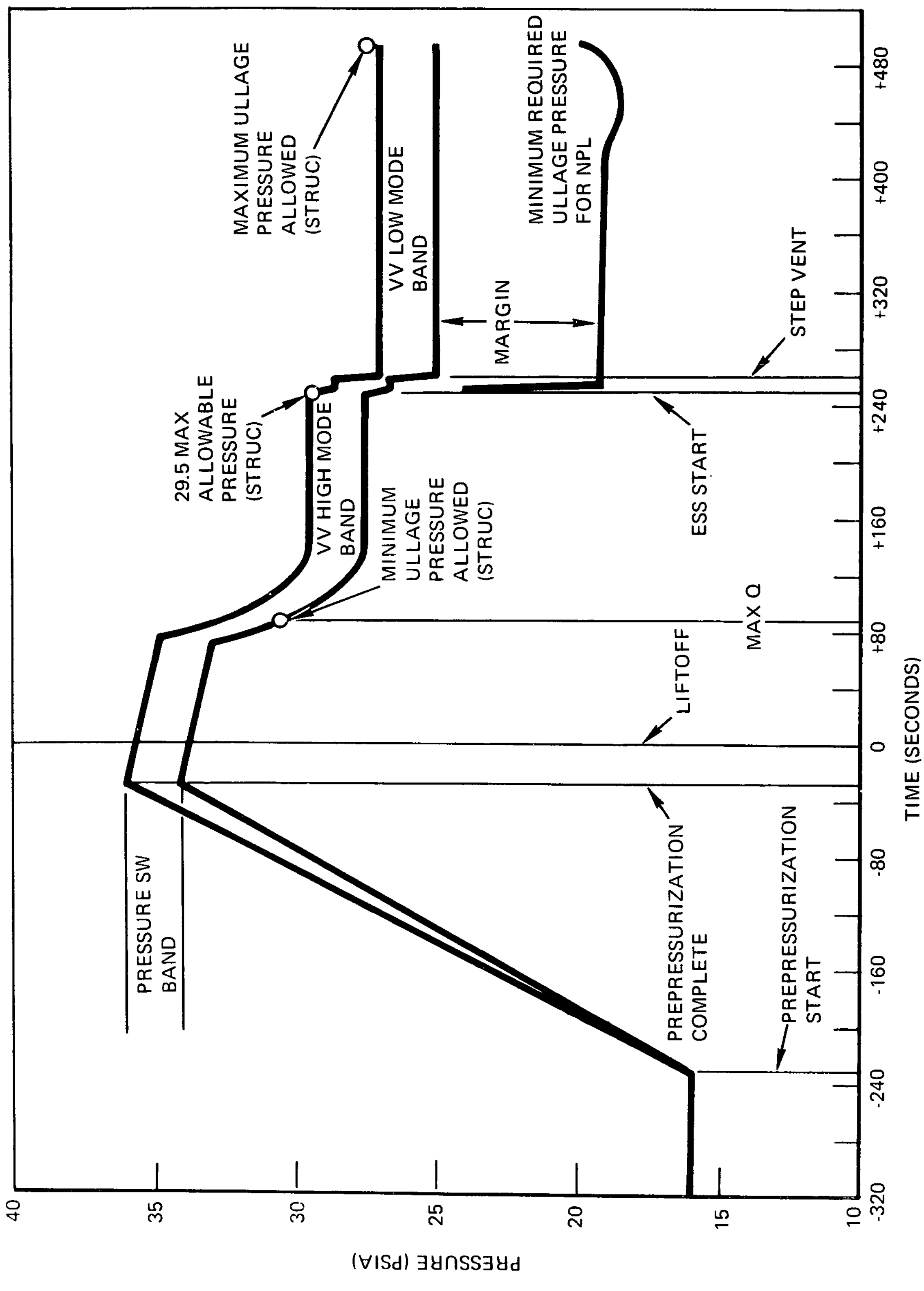


Figure 3-2. ESS LH_2 Tank Ullage Pressure—675,000 Propellant Loading

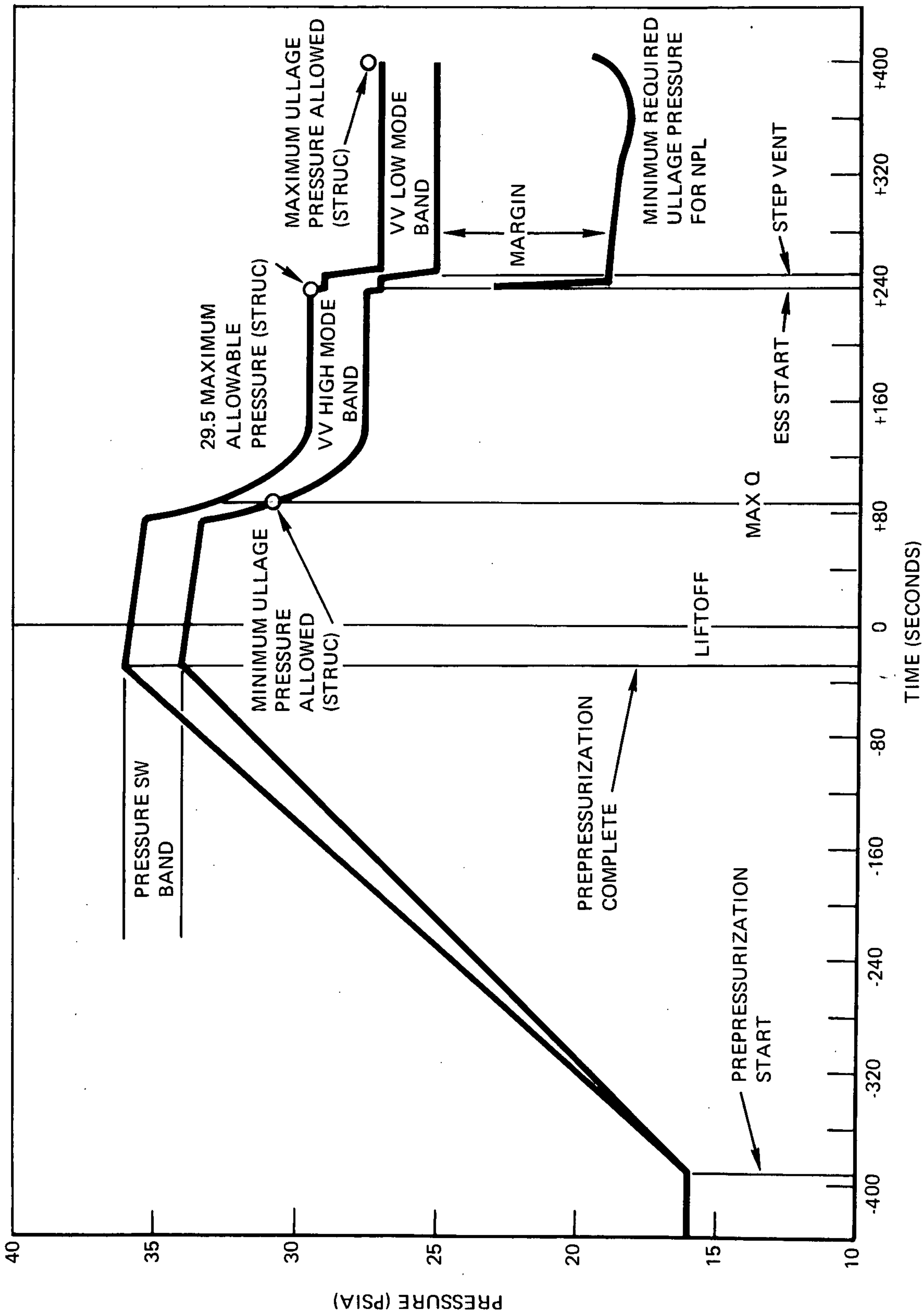


Figure 3-3. ESS LH_2 Tank Ullage Pressure—450,000 Propellant Loading

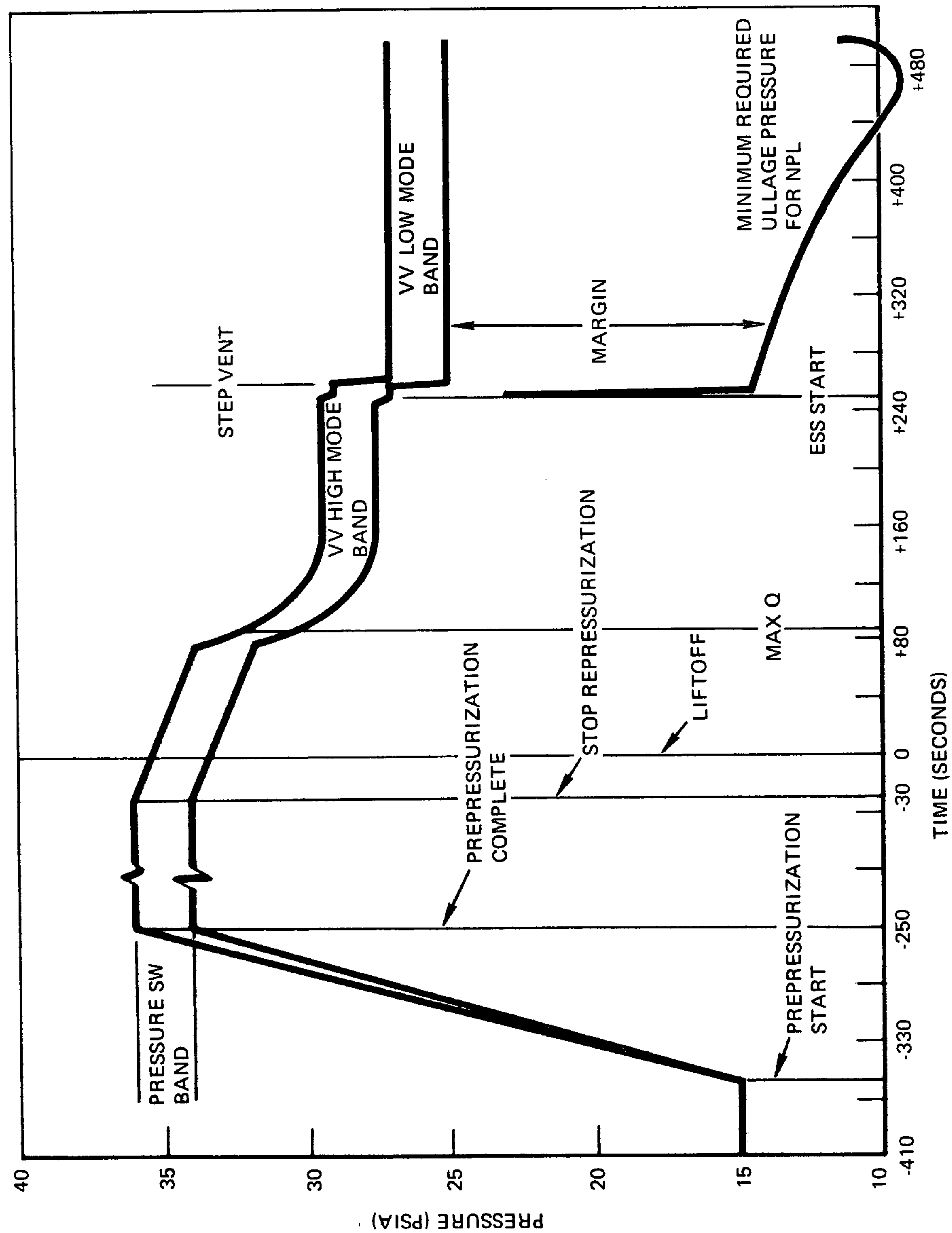


Figure 3-4. ESS LO_2 Tank Ullage Pressure—675,000 Propellant Loading

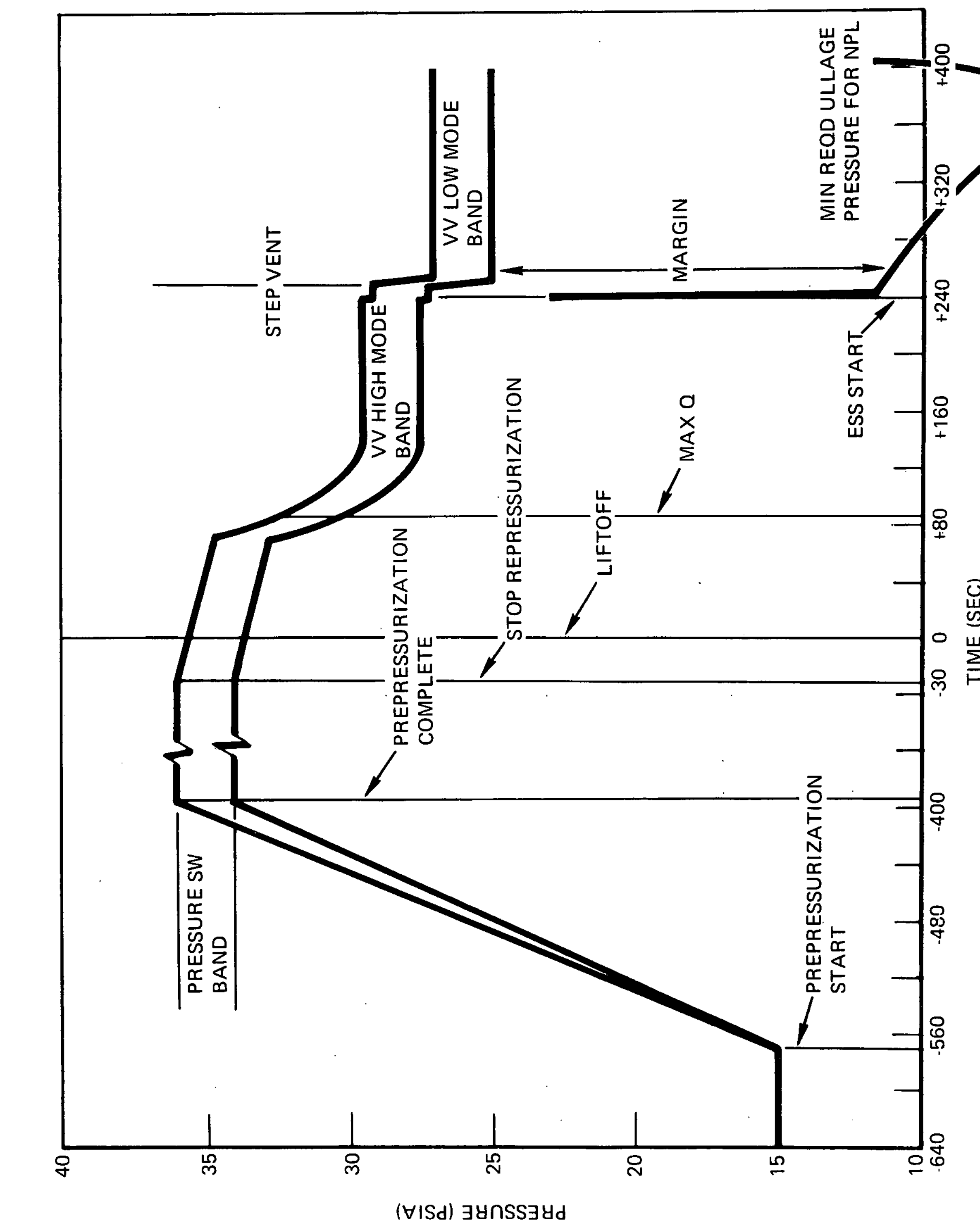
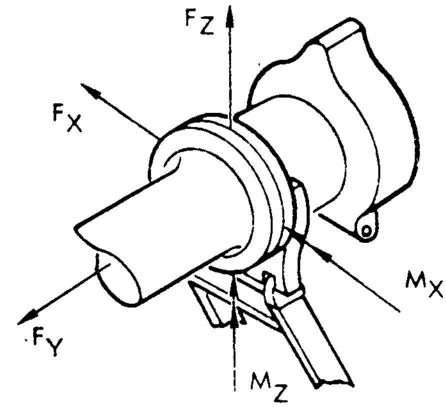


Figure 3-5. ESS LO_2 Tank Ullage Pressure—450,000 Propellant Loading

LO_2 LINE (LIMIT LOADS)

LOADS ARE APPLIED AT KSC/MSFC INTERFACE



PRE-LAUNCH

LOADING	F_Y (LB)	F_Z (LB)	F_X (LB)	M_Z (IN-LB)	M_X (IN-LB)
PROPELLANT MOMENTUM & INTERNAL PRESSURE	4300	-70	0	0	-2110
DEAD LOAD OF LINES & PROPELLANT	730	-230	0	0	-7420
WIND LOAD	±80	0	∓20	±640	0
TOTAL	5100	-300	-20	±640	-9530

LAUNCH

LOADING	F_Y (LB)	F_Z (LB)	F_X (LB)	M_Z (IN-LB)	M_X (IN-LB)
DEAD LOAD OF LINES	440	-170	0	0	-6300
PRIMARY LANYARD	②	230	0	0	1550
SECONDARY LANYARD	②	-693	0	0	-4660
WIND LOAD	±80	0	∓20	±640	0
VIBRATION ① ③	±705	±1678	±1678	∓14889	±20776

NOTES: ① VIBRATION LOADS IN X, Y & Z DIRECTION ARE USED INDEPENDENTLY ~ X DIR. USE F_X & M_Z, Y DIR. USE F_Y, Z DIR USE F_Z & M_X.

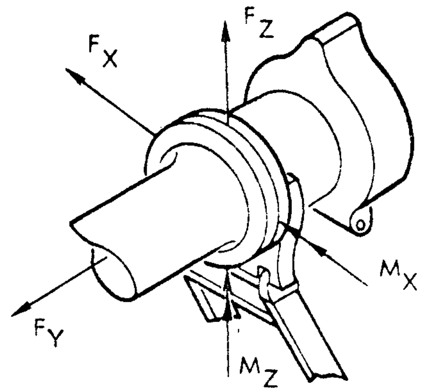
② 400 # LOAD IS APPLIED AT RELEASE COLLET OF COUPLING

③ VIBRATION LOADS INCLUDE EFFECT OF 19# LANYARD BRACKET.

Figure 3-6. ESS LO_2 Fill Line Attach Point Loads

LH$_2$ LINE (LIMIT LOADS)

LOADS ARE APPLIED AT KSC/MSFC INTERFACE



PRE-LAUNCH

LOADING	F_Y (LB)	F_Z (LB)	F_X (LB)	M_Z (IN-LB)	M_X (IN-LB)
PROP. MOMENTUM & INTERNAL PRESSURE	2370	350	0	0	11100
STATIC WT OF LINES & PROPELLANT	420	-110	0	0	-3490
WIND LOAD	±80	0	∓20	±640	0
TOTAL	2870	240	∓20	±640	7610

LAUNCH

LOADING	F_Y (LB)	F_Z (LB)	F_X (LB)	M_Z (IN-LB)	M_X (IN-LB)
STATIC WT OF LINES	420	-110	0	0	-3490
PRIMARY LANYARD	②	230	0	0	1550
SECONDARY LANYARD	②	-693	0	0	-4660
WIND LOAD	±80	0	∓20	±640	0
VIBRATION ① ③	±394	±539	±539	∓4758	±6530

NOTES: ① VIBRATION LOADS IN X, Y, & Z DIRECTION ARE USED INDEPENDENTLY ~ X DIR. USE F_X & M_Z, Y DIR. USE F_Y, Z DIR. USE F_Z & M_X

② 400 # AT COUPLING RELEASE COLLET

③ VIBRATION LOADS INCLUDE EFFECT OF 19# LANYARD BRACKET.

Figure 3-7. ESS LH$_2$ Fill Line Attach Point Loads

LOAD	FORWARD UMBILICAL	AFT UMBILICAL
F_1 (LB)	340	340
F_2 (LB)	523	438
F_3 (LB)	710	250

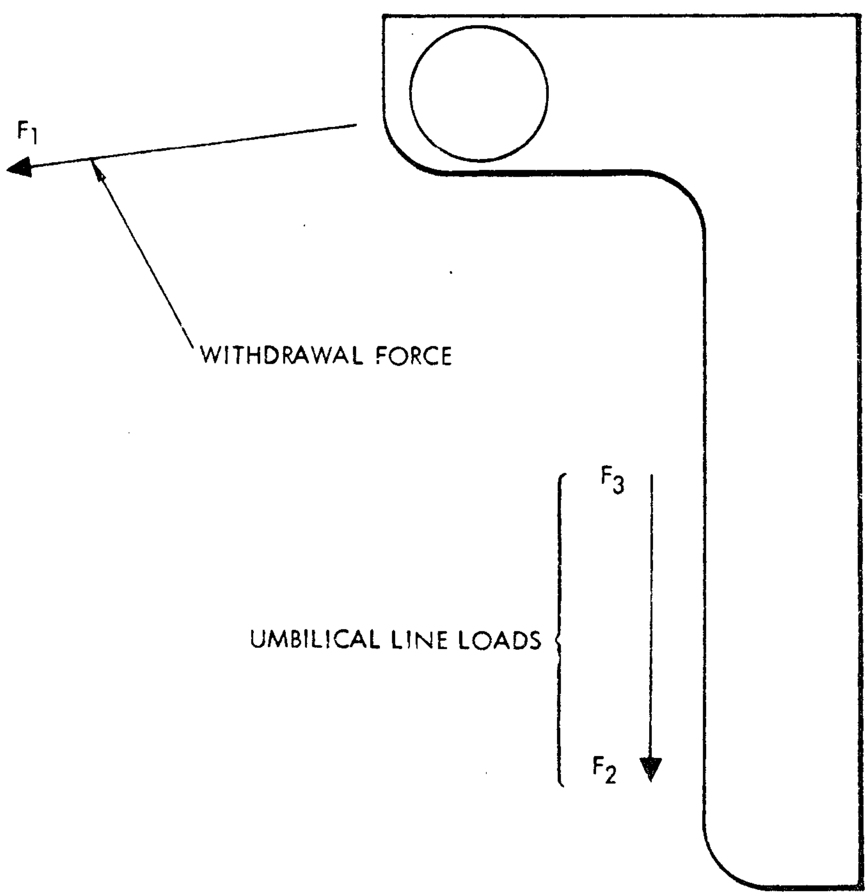


Figure 3-8. ESS Umbilical Attach Loads

transient conditions of shuttle booster engine start, vehicle release following normal holddown and booster engine cutoff during holddown and rebound. The ESS shall be designed to withstand loads applied at the propellant fill line attach points as specified in Figures 3-6 and 3-7.

3.1.1.2.1.4 Flight Loads. The ESS shall be designed to support the flight loads imposed by shuttle booster thrust and associated aerodynamic loading. The ESS shall withstand loads resulting from limits of main propulsion engine thrust buildup indicated in Figure 3-9. Maximum total thrust for structural design shall be 1,398,000 pounds. The ESS structure shall be capable of withstanding maximum aerodynamic ($q\alpha$ and $q\beta$) loads resulting from shuttle booster/ESS flight through a 95-percentile wind profile plus a 9-meter/second gust per NASA TMX-53872. The wind shear and the discrete gust must be multiplied by a factor of 0.85 when constructing the synthetic wind profile. The vehicle trajectory load factor after booster staging shall not exceed 4g in accordance with the trajectory specified in Figure 3-10. The structure shall be capable of withstanding gimbal loads resulting from one engine out and the other engine gimbaled hard over at maximum thrust (699,000 pounds) at end of ESS boost. The ESS structure shall also be capable of withstanding loads resulting from vehicle course and attitude corrections using the main propulsion engines, orbital maneuvering engines and attitude control thrusters. External loads shall be combined with maximum or minimum limit internal tank pressures and with loads resulting from propellant dynamic head as defined in Paragraph 3.1.1.2.1.1. Maximum external loads shall also be combined with differential pressures for the forward skirt compartment, including the effect of acoustic pressure. The forward skirt compartment burst pressure shall be neglected in cases where it reduces the effect of basic flight loads.

3.1.1.2.1.5 Separation Loads. The ESS shall be designed to support the shuttle booster separation loads specified in (TBD).

3.1.1.2.1.6 Ground Handling, Transportation, and Erection Loads. The ESS shall be designed to withstand and support the loads imposed during ground handling, transportation, erection, and assembly. The resultant design load factor due to assembly, transportation, ground handling, and erection shall not exceed 2 g. These criteria are applicable to the complete stage and all structural subassembly thereof. The main propellant tanks will be pressurized to 2 to 8 psig during transportation, storage, ground handling, or erection to avoid collapse pressures resulting from barometric pressure or temperature changes.

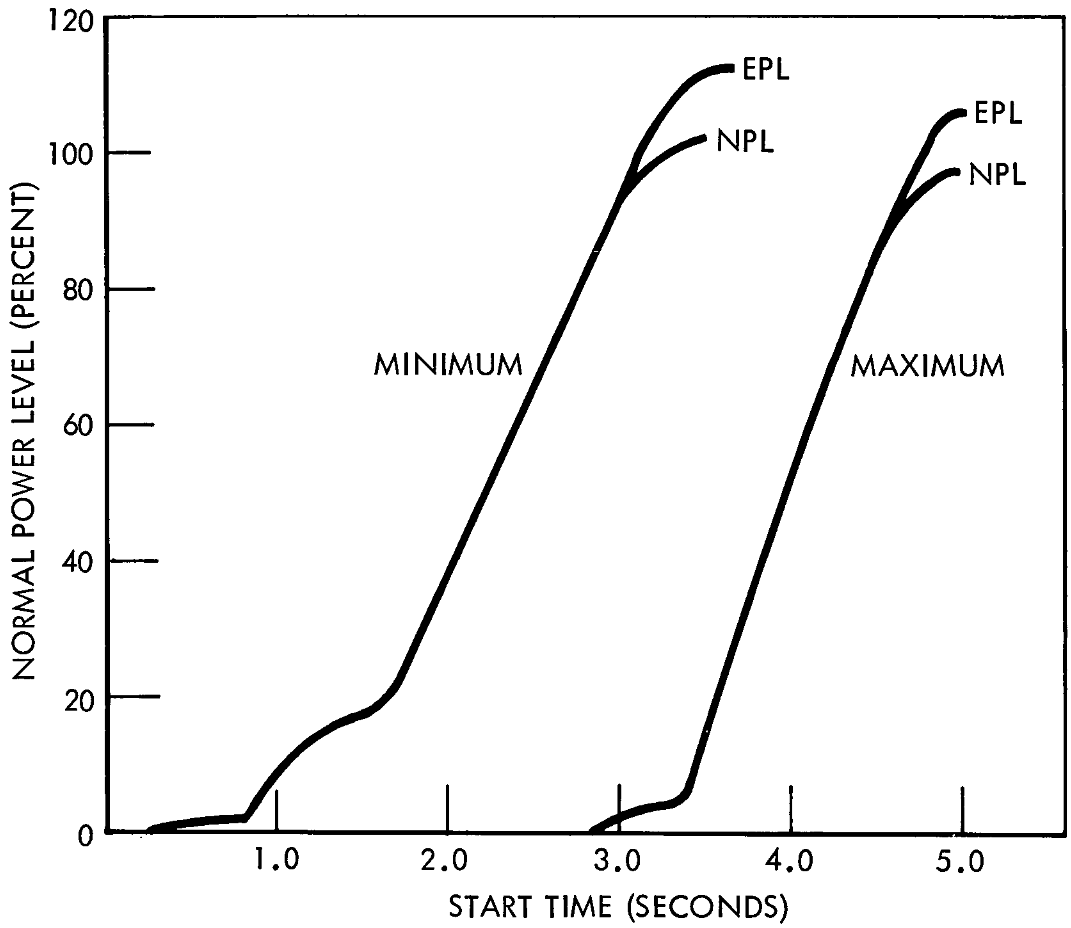


Figure 3-9. Main Engine Thrust Buildup Envelope

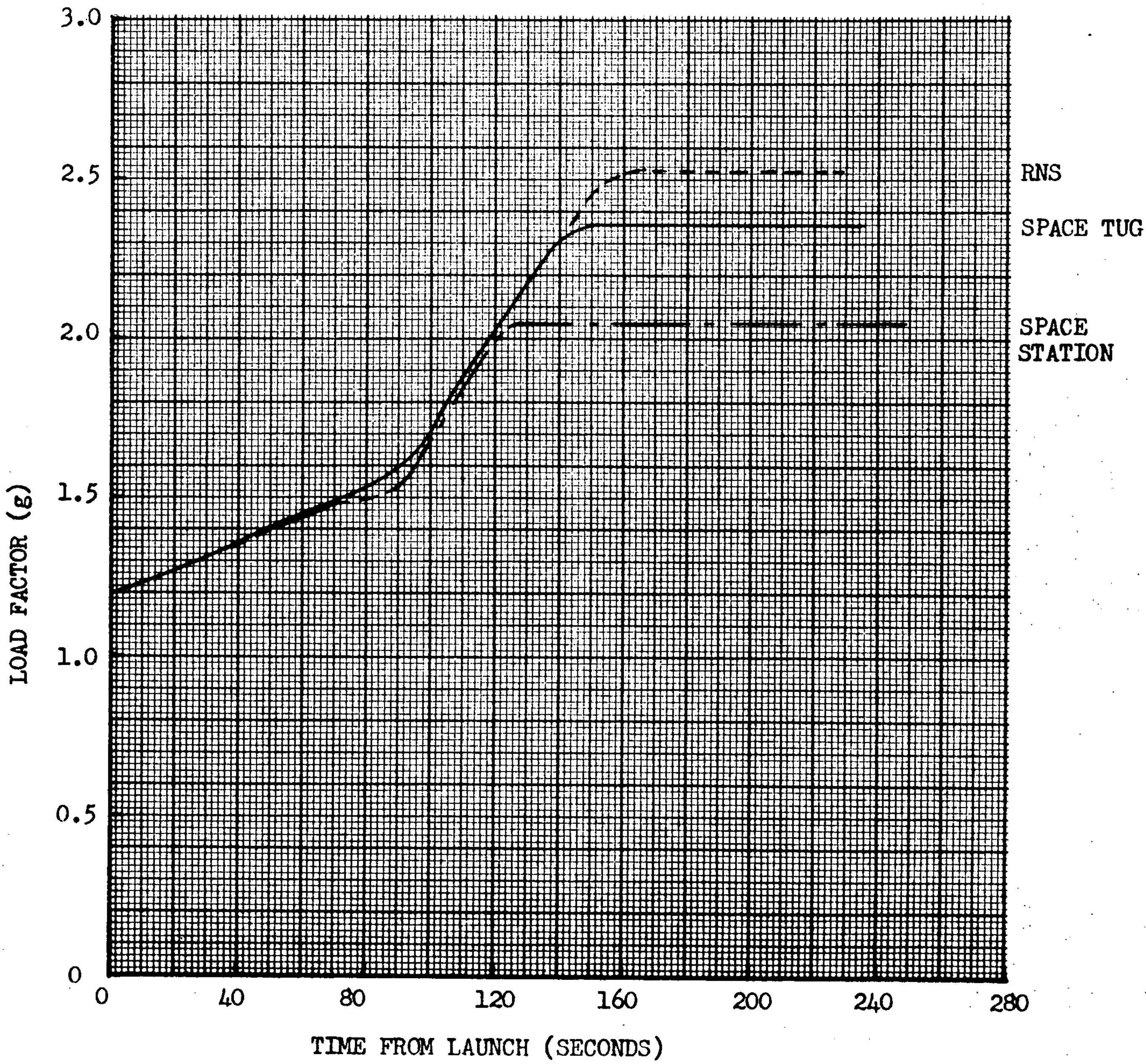


Figure 3-10. Shuttle Booster/ESS Load Factor

3.1.1.2.1.7 Static Firing Loads. The ESS shall be designed to withstand loads imposed by static firing. Static firing loads shall be constrained by a limitation on the maximum thrust for sea level static firing of 1,090,000 pounds total for both main propulsion engines. Engine gimbaling programs will be limited as necessary to avoid dynamic loads that could exceed the structural capability of the stage, static-firing skirt, or test stand. The ESS shall be supported in a vertical attitude by a static-firing skirt attached to the aft skirt. The ESS fueled or unfueled shall withstand a 0.4-psig peak blast overpressure with the propellant tanks pressurized and 99-percentile ground winds for a 30-day exposure per NASA TMX-53872. The tanks shall be pressurized to not less than 4 psig to withstand the 0.4-psig peak blast overpressure.

3.1.1.2.1.8 Docking Loads. The ESS shall be designed to withstand the following load conditions imparted at the docking adapter:

	Engagement	Docked	Release
a. Translational Loads			
± X (lb)	TBD	TBD	TBD
± Y (lb)	TBD	TBD	TBD
± Z (lb)	TBD	TBD	TBD
b. Rotational Loads			
± O_x (ft-lb)	TBD	TBD	TBD
± O_y (ft-lb)	TBD	TBD	TBD
± O_z (ft-lb)	TBD	TBD	TBD

3.1.1.2.2 Separation System. The ESS shall support the shuttle booster separation system by initiating a main engine start sequence in accordance with the requirements of Figure 3-11.

3.1.1.2.3 Main Propulsion Propellant Control Systems

3.1.1.2.3.1 Propellant Management. The ESS shall be designed with a capability for propellant management as defined in Paragraphs 3.1.1.2.3.1.1 and 3.1.1.2.3.1.2.

3.1.1.2.3.1.1 Propellant Loading. The ESS propellant management system shall use concentric continuous capacitance sensing probes and discrete point level sensors. The system shall provide propellant level data to a GSE interface to control propellant entering the main propellant tanks during loading. (See Table 3-1 for propellant fill rates.)

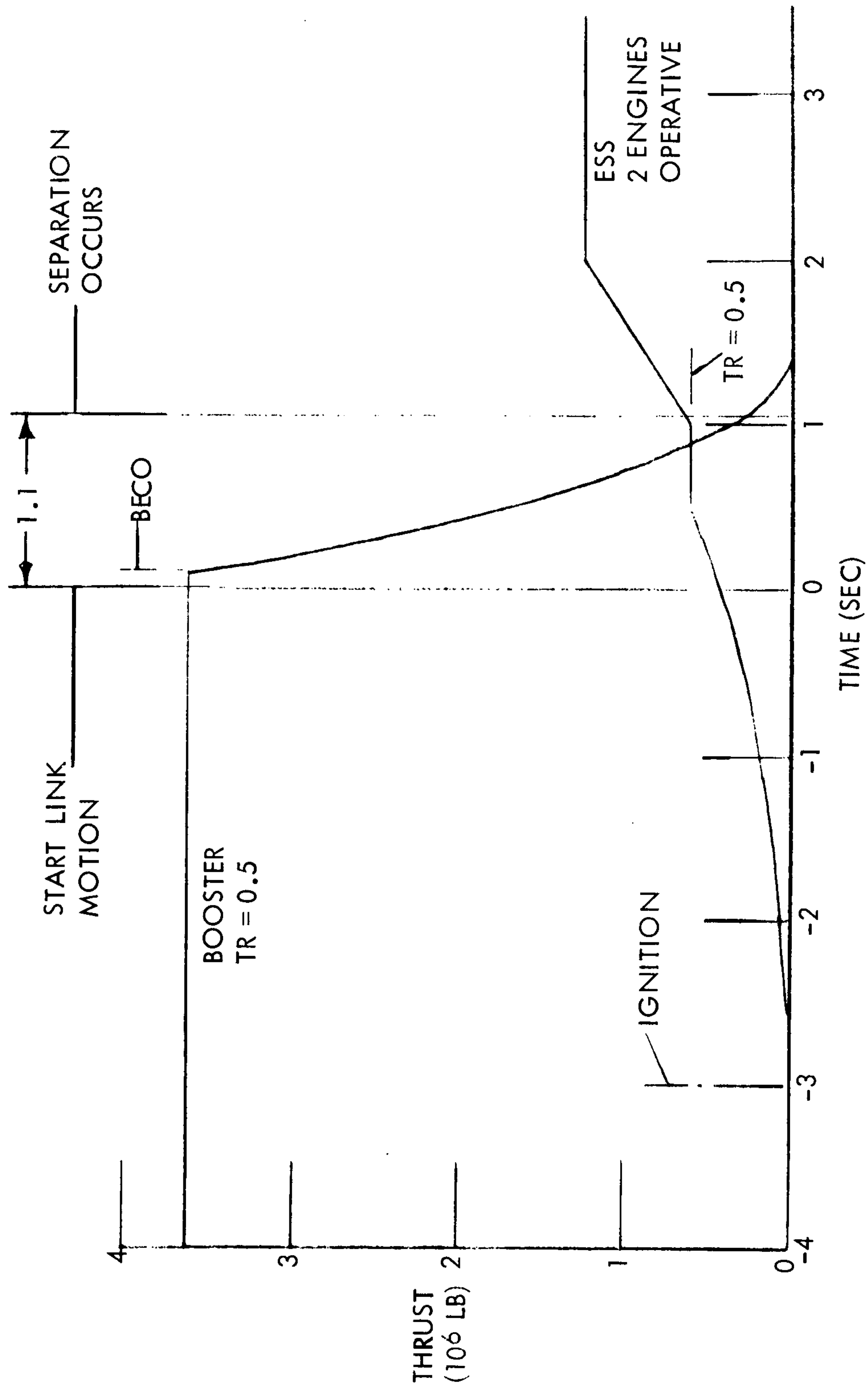


Figure 3-11. Thrust Scheduling for Normal Staging - ESS With RNS Payload

3.1.1.2.3.1.1.1 Propellant Tank Purge. The ESS shall be designed for propellant tank purging. In the liquid hydrogen tank, the purge shall be accomplished by displacing the tank atmosphere with gaseous helium or gaseous nitrogen. If gaseous nitrogen is used, it must be replaced by gaseous hydrogen or gaseous helium prior to liquid hydrogen loading. Liquid oxygen tank purging shall be accomplished by displacing tank atmosphere with gaseous nitrogen. Gaseous helium, gaseous hydrogen, and gaseous nitrogen shall be supplied from an external source. Tank purging shall be accomplished prior to propellant loading and after draining.

3.1.1.2.3.1.1.2 Discrete Loading Sensors. The ESS shall be designed with four discrete point level sensors (two primary and two backup) to provide a fast-fill shutoff signal and an overfill emergency signal to the GSE interface. The fast-fill shutoff sensors shall be located approximately at 98 percent of the total tank volume in each tank. The over-fill sensors shall be located at least 6 inches below the centerline of the vent outlet in the liquid hydrogen tank and approximately 4 inches below the vent outlet in the liquid oxygen tank. The indication of the fast-fill cutoff sensors system shall have an overall accuracy of ± 0.5 inch (vertically) at the lowest expected propellant density conditions (see Paragraph 3.3.1.3). Circuitry for the sensors shall be independent of the circuitry of the continuous capacitance probes.

3.1.1.2.3.1.1.3 Propellant Capacitance Assembly. The propellant capacitance assembly shall be designed to provide signals proportional to propellant mass in each tank.

3.1.1.2.3.1.2 Engine Cutoff (ECO). Propellant management shall incorporate an engine cutoff subsystem (independent of velocity cutoff) consisting of four point sensors in each main propellant tank (two at each feedline) plus associated electronics. The liquid hydrogen and liquid oxygen point sensors shall be removable. Sensors shall be of the hot-wire type. The ECO subsystem shall be designed to initiate a signal to shut down the main propulsion engines when two out of four sensors from the same tank indicate a dry condition. The depletion signal to initiate cutoff shall be given at a propellant level that minimizes trapped propellants. The signal output from each individual sensor shall be 28 ± 4 vdc when the sensor is dry and zero volts when the sensor is immersed in liquid.

3.1.1.2.3.2 Propellant Feed, Fill and Drain System. The ESS shall be designed with a propellant servicing subsystem that will transfer propellant at flow rates and pressures as specified in Table 3-1 between the stage tanks and ground sources. The fill valves shall not be used to control incoming flow but shall be used to close the fill lines after propellant flow ceases. The fill valves shall be pneumatically actuated, from an external source, in both directions and shall be designed to prevent inadvertent opening. Provisions shall be made to drain and purge the liquid oxygen fill line from the fill valve to the fill disconnect coupling shutoff valve. A liquid hydrogen fill flow deflector shall be provided.

3.1.1.2.3.2.1 Engine Feed. The engine feed subsystem shall be designed with normally open, pneumatically actuated, electrically controlled liquid oxygen and liquid hydrogen prevalves in the lines between the tanks and the engine interface. Pressure relief capability providing reverse flow back to the tank shall be incorporated in the prevalves. The engine feed lines shall allow for structural variations due to changes in temperature and thrust loads. Propellant tank outlets shall be designed with screens of 4 by 4 per square inch wire mesh. A capability to install and/or remove a special screen (80 to 100 mesh) shall be designed into the engine pump inlet interface of each feed duct. These special screens shall not be used during static firing or flight. The engine feed lines shall interface with the main propulsion engine as specified in Paragraph 3.2.1.

3.1.1.2.3.3 Slosh and Vortex. The slosh and vortex control requirements of Paragraph 3.1.1.1.3.3 shall be met by use of baffles. A damping equivalent to 3 percent of critical damping of a 6-inch double amplitude slosh wave shall be provided for the ESS liquid oxygen tank during space shuttle boost.

3.1.1.2.4 Main Propulsion Engines. The ESS shall be designed for servicing and conditioning the MPS engines as defined in the following sections.

3.1.1.2.4.1 Not used

3.1.1.2.4.2 Fuel Pump Seal Drain. The fuel pump seal drain system shall be designed to provide a common manifold for venting from the engine interface for the hydrogen pump seal cavities. Hydrogen that may leak through the pump seals into the seal cavity will be vented so that the hydrogen will not enter the turbine. The system shall also provide a common vent for the helium discharged during turbopump purge operations. This system shall be designed for helium flow rates at each engine interface not greater than TBD scfm at 75 ± 25°F.

3.1.1.2.4.3 Not used

3.1.1.2.4.4 Not used

3.1.1.2.4.5 Not used

3.1.1.2.4.6 Not used

3.1.1.2.4.7 Not used

3.1.1.2.4.8 Engine Prestart Conditioning System. The engine prestart conditioning system shall be designed to provide liquid oxygen and liquid hydrogen temperature conditions at the ESS stage/MPS engine interface which will satisfy the net positive suction pressure (NPSP) requirements of Figures 3-12 and 3-13 at engine start command. The liquid hydrogen system shall be conditioned prior to launch and during first stage boost by a forward flow recirculation provided by driving the engine boost pump with an electric motor. The liquid oxygen system shall use natural convection supplemented by helium injection for both flight and ground operations. Injected helium shall be controlled and supplied by the pressurization system.

3.1.1.2.4.9 Helium Purge. The helium purge system shall be designed to store, control and distribute gaseous helium to each engine interface at a pressure of 1400 to 1800 psia, a temperature of 490 to 660°R and a flow rate of 0 to 23,200 scfm. Inflight helium storage shall provide for 17 pounds of usable gas at a storage pressure of 3000 ± 200 psia.

3.1.1.2.4.10 Nitrogen Supply. The nitrogen supply system shall be designed to distribute gaseous nitrogen from an external source to each engine interface at a pressure of 600 ± 400 psia, a temperature of 510 to 660°R and a nominal flowrate of 0.5 lb/sec.

3.1.1.2.5 Pressurization. The ESS pressurization system shall be designed to maintain the ullage pressure as required in Paragraph 3.1.1.2.5.1. The pressurization system shall provide pneumatic pressure to actuate the recirculation valves, prevalves and the propellant fill and vent valves as required in Paragraph 3.1.1.2.5.2 and supply helium to the liquid oxygen recirculation system as required in Paragraph 3.1.1.2.4.8.

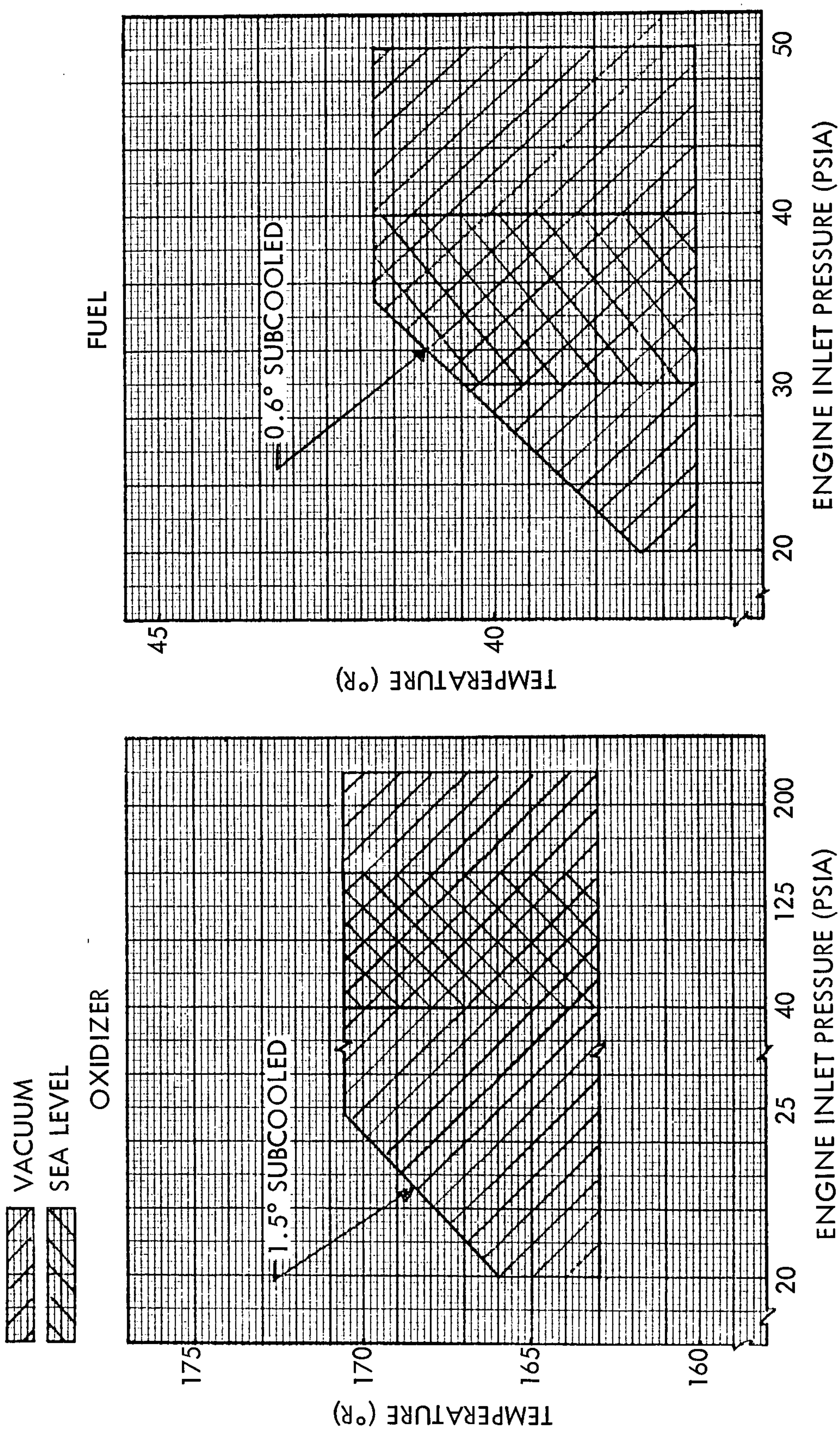


Figure 3-12. Prestart Propellant Conditions

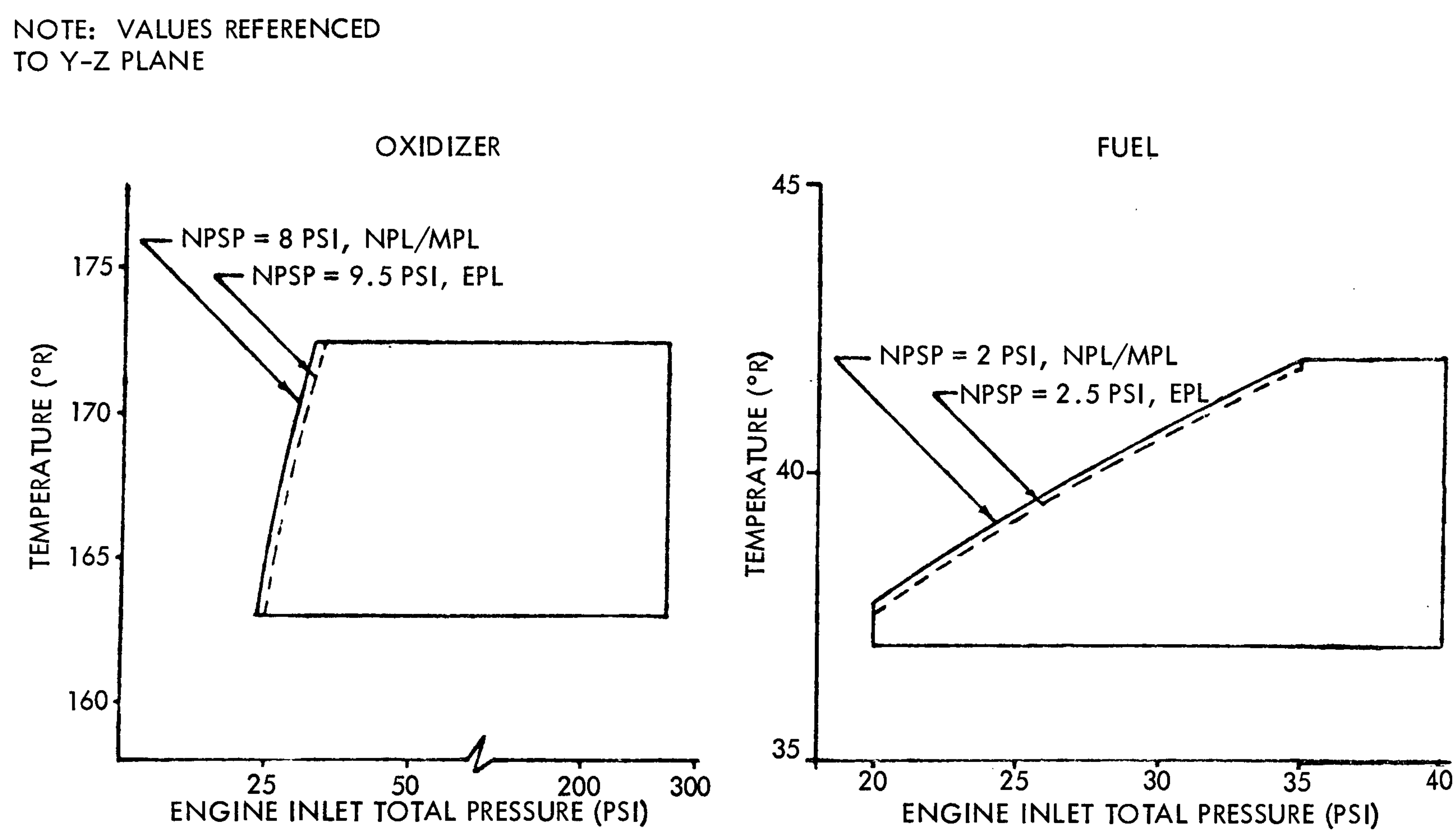


Figure 3-13. Engine Propellant Inlet Conditions - Main Stage Operation

3.1.1.2.5.1 Propellant Tank Pressurization and Venting. The ESS pressurization system shall be designed to prepressurize the liquid hydrogen tank with gaseous helium. The ESS pressurization system shall be designed to prepressurize the liquid oxygen tank with gaseous helium. Prepressurization shall be accomplished using externally supplied gases during engine nonoperating ground operations. During MPS engine operation, pressures shall be maintained in the liquid hydrogen tank using gaseous hydrogen from the engine interface and in the liquid oxygen tank using gaseous oxygen from the engine interface. The ullage pressures shall satisfy the minimum liquid oxygen and liquid hydrogen pressure and NPSH requirements at the stage/engine interface as shown in Figure 3-13. Tank vent vales shall be provided to control tank pressure and to allow venting during propellant loading. The tank vent valves shall limit the ullage pressure to the maximum values specified in Figures 3-2 through 3-5. GSE controlled override capability shall be provided to control the maximum propellant tank pressurizing levels. The ESS shall be designed on the basis of the engine liquid oxygen heat exchanger and hydrogen pressurant gas conditions specified here:

	GO_2	GH_2
Flowrate (lb/sec/engine)	2.55	0.50
Temperature (^oR)	800 ± 50	530 ± 130
Pressure (PSIA)		
Maximum	1000	1000
Minimum	200	200

3.1.1.2.5.2 Vent Valve and Propellant Fill Valve Actuation System. The vent and fill valves shall be pneumatically actuated during propellant filling and ground operations with 750-psig ambient helium provided from an external source.

3.1.1.2.6 Compartment and Component Conditioning

3.1.1.2.6.1 Engine Compartment Conditioning System (ECCS). The ECCS shall be designed to provide for maintaining: (1) the ambient temperature around the thermally sensitive components (including the equipment containers) in the engine compartment between 0°F and 100°F; (2) the compartment explosively inert within the following constraints and conditions.

3.1.1.2.6.1.1 Source and Controls. The ECCS shall distribute dry air or gaseous nitrogen supplied from an external source at flow rates of from 300 pounds to 500 pounds per minute at temperatures from 30°F to 250°F. The flow rates and temperatures of the externally supplied gas shall be controlled by auxiliary sensors and detectors, as supplied by NASA, installed in the engine compartment. The externally supplied gas shall be distributed by a manifold in directions and at velocities that will minimize impingement on the engines or on the propellant feed and recirculation lines after tanking of propellants in preparation for vehicle launch.

3.1.1.2.6.1.2 Venting. Venting shall be designed to produce a compartment gas flow pattern to provide thermal control and hazardous gas expulsion. Vent areas shall be designed to prevent excessive pressure differential during the first stage boost. Venting areas shall be designed compatible to the purge flow to exclude ambient external air from the engine compartment during purging operation. Engine compartment vents shall be divided among two positions: above the thrust cone and between the thrust cone and the heat shield. Shrouds shall prevent the gaseous nitrogen inside the shroud chilled by contact with the liquid oxygen tank from mixing with gaseous nitrogen in the vicinity of thermally sensitive components outside the shroud.

3.1.1.2.6.2 Thermal Control. The thermal control system shall be designed to use air for operations without propellants loaded and gaseous nitrogen for operations with propellants loaded. The air or gaseous nitrogen shall be supplied at the umbilical disconnect by an external source. The thermal control system shall provide an explosively inert, thermally controlled atmosphere within the equipment containers located in the forward and aft skirts by purging with gaseous nitrogen supplied by an external source. The electronic equipment containers shall be purged to obtain an explosively inert atmosphere containing less than 4 percent oxygen by volume.

3.1.1.2.7 Thrust Vector Control (TVC). The thrust vector control system shall provide the hydraulic energy to:

1. Gimbal the main engines
2. Gimbal the OMS engines
3. Provide hydraulic power to the main engines for engine usage if required.

The TVC system shall consist of four independent hydraulic subsystems, one for each of the main and orbital maneuvering engines.

3.1.1.2.7.1 Main Engine TVC Subsystem. An independent subsystem shall be provided for each main engine and shall consist of an engine driven main pump* for thrust vector control during mainstage, an electric motor driven pump for engine hydraulic power requirements (valve control and nozzle translation) and ground checkout, an accumulator/reservoir manifold assembly and two servo-actuators. The accumulator system shall provide an emergency power source for engine hydraulic power and also to center the engine (null the servoactuators) in the event the main power source is lost. Main engine TVC requirements shall be in accordance with the following:

Max gimbal moment	1.5×10^6 in-lb
Engine deflection	± 8 degrees square pattern
Gimbal rate	TBD (deg/sec)
Operating Pressure	3000 ± TBD psig
Max system flow	
Main TVC	TBD (gpm)
Engine controls	18 gpm

3.1.1.2.7.2 Orbital Maneuvering Engine TVC Subsystem. Each of the orbital maneuvering engines shall be gimbaled with two servoactuators. Gimbaling power to each set of servoactuators shall be generated from an electric motor driven pump. An accumulator system shall provide an emergency power source to center the engine in the event the main power source is lost. Orbital maneuvering engine TVC requirements shall be as follows:

Max gimbal moment	6.0×10^3 in-lb
Engine deflection	±6.0 degrees square pattern
Gimbal rate	TBD (deg/sec)
Operating pressure	3000 ± TBD psig
Max system flow	TBD

3.1.1.2.7.3 Hydraulic Power Fluid Requirements. The TVC system shall utilize MIL-H-5606 hydraulic fluid and shall provide for filtration per the requirements of MIL-H-8891. The hydraulic fluid in the OMS TVC subsystem shall be controlled within the limits of -65°F to +275°F. Heating shall be provided by circulating the fluid using the electric motor driven pump.

* For this specification, it is assumed that although ICD 13M15000B, space/shuttle vehicle/engine 550 (SL) Interface Control Document, does not provide for this capability, such capability will be provided in the future.

3.1.1.2.8 Avionics System. The ESS shall be electromagnetically compatible to the extent that no adverse electromagnetic interactions occur between equipments or subsystems comprising the stage. Adverse electromagnetic interaction shall be as defined in MIL-E-6051. The means by which the contractor intends to assure electromagnetic compatibility shall be delineated in the MIL-E-6051 required control plan and test plan.

3.1.1.2.8.1 Electrical Control. The electrical control subsystem shall be designed to provide or route electrical stimuli to perform functions for the control of propellant fill valve solenoids during fill and detanking. The subsystem shall provide electrical sensors to measure tanked propellant mass. The subsystem shall provide electrical stimuli for the control of propellant tank pressurization and vent valve solenoids. The subsystem shall provide electrical stimuli for the control of the fuel and oxidizer recirculation system. The subsystem shall provide electrical stimuli for the control of engine start and cutoff. The subsystem shall provide electrical stimuli to monitor engine operation and transmit engine conditions as required. The subsystem shall provide electrical stimuli for the control of propellant prevalve operation during engine shutoff, malfunction, and standard operations. The subsystem shall provide electrical stimuli for the control of hydraulic actuator lockup solenoids. The subsystem shall provide electrical stimuli for the control of the auxiliary propulsion system and the payload deployment system.

3.1.1.2.8.1.1 Electrical Control Design Features. The electrical control system control voltage shall be nominally 28 or 56 vdc. Control switching shall use power control switches. A standardized acquisition, control and test unit (ACT), shall provide the primary digital interface between the operational data bus and the subsystem components. The ACT unit shall respond to commands from the DCM subsystem in sending control signals to subsystem components and in acquiring subsystem response data.

3.1.1.2.8.2 Electrical Power and Distribution (EPD). The electrical power and distribution (EPD) subsystem shall provide electrical energy and distribution for operation of the stage systems throughout the ESS 24-hour mission. Redundant and separate dc power sources, ac power conversion, and distribution bus systems shall be utilized. Specific design and performance requirements of the EPD subsystem are as follows:

a. Provide +28(+4, -2) vdc primary electrical power and distribution capable of satisfying ESS system loads from liftoff through deorbit.

b. Provide ac power conversion operating from a +56(±4) vdc input battery source to produce 115/200 vac, 3∅, 400 Hz power capable of satisfying ESS ac loads from liftoff through deorbit.

c. Stage power shall be transferred from external to flight batteries without interruption.

d. Circuit protection shall not use circuit breakers or fuses. Power sources shall be isolated from faulted busses without damage to power sources or interruption of power to essential subsystem loads.

e. Batteries shall be sized and grouped for each of the redundant sources to handle the overall stage electrical load from liftoff through deorbit. Battery sizing shall be based on a 28 vdc load of 90,000 watt-hours and an ac load (56 vdc source) of 7,760 watt-hours.

f. The ESS grounding system shall utilize the stage structure as a power return for the primary +28 vdc and +56 vdc power sources. Secondary power supplies and command/response signals shall use a signal return.

g. Remote sensing from the ESS flight busses shall be used to control the external power supplies for these busses.

3.1.1.2.8.3 Emergency Detection. (TBD)

3.1.1.2.8.4 Communications. The communications subsystem shall provide for the transmission and reception of signals between the ESS and MSFN, shall provide for the processing of all such signals and shall include a secure range safety command system.

3.1.1.2.8.4.1 S-Band Function. The ESS to ground station (MSFN) data link shall be accomplished with an S-band r-f system. The S-band function shall provide for simultaneous transmission and reception of up and down data and turn around of a ranging signal. Two independent functional elements shall be provided for up data and PM down data. The FM transmit element shall be a single functional element.

3.1.1.2.8.4.1.1 Receive Characteristics. The performance requirements of the receive function shall be as follows:

Carrier frequency	2106.40625 MHz
Tracking threshold	-127 dbm
Modulation	Phase-modulated
Bandwidth	150 kHz
Data rate	1 kbps (on 70 kHz Carrier)
Ranging	PRN modulation

3.1.1.2.8.4.1.2 Transmit Characteristics. The performance requirements of the transmit function shall be as follows:

PM— carrier frequency (data bus data)	2287.5 MHz
FM— carrier frequency (CBW telemeter)	2272.5 MHz
PM— bandwidth	TBD kHz
FM— bandwidth	200 kHz
Data rate (PM)	50 kbps and 2 kbps
Ranging	PRN modulation
RF power output	11.2 watts (min)/transmitter

3.1.1.2.8.4.1.3 Antenna Characteristics. Four USBE antennas, helical, cavity backed and flush mounted shall be provided to accommodate the S-Band communication requirements. The antenna installation shall be such that vehicle attitude does not restrict communications with the earth or a data relay satellite.

3.1.1.2.8.4.2 Signal Processing. Signal processors shall provide the interface between the stage data collecting equipment and the RF electronics for the purposes of signal reduction, modulation and switching. Signal processing characteristics shall be as follows:

a. 1.25 MHz modulators (2) to provide phase modulation of 10 kbps serial data

b. 1.0 MHz modulator (1) to provide phase modulation of 50 kbps or 2 kbps data

c. Amplifiers for three modulators to provide for varying deviation of the USBE transmitters

d. CBW/FM and modulator mixing amplifier

e. Switching functions to provide proper deviation of the USBE transmitters for mode selected

3.1.1.2.8.4.3. Range Safety Command System. The ESS shall be designed to include an RF subsystem composed of a dual, secure, range safety command system (SRSCS) and an antenna subsystem. The SRSCS shall include two receivers and two decoders. The SRSCS shall be capable of accepting signals, decoding these signals, and forwarding information to the engine cutoff and propellant dispersion subsystems. Operation power for each SRSCS shall be obtained from separate sources. There shall be a separate antenna subsystem for SRSCS. All antenna subsystem patterns, including coutour plots, shall be submitted to NASA for approval. The SRSCS antenna subsystem shall operate at 450 mc and shall provide coverage in accordance with AFETRM 127-1. The antenna subsystem shall be capable of closed-loop checkout through the RF umbilical connector.

3.1.1.2.8.4.4 Instrumentation. The instrumentation design shall provide the necessary sensors and signal conditioning to collect data for all stage measurements. The design shall incorporate a remote calibration capability.

3.1.1.2.8.5 Static Firing Instrumentation. Ground measurements required for static firing shall be transmitted by hardwire to GSE signal conditioners and recorders.

3.1.1.2.8.6 Data and Control Management (DCM). The data and control management subsystem shall provide the means of integrating, managing and controlling the ESS vehicle. The DCM shall be capable of exercising computerized control over the functions of (1) guidance, navigation and flight control, (2) vehicle sequencing and control, (3) subsystem redundancy management, and (4) data management.

3.1.1.2.8.6.1 Guidance, Navigation and Flight Control. The DCM subsystem shall provide the capability of obtaining subsystem generated velocity and attitude data, perform calculations of all necessary equations to establish position data, shape the data and provide commands to the vehicle flight control subsystem to maintain vehicle trajectory during mission boost phase and attitude control during on-orbit operations.

3.1.1.2.8.6.2 Vehicle Sequencing and Control. The DCM subsystem shall provide the capability of controlling the stage subsystems to accomplish the following mission phase-oriented operations:

a. Prelaunch Operations

Conduct subsystem readiness checks
Perform final "T" timed sequence events in preparation for launch
Provide ESS status to the booster and ground
Perform subsystem statusing

b. Booster Boost Phase

Verify final engine prestart readiness
Provide ESS status to the booster and ground
Maintain mission sequence
Perform subsystem status testing
Initiate abort sequence as required

c. ESS/Booster Separation Through Main Engine Cutoff

Initiate main engine start function when booster permits are satisfied
Support separation
Initiate main engine and supporting subsystems performance monitoring
Maintain mission sequence
Provide ESS status to the ground

d. ESS Safing

Initiate safing commands for main propellant tanks

e. Orbit Insertion

Control OMS engine burn to obtain required delta V
Maintain vehicle attitude
Maintain vehicle performance monitoring
Provide ESS status to the ground
Maintain mission sequence of events

f. On-orbit Operations

Maintain attitude with ACPS
Maintain vehicle performance monitoring
Provide ESS status to the ground and orbiter
Separate ESS from the payload
Transmit all CPU core data to ground
Initiate equipment recovery sequences

g. De-Orbit

Perform ESS preps for de-orbit
Initiate de-orbit sequence

3.1.1.2.8.6.3 Subsystem Redundancy Management. The DCM subsystem shall be capable of performing checkout and fault isolation for all individual ESS subsystems. It shall be able to detect all functional path failures including those internal to the DCM and implement the available redundancy to continue the ESS missions.

3.1.1.2.8.6.4 Data Management. The DCM subsystem shall contain the software/hardware capability for acquisition, processing, and distribution of ESS vehicle data. These data consist of the following:

a. Vehicle sequence status data
b. Vehicle subsystem performance monitoring data
c. Uplink data

3.1.1.2.8.7 Guidance, Navigation, and Control (GN&C). The GN&C, in conjunction with appropriate interfacing subsystem elements (DCM, main engines, OMS, and ACPS), and available ground or satellite aids (MSFN and/or TDRS), shall provide the capability to determine the position, velocity, and inertial attitude of the ESS/payload from launch through de-orbit. It shall also provide attitude control from booster separation, through ascent, on-orbit operations, on-station operations and de-orbit. This includes thrusting modes (main engine and OMS velocity changes) and non-thrusting modes (angular maneuvers and attitude holds using ACPS). The GN&C shall perform the above functions by providing individual equipment with accuracies and drift characteristics compatible with the performance requirements defined in Table 3-3. The GN&C shall be compatible with the function requirements by mission phase listed in Table 3-4 for the non-rendezvous baseline mission and Table 3-5 for the rendezvous mission. The GN&C shall be capable of self alignment during prelaunch and require no attitude updates throughout the mission.

Table 3-3. GN&C Performance Requirements

Performance Parameter	Mission		
	100 nm	270 nm	270 nm (w/rendezvous)
Injection Errors (3σ)			
Radial position	±3 nm	±5 nm	--
Radial velocity	±20 fps	±50 fps	--
Tangential velocity	±15 fps	±15 fps	--
Inclination	$\pm 0.1^{\circ}$	$\pm 0.1^{\circ}$	
Rendezvous Errors (3σ)			
Position	--	--	11 ± 10 nm
Velocity	--	--	±15 fps
De-orbit ΔV Errors			
Direction (pitch and yaw)	$\pm 5^{\circ}$	$\pm 5^{\circ}$	$\pm 5^{\circ}$
Magnitude	±4%	±4%	±4%

Table 3-4. GN&C Functional Requirements
(Nonrendezvous Baseline Mission)

Mission Phase	Functional Requirement
1. Prelaunch	
Ground operations	Checkout avionics system (combination of on-board and ESE)
	Load and verify flight program
	Load targeting data and other parameters
	Align IMU (platform level and gyro compass)
On-board operations	Provide on-board targeting refinement to time of launch
	Provide navigation (after ground release)
2. Ascent	
Mated ascent	Perform powered flight navigation
	Provide abort capability
	Provide for main propulsion system (MPS) start ups
Separation	Start ups
	Provide attitude control and stabilization
Boost to insertion (66 x 100 orbit)	Provide powered flight navigation
	Provide ascent phase guidance
	Perform attitude control and stabilization

Table 3-4. GN&C Functional Requirements
(Nonrendezvous Baseline Mission)(Cont)

Mission Phase	Functional Requirement
2. Ascent (Cont)	
Coast to apogee	Perform coast phase navigation
	Provide attitude control
	Provide for OMS start up
Boost to circulation orbit (100 x 100 orbit)	Provide powered flight navigation
	Provide ascent phase guidance
	Provide attitude control and stabilization
3. Orbital Operations	
Coast in parking orbit	Provide orbital navigation
	Provide attitude control and stabilization
	Perform navigation updates
	Compute transfer burn parameters
	Compute and count time to transfer maneuver
Boost into coelliptic transfer orbit (100 x 270)	Provide powered flight navigation
	Provide transfer phase guidance
	Provide attitude control and stabilization

Table 3-4. GN&C Functional Requirements (Nonrendezvous Baseline Mission) (Cont)

Mission Phase	Functional Requirement
3. Orbital Operations (Cont)	
Coast to apogee*	Provide coast phase navigation
	Provide attitude control and stabilization
	Compute time to circularization burn
	Perform navigation updates (when coverage is available)
Circularize orbit (270 x 270)	Provide powered flight navigations
	Provide transfer phase guidance
	Perform attitude control and stabilization
4. On-Station Operations	
Station keeping	Provide coast phase navigations
	Provide attitude control and stabilization
	Perform navigation updates
	Compute burn parameters for station* corrections
	Execute burns (ACPS engines)*

*Midcourse correction may be needed during the ascent phase to correct out-of-plane conditions.

Table 3-4. GN&C Functional Requirements (Nonrendezvous Baseline Mission) (Cont)

Mission Phase	Functional Requirement
4. On-Station Operations (Cont)	
Jettison payload	Provide coast phase navigation
	Provide attitude control and stabilization
	Initiate payload jettison
Provide cooperative docking (for shuttle docking)	Provide attitude for docking
	Provide rate hold mode
	Disable attitude control at contact
Salvage components	(None)
Prepare for de-orbit	Initialize de-orbit system (data and positioning by shuttle)
Shuttle-ESS undock	Provide rate damping and attitude hold mode after separation
5. De-Orbit	
Coast in orbit	Establish and maintain de-orbit attitude
	Count time to de-orbit burn (or await command through radio command)
Perform retro burn	Initiate burn
	Provide attitude control and stabilization
	Measure burn time (or velocity change)
	Terminate burn

Table 3-5. GN&C Functional Requirements
(Rendezvous Mission)

Mission Phase	Functional Requirements
1. Prelaunch	(Same as for nonrendezvous mission; see Table 3-4)
2. Ascent	(Same as for nonrendezvous mission; see Table 3-4)
3. Orbital Operations	
Coast in phasing orbit	Provide orbital navigation
	Provide attitude control
	Perform navigation updates
	Compute transfer burn parameters
	Compute and count time to transfer maneuver
Boost into coelliptic transfer orbit (100 x 260)	Provide powered flight navigation
	Provide transfer phase guidance
	Provide attitude control and stabilization
Coast to apogee*	Provide coast phase navigation
	Provide attitude control and stabilization
	Count time to circularization burn
	Perform navigation updates*

*Navigation updates required during ascent.

Table 3-5. GN&C Functional Requirements (Rendezvous Mission) (Cont)

Mission Phase	Functional Requirements
3. Orbital Operations (Cont)	
Circularize orbit (260 x 260)	Provide powered flight navigation
	Provide transfer guidance
	Provide attitude control and stabilization
Coast in parking orbit	Provide orbital navigation
	Provide attitude control and stabilization
	Perform navigation updates
	Compute rendezvous burn parameters
	Compute and count time to start rendezvous maneuvers
Rendezvous with target	Provide rendezvous phase guidance
	Provide powered/coast navigation
	Provide attitude control and stabilization
	Perform navigation updates
4. On-Station Operations	
Station keeping	Provide coast phase navigation
	Provide attitude control and stabilization

Table 3-5. GN&C Functional Requirements (Rendezvous Mission) (Cont)

Mission Phase	Functional Requirements
4. On-Station Operations (Cont)	
	Perform navigation updates
	Compute burn parameters for station corrections
	Execute burns (ACPS engines)
Jettison payload	
Provide cooperative docking (for shuttle docking)	(Same as for nonrendezvous mission, see Table 3-4)
Salvage components	
Prepare for de-orbit	
Shuttle-ESS undock	
5. De-Orbit	(Same as for nonrendezvous mission, see Table 3-4)

3.1.1.2.9 Propellant Dispersion. The ESS shall be designed to rupture the propellant tanks (propellant dispersion) upon receipt of a coded RF signal by using linear-shaped explosive charges. The explosives shall be initiated by exploding bridgewire (EBW) techniques with power supplied from dual independent power sources. The coded RF signal shall be received by command destruct antennas that shall meet the requirements of AFETRM 127-1. Propellant dispersion shall not be performed until after an arm and engine cutoff signal is received by the ESS. The removal of electrical power from the engine control circuitry shall be provided upon receipt of a propellant dispersion command for main engine cutoff. The propellant dispersion system shall be inoperative until after booster separation. The safe and arm device shall be remotely armed electrically after separation of TBD miles from the shuttle booster. After receiving an arm and cutoff command signal, the MSFC-DWG-40M39515 EBW firing unit shall release a high-energy pulse to the DACO part no. 7865742 EBW detonators in the DACO part no. 1B33735-1 safe and arm (S/A) device. The S/A shall block detonation propagation when in the safe position and allow detonation to be transferred to the confined detonating fuze (CDF) assemblies when in the armed position. CDF assemblies shall transfer the propellant dispersion command to liquid hydrogen and liquid oxygen tank destruct assemblies. Ordnance tees shall be used with the CDF assemblies to ensure redundant detonation initiation of the tank destruct charges. No explosives more sensitive than pentaerythrite tetranitrate (PETN) shall be used.

3.1.1.2.10 Common Bulkhead Purge. The ESS shall be designed to purge the common bulkhead and other required areas during ground operation with purge gas furnished from a ground facility. The system shall be capable of continuous distribution of purge gas during ground hold and throughout the propellant loading and detanking sequence. The purge capability of the common bulkhead circuits and other circuits as applicable may be interrupted or discontinued during vacuum leak tests, evacuation to reduce heat leak, and similar planned activities.

3.1.1.2.11 Not used

3.1.1.2.12 Safing System. The ESS shall be designed to provide a safing system to vent the main LH_2 and LO_2 propellant tanks. Dual ordnance valves shall be used to vent each tank and the system shall be designed to impart zero impulse to the vehicle during venting.

3.1.1.2.13 Auxiliary Propulsion System (APS). ESS auxiliary propulsion system shall be designed to accomplish orbit maneuvering and attitude control in accordance with the requirements of the following system elements:

Orbit maneuvering engines
Attitude control thrusters
Propellant tankage
Propellant feed
Propellant conditioning
Propellant distribution
Pressurization

3.1.1.2.13.1 Orbital Maneuvering Engines. The orbital maneuvering function shall be accomplished with two non-throttleable, gimbaled, pump-fed rocket engines using liquid oxygen and liquid hydrogen propellants. Each engine shall produce the following normal vacuum performance:

Rated thrust	10,000 lb
Operating life	15 min
No. of starts (nom)	5
Specific impulse (nom)	454 sec
Mixture ratio	6:1
Nozzle expansion ratio	255:1
Chamber pressure	800 psia

3.1.1.2.13.2 Attitude Control Thrusters. The attitude control function shall be accomplished with fourteen thrusters utilizing gaseous oxygen and gaseous hydrogen propellants. The thrusters shall be located on the vehicle in a manner that permits multiple attitude control functions to be performed by a single thruster, and shall be capable of being fired in any combination selected by the GN&C subsystem. The nominal performance characteristics of the thrusters shall be as follows:

Thrust	2100 lb
Operating life	900 sec
No. of start cycles	TBD
Specific impulse, thruster	425 sec
Mixture ratio, thruster	4:1
Nozzle expansion ratio	20:1
Chamber pressure	300 psia

3.1.1.2.13.3 APS Propellant Tankage. APS propellant tankage requirements shall be as follows:

a. The cryogenic thermal protection system shall be optimized for an orbital stay time of 24 hours.

b. Feed tanks shall be capable of providing 100-percent liquid propellant feedout throughout all the mission phases. In particular, liquid feedout shall be accomplished during zero-g and multiple and adverse load environments of 0.03 g during orbit.

c. No icing or moisture condensation shall occur on the tankage system surface due to thermal environments created by cryogenic propellants.

d. The vapor pressure of hydrogen and oxygen propellants shall be controlled to the following maximum and minimum conditions:

Propellant	Vapor Pressure (psia) Minimum	Maximum
Hydrogen	18	20
Oxygen	15	20

e. The hydrogen and oxygen tank maximum operating pressure shall be 34 psia and 37 psia, respectively.

f. Propellant utilization shall be as shown below:

	Quantity (lb)		
	LH_2	LO_2	Total
Orbit maneuvering Delta V = 1196 ft/sec	2300	13,850	16,150
Attitude control	350	1050	1400
Boiloff and line loss	50	0	50
Chilldown loss (lines)	170	0	170
Residual	20	100	120
Contingency	680	2890	3570
Total loaded (max capacity)	3570	17,890	21,460
Basic mission of 1220 ft/sec delta V (OMS + ACPS)	2650	14,900	17,550

g. The maximum allowable heat rate per tank shall be 24 BTU/hr for the four LH_2 tanks, and 47 BTU/hr for the LO_2 tank.

3.1.1.2.13.4 APS Propellant Feed. The Propellant Feed Subsystem shall be designed to control the transfer of liquid propellants from the APS tanks to the propellant conditioning system turbopumps, and from the ground fill and drain interface to the APS tanks. Multiple tanks shall be connected in series, with screens at the tank discharge to provide propellant retention. Propellant transfer lines shall be vacuum jacketed/radiation shielded. In addition, the propellant feed lines to the turbopumps shall be wrapped with cooling coils, utilizing LH_2 from the APS tanks for feed system conditioning to assure subcooled propellant at the pump inlets. Redundant series prevalves shall be provided to permit isolation of each turbopump/propellant conditioning circuit. The prevalves shall be electrically actuated requiring power only during actuation. Each propellant fill and drain line shall contain redundant shut-off valves capable of opening to intermediate positions to control APS tanking rates. Specific performance requirements of the APS feed subsystem are as follows:

a. Fill Rates

Slow fill 0-5 percent, 90-100 percent

LH_2	32 gpm
LO_2	16 gpm

Fast fill 5-90 percent

LH_2	325 gpm
LO_2	160 gpm

b. Maximum Heat Leak

LH_2 feed system (TBD) BTU/hr

LO_2 feed system (TBD) BTU/hr

c. Pump Inlet Conditions

	H_2	O_2
Inlet pressure (min)	24 PSIA	30 PSIA
Inlet temp (max)	$39^{o}R$	$168^{o}R$

d. Maximum Pressure Drop, Each Pump Feed Circuit

LH_2 (TBD) psid at 3.2 lb/sec

LO_2 (TBD) psid at 19 lb/sec

3.1.1.2.13.5 APS Propellant Conditioning. The APS propellant conditioning subsystem shall be designed to provide the proper quality (pressure and temperature) propellants for the orbit maneuvering engines and the attitude control thrusters. Separate gas generators shall be used to drive independent LH_2 and LO_2 turbopumps for each OMS engine. An additional gas generator with a heat exchanger shall be combined with each turbopump/gas generator system to provide vaporized propellants for the ACS whenever the OMS engines are not firing. Each set of heat exchangers shall be designed to meet the maximum flow requirements of four attitude control thrusters or one orbit maneuvering engine operating at steady state conditions. The heat exchanger assemblies, with their respective gas generators and controls, shall be designed to operate in phase with the corresponding turbopump machinery in meeting the transient response characteristics of the attitude control or orbit maneuvering systems. The gas generator supplying the pump turbine shall be designed to operate at a nominal O/F of 0.76 (with an equivalent combustion temperature of $1700^{o}R$). The propellant conditioning gas generators shall be designed to operate at a nominal O/F of 0.95 (corresponding to a combustion temperature of $2000^{o}R$). The nominal performance characteristics of the propellant conditioning system shall be as follows:

	H_2	O_2
Pump discharge pressure	1250 psia	1250 psia
Pump flow rate	3.2 lb/sec	19 lb/sec
Heat exchanger outlet pressure (min)	950 psia	950 psia
Heat exchanger outlet temperature	$300^{o}R$	$400^{o}R$
Pump NPSP	2 psia	8 psia

3.1.1.2.13.6 APS Propellant Distribution. Two functionally identical distribution systems, one for the conditioned GO_2 and one for the GH_2 shall be provided. Each system shall have two accumulators with sufficient capacity to pressurize the APS propellant tank to obtain turbopump net positive suction pressure prior to orbit maneuver engine, or attitude control operation. The distribution system shall connect the conditioning system to the thruster manifold, the gas generator manifold and the APS propellant tank pressurization regulator by means of transfer lines. Conditioned propellant storage accumulators shall be in series with these transfer lines. The transfer line from the conditioning equipment to the thruster manifolds shall be sized to sustain four thruster steady state and/or pulsing operations. The lines within the thruster manifolds shall be sized for two-thruster operation. The inlet manifold of the distribution system shall be isolated from potential failures in the conditioning equipment by series redundant check valves. Each thruster manifold and the two gas generator manifolds shall be isolated in the event of a failure within the manifold by series redundant electrically operated isolation valves. The inlet pressure to each of these manifolds shall be maintained at 400 ± 10 psia. The distribution system shall contain the necessary fill/drain valves required for ground servicing (preflight system charging and post-flight drain and purging and component testing), and the pressure relief valves to prevent system over pressurization due to temperature rise of the conditioned propellants. The servicing valves shall provide system closeout with series redundant sealing surfaces. The relief valves shall be triple redundant parallel circuits with series redundant isolation of the primary relief circuit and single isolation of the secondary circuit. The safety circuit relief valve shall be isolated from the distribution system pressures by a burst disc assembly. The primary circuit shall relieve at 1100 +25, -0 psia, the secondary at 1135 +25, -0 psia and the safety burst disc ruptures at 1225 +50, -0 psia. The propellant distribution performance characteristics shall be as follows:

	H_2	O_2
Max system operating pressure	1100 psia	1100 psia
Propellant storage capacity (min)		
100 psia to 500 psia at 500°R	14.21 lb	42.6 lb
Thruster and GG manifold/regulation		
Inlet pressure	480-1100 psia	480-1100 psia
Outlet pressure	400 ± 10 psia	400 ± 10 psia
Flow rate	0 - 2 lb/sec	0 - 8 lb/sec

3.1.1.2.13.7 APS Pressurization. The APS pressurization functions are as follows:

a. Provide adequate ullage pressure for the APS propellant tanks to supply turbopump NPSP requirements under all operating conditions.

b. Vent tank boiloff during propellant fill.

c. Provide pressure relief for the propellant storage tanks.

Pressurant for all phases of operation shall be obtained from the APS propellant distribution system accumulators. The performance characteristics of the APS pressurization system shall be as follows:

	LH_2	LO_2
Propellant tank pressurization		
Pressure	32-34 psia	35-37 psia
Temperature	300°R	400°R
Propellant tank vent and relief		
Primary vent	35-37 psia	38-40 psia
Burst disc relief	38-40 psia	41-43 psia

3.1.1.2.14 Payload Deployment. The ESS payload deployment system shall use the exploding bridgewire (EBW) ordnance technique for separation. The ESS shall contain the ordnance (linear shaped charge assembly) and two EBW firing units for ESS/payload separation. The two EBW firing units shall be armed and triggered from two separate and independent power sources. The ordnance linear shaped charge assemblies shall consist of a piggyback design (one charge on top of another) to provide redundant initiation and continuous propagation of the linear shaped charge detonation. The separation system design shall provide for verification of proper electrical function with or without live ordnance items installed. The payload deployment system shall be designed to receive signals from the digital computer in the DCM subsystem for the separation sequence initiation. The separation ordnance initiation shall be inhibited before liftoff and shall be armed and triggered upon receipt of separate electrical signals from the DCM subsystem. The attitude control thrusters shall be utilized to obtain the required separation distance following ESS/payload separation.

3.1.2 Operability

3.1.2.1 Reliability. ESS reliability shall be achieved by the use of qualified, and controlled parts; derating of electrical and electronic parts; adequate margins of safety on mechanical and electromechanical parts; the avoidance of Single Points of Failure; and an optimal selection of redundancy techniques to be used in subsystem design.

3.1.2.1.1 Redundancy. The following characteristics shall be used as guidelines for all ESS design.

a. ESS system redundancy techniques shall be selected and implemented such that switching of system functions between redundant elements or paths in the event of a failure in an active function path, does not create a transient condition causing unacceptable stage performance.

b. All subsystems except primary structure and pressure vessels shall be designed to fail operational after the failure of the most critical component and to fail safe for crew survival after the second failure. Electronic systems shall be designed to fail operational after failure of the two most critical components and to fail safe for crew survival after the third failure. Existing subsystems that do not meet this criteria shall be identified. The FO/FO/FS criteria shall be observed for all new avionics equipment design, subject to item-by-item waiver. Existing avionics equipments which do not conform to FO/FO/FS criteria may be selected to provide cost-effective design solutions providing the hardware selection consistently maintains at least Saturn/Apollo reliability standards. The FO/FS criteria shall be observed for all new mechanical subsystems proposed for the expendable second stage, subject to item-by-item waiver. Existing S-II stage subsystems excepting the primary propulsion system, primary structures and pressure vessels shall be reviewed for FO/FS compliance and alternate approaches identified. Subsystem modifications which significantly improve booster/ESS launch success will be identified. Emphasis shall be placed on booster safety particularly during stage separations and abort.

c. The expendable second stage on a reusable space shuttle booster system shall provide for safe mission termination in the event major malfunctions occur during prelaunch preparation and subsequent to lift-off. The desired safe mission termination capabilities should allow for crew egress prior to lift-off and for separation of expendable second stage from booster following lift-off.

3.1.2.2 Maintainability

3.1.2.2.1 Maintenance Requirements

3.1.2.2.2 Maintenance Repair Cycle

3.1.2.2.3 Service and Access. Provisions shall be made for personnel and equipment access into the forward skirt, aft skirt and thrust section areas. Manways shall also be provided for access to the interior of the main LO_2 and LH_2 tanks.

3.1.2.3 Useful Life. The ESS shall be designed for operational usage, without reconditioning, after a maximum 3-year storage period when stored according to Paragraph 3.3.11.

3.1.2.3.1 Not used

3.1.2.3.2 Useful Life—Elastomers. Ultimate age of elastomers shall not exceed the maximum installed life of 24 quarters plus the maximum shelf life of 8 quarters. Shelf life of replacement assemblies containing elastomers shall not exceed 20 quarters. At the expiration of the maximum age of assemblies containing elastomers, these elastomers shall be replaced, except when the expiration date occurs while the stage is in storage. In the latter event, the elastomers shall be replaced after removal of the stage from storage.

3.1.2.4 Environments

3.1.2.4.1 Natural Environment. The ESS shall be designed in accordance with the natural environmental criteria specified in NASA TMX-53957 and NASA TMS-53872, as modified by the requirements of this specification.

3.1.2.4.1.1 Not used

3.1.2.4.1.2 Not used

3.1.2.4.1.3 Not used

3.1.2.4.1.4 Astrodynamic Constants. The astrodynamic constants for trajectory calculation are specified in TMX (TBD).

3.1.2.4.2 Induced Environment. The ESS shall be capable of withstanding the induced environmental levels of acoustics, vibration, shock, acceleration, aerodynamic, and thermal as follows:

3.1.2.4.2.1 Acoustics (TBD)

3.1.2.4.2.2 Vibration (TBD)

3.1.2.4.2.3 Shock. The shock environment of the ESS components due to engine start, aerodynamic effect and separation shall be considered. To provide a design margin for equipment variation due to production variation, and support bracketry amplification, a margin of two times the predicted shock value shall be used.

3.1.2.4.2.4 Acceleration. The maximum longitudinal acceleration to which the ESS will be subjected in unmanned missions is 4.0 g. The maximum lateral acceleration to which the ESS will be subjected is (TBD) g.

3.1.2.4.2.5 Thermal Environment. The thermal environment of the ESS shall be determined by aerodynamic heating and the base heating induced by flight usage of the main propulsion system.

3.1.2.4.2.5.1 Aerodynamic Heating. The design aerodynamic heat-transfer rates for the ESS shall be computed on the basis of total flight vehicle as in Figure 3-1 and the trajectories in Figures 3-14 through 3-19.

3.1.2.4.2.5.2 Base Heating. The stage design base region thermal environment for the ESS shall be based on gimbaling for trimmed flight with a hydraulic actuator system failure or with one engine out.

3.1.2.5 Transportability. The ESS shall be designed to withstand a maximum imposed transportation load of 2 g in the longitudinal, vertical,

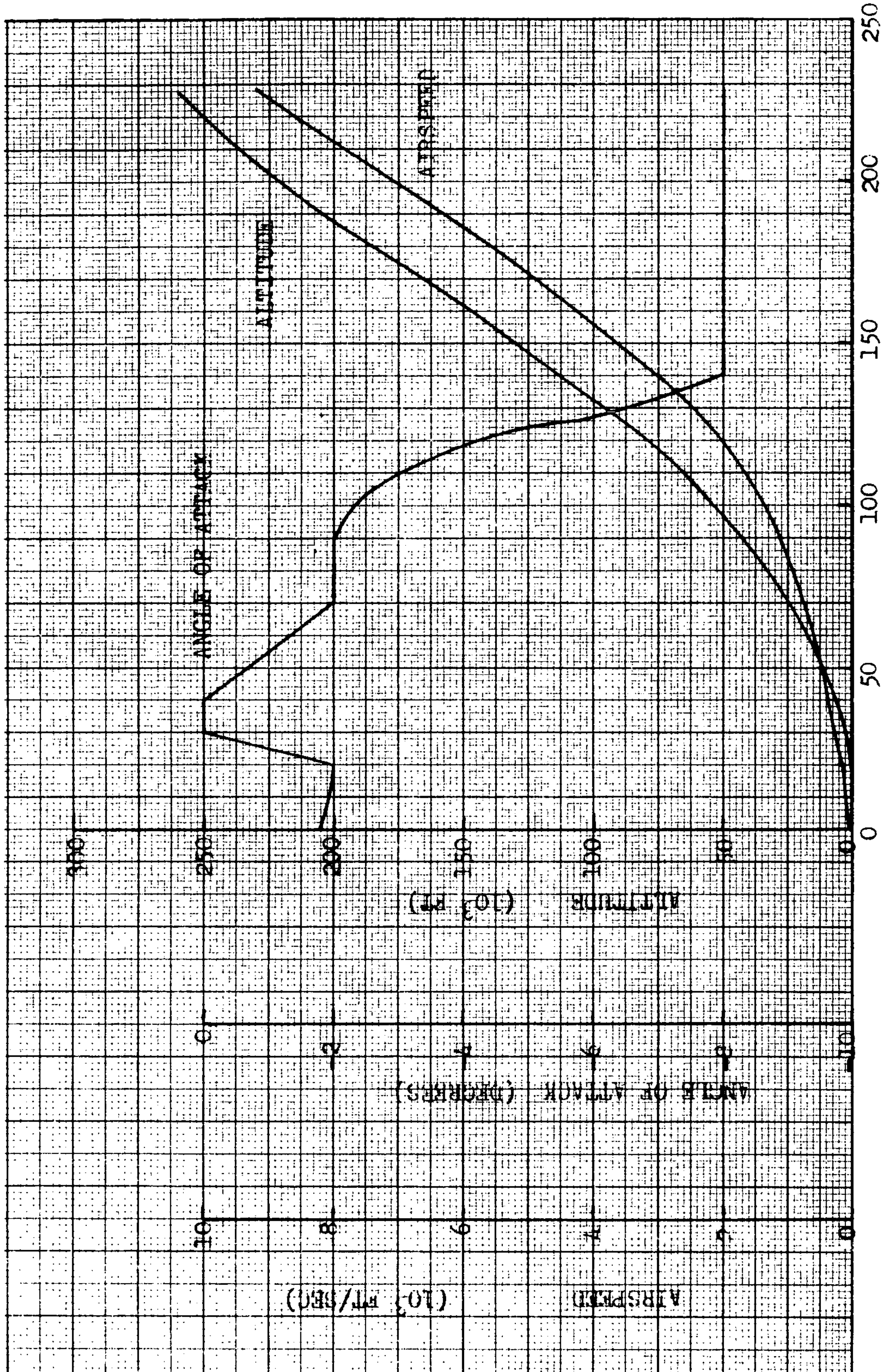


Figure 3-14. Design Aerodynamic Heat Transfer Trajectory
(Mated Ascent - RNS Payload)

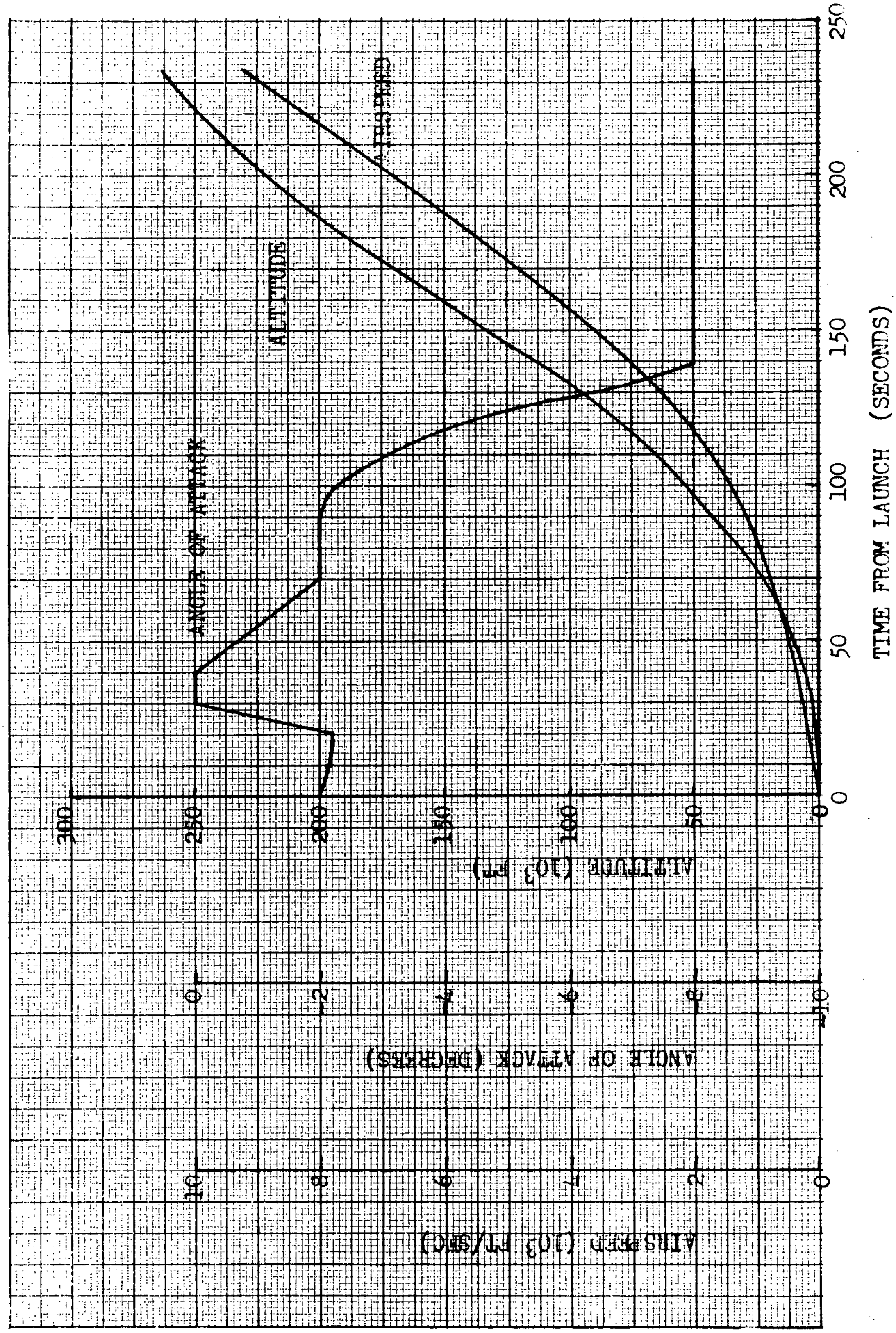


Figure 3-15. Design Aerodynamic Heat Transfer Trajectory (Mated Ascent - Space Tug Payload)

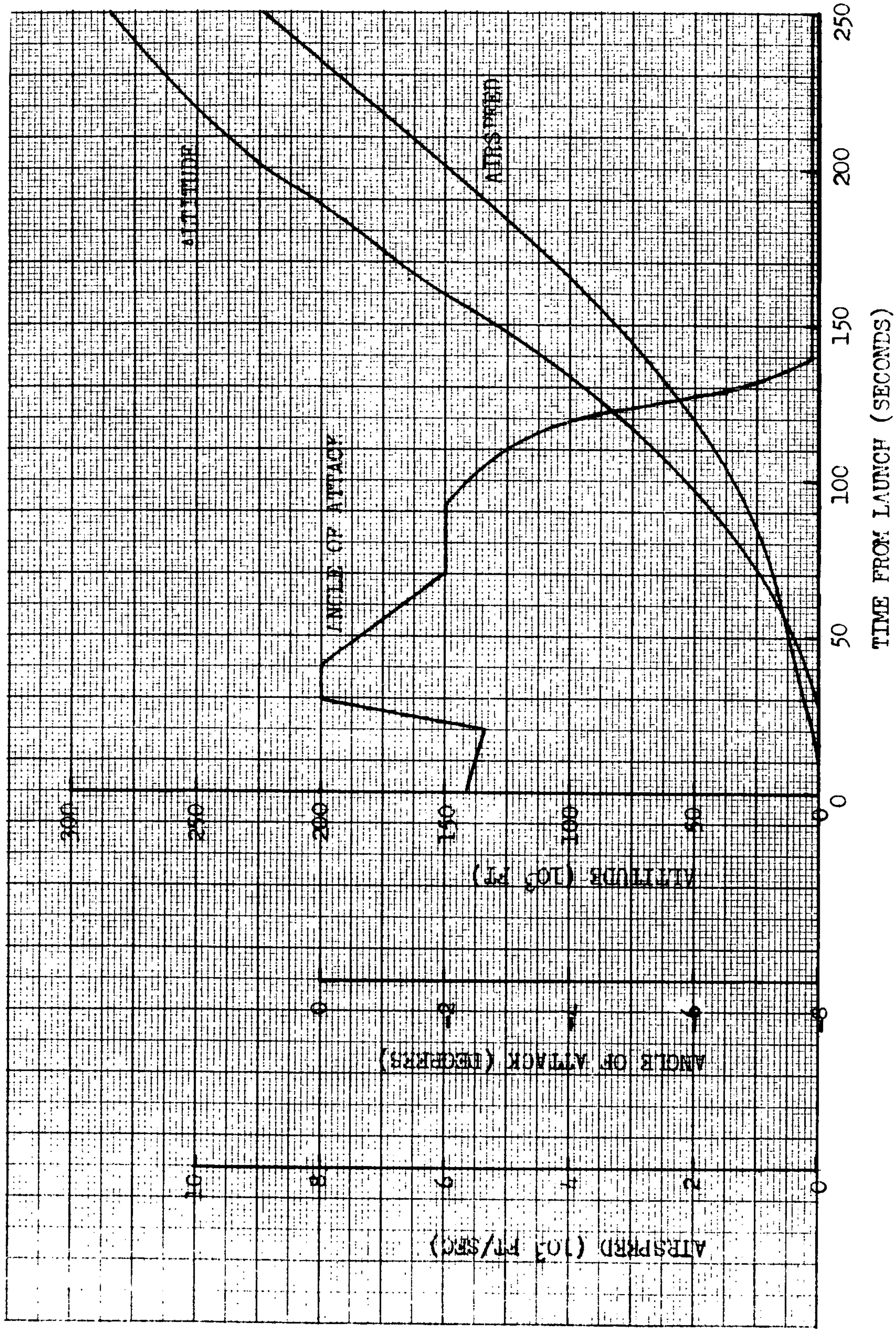


Figure 3-16. Design Aerodynamic Heat Transfer Trajectory
(Mated Ascent - Space Station Payload)

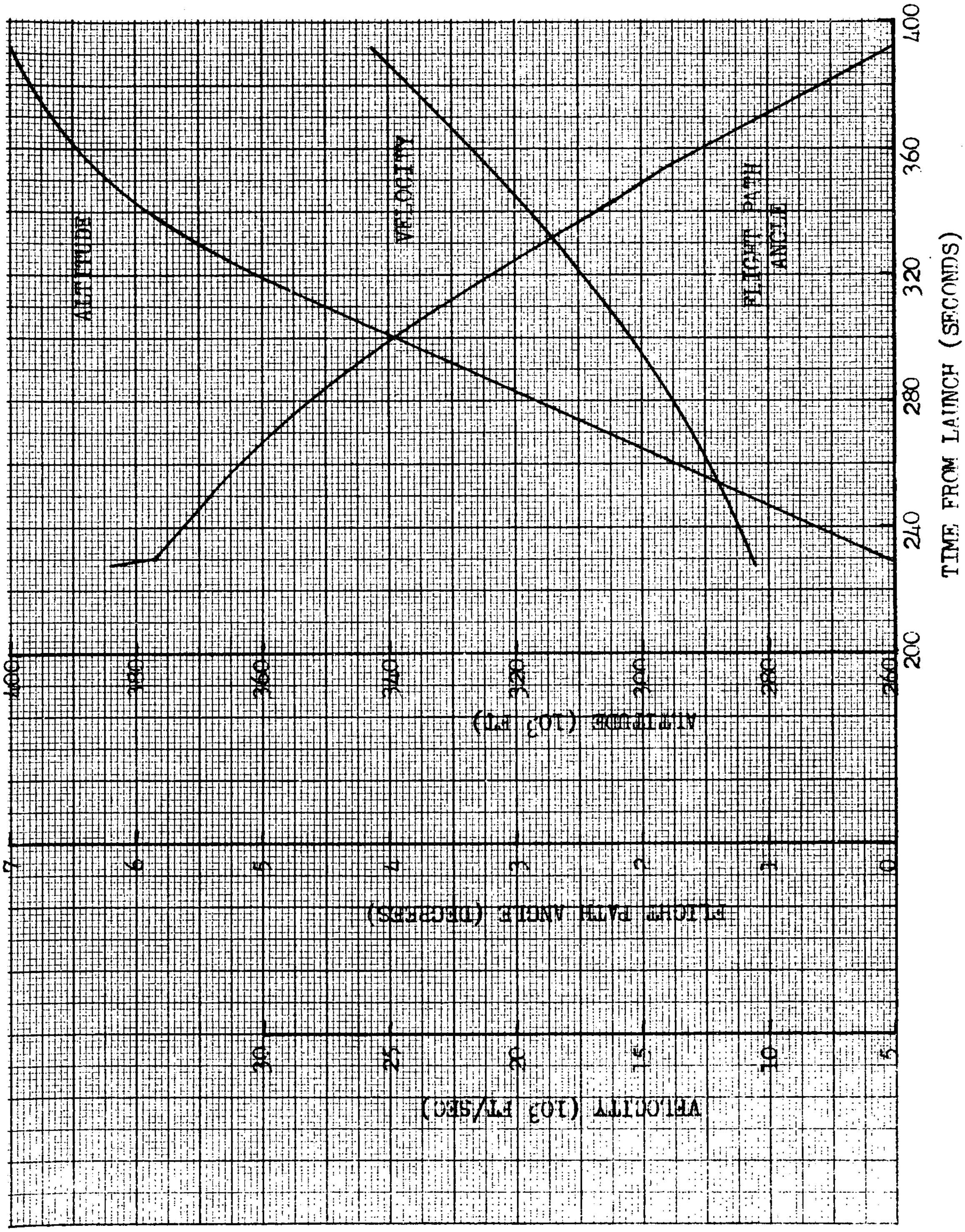


Figure 3-17. Design Aerodynamic Heat Transfer Trajectory (ESS Boost - RNS Payload)

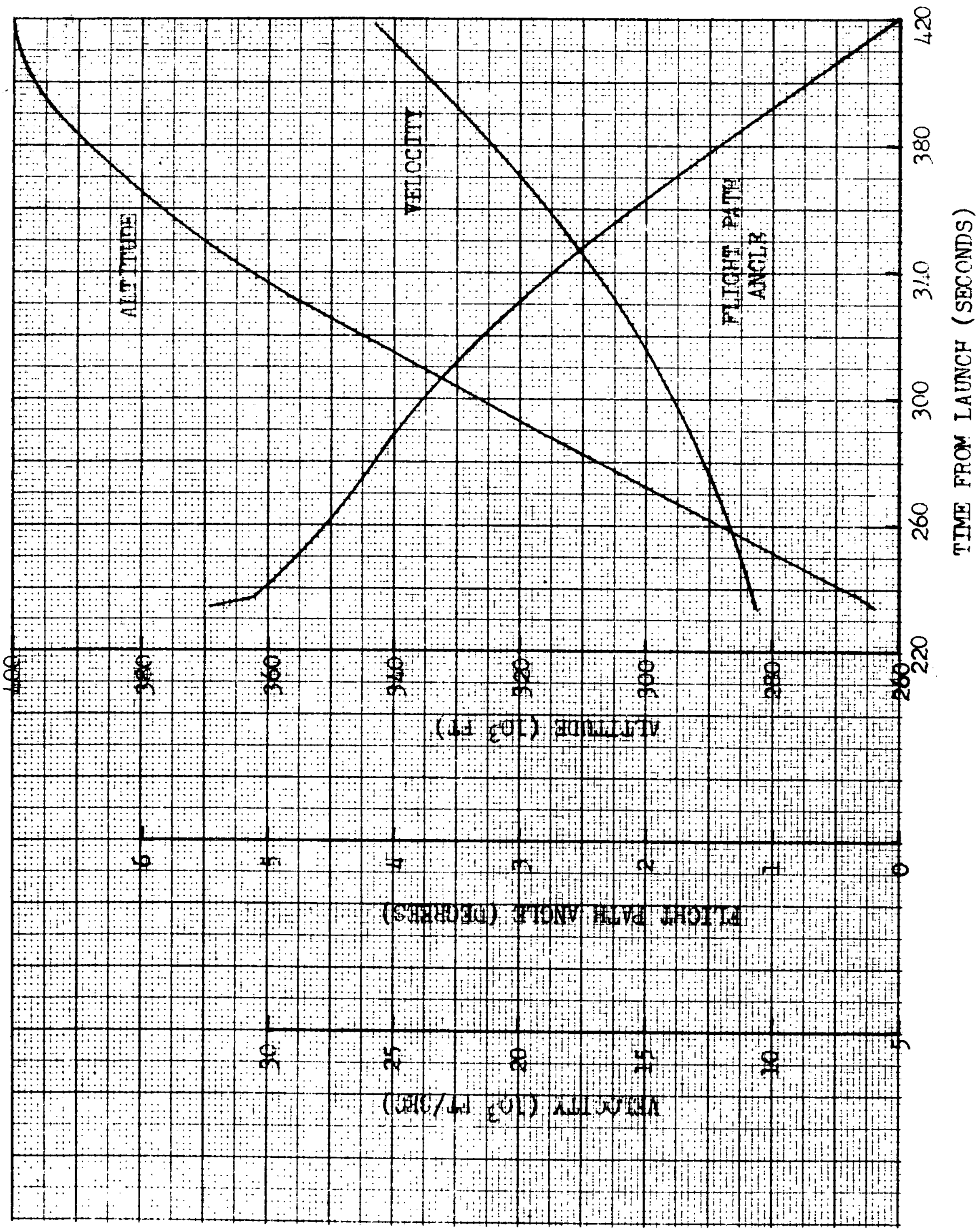


Figure 3-18. Design Aerodynamic Heat Transfer Trajectory (ESS Boost - Space Tug Payload)

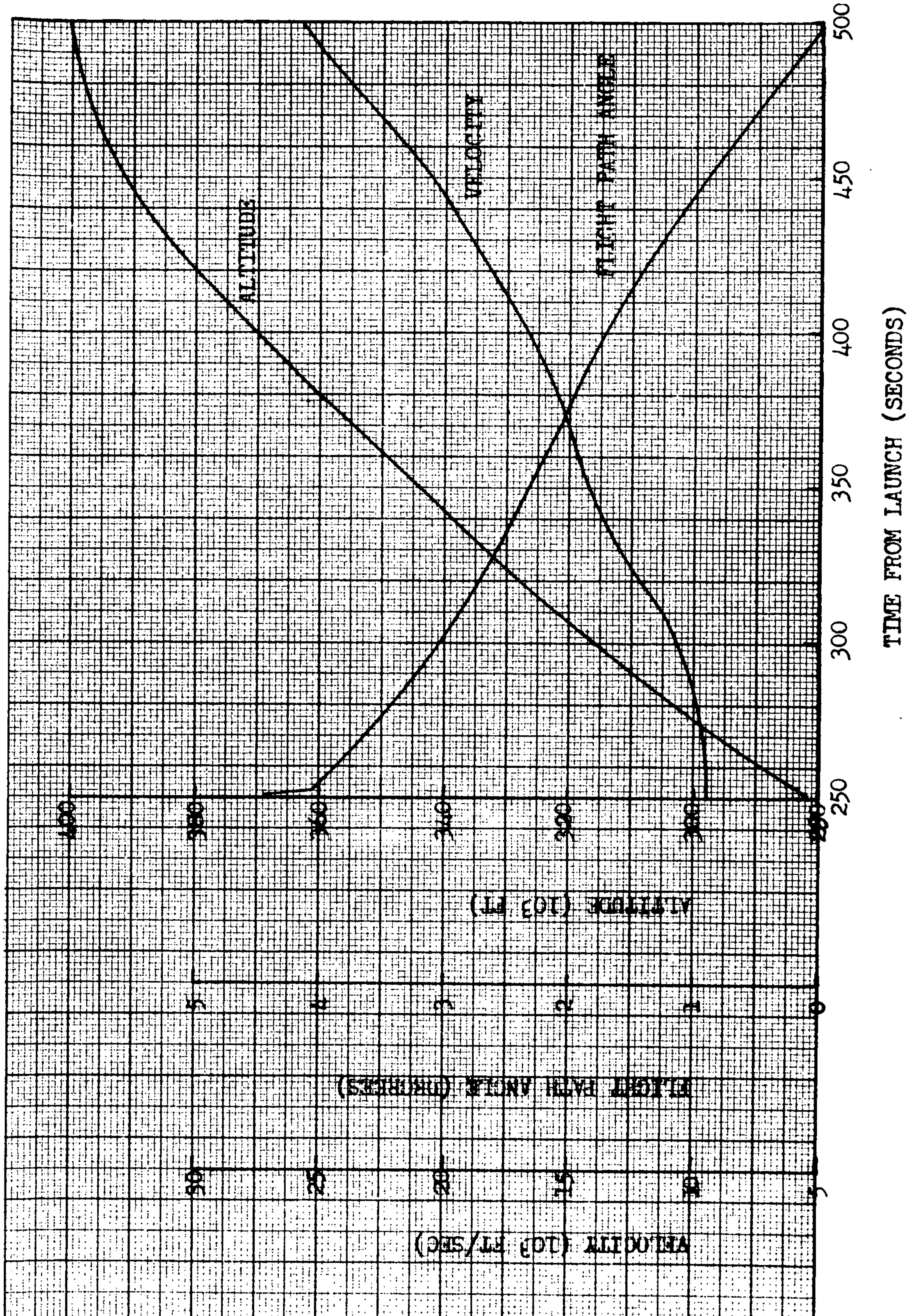


Figure 3-19. Design Aerodynamic Heat Transfer Trajectory
(ESS Boost - Space Station Payload)

and lateral planes. ESS land transportation speed shall not exceed 5 miles per hour on any road. The natural environmental limitations imposed during transportation are indicated in Paragraph 3.1.2.4.

3.1.2.6 Human Performance

3.1.2.7 Safety. With respect to mated boost, the ESS shall be designed compatible within the limits defined in OMSF Safety Program Direction 1A, System Safety Requirements for Manned Spaceflight.

3.1.2.8 Recoverability. The avionics installation and main propulsion engine installation shall be designed to permit in-orbit recovery of the following:

a. Both main engines

b. Avionics components

3.2 CEI Definition. The ESS shall be designed to interface with other end items and components of the integrated space transportation system to the extent specified in these subsections.

3.2.1 Interface Requirements. The ESS shall be designed to interface with the shuttle booster, ESS payloads, the ESS main engines, the shuttle orbiter, and GSE facilities.

3.2.1.1 Schematic Arrangement. The ESS inboard profile is shown in Figure 3-20.

3.2.1.2 Space Shuttle Booster to ESS Interface Definition. The shuttle booster to ESS functional, physical, and procedural requirements shall be in accordance with Interface Control Drawing No. S080-1001.

3.2.1.3 Space Shuttle Engine to ESS Interface Definition. The space shuttle engine to ESS functional and physical requirements shall be in accordance with Interface Control Drawing No. S080-1002.

3.2.1.4 ESS to GSE/Facility Interface Definition. The ESS to GSE functional and physical interface requirements shall be in accordance with Interface Control Drawing No. S080-1003.

3.2.1.5 ESS to Payload Interface Definition. The ESS to payload functional, physical, and procedural requirements shall be in accordance with Interface Control Drawing No. S080-1004.

3.2.1.6 ESS to Space Shuttle Orbiter Interface Definition. The ESS to orbiter interface during ESS equipment recovery operations for physical, functional, and procedural requirements shall be in accordance with Interface Control Drawing No. S080-1005.

3.3 Design and Construction. The design and construction of the ESS shall meet the requirements of this specification.

3.3.1 General Design Features

3.3.1.1 Structures

3.3.1.1.1 Dimensions. The dimensions, configuration, and inboard profile of the ESS shall be as indicated in Figures 3-1 and 3-20.

3.3.1.1.2 Material Strength. The ESS shall be designed employing material strengths based on Handbook MIL-HDBK-5A or on other authorized sources approved by the contractor and the procuring agency. The minimum guaranteed values shall be used. Allowables for a particular material shall be established by test when applicable data is not available. In selecting material strength allowables from materials that show no pronounced yield point, the yield point shall be the 0.2 percent offset value. Material strength allowable shall include all environmental effects to which the material will be exposed from fabrication through flight. For materials where the yield point cannot be established, the safety factor against ultimate shall govern.

3.3.1.1.3 Factors of Safety. The ESS shall be designed applying the factors of safety given in Table 3-6 to the items listed. The structural margin of safety determined on the basis of these factors shall be not less than zero percent.

3.3.1.1.4 Structural Components. The ESS major structural components are the liquid hydrogen tank, liquid oxygen tank, liquid hydrogen tank/liquid oxygen tank common bulkhead, aft skirt, forward skirt, and thrust structure. These structural components shall be designed to withstand the general structural loading specified in Paragraph 3.1.1.2.1 and shall include provisions for systems installations as appropriate and provide structural capability to withstand local loadings resulting from such systems installations.

3.3.1.1.4.1 Liquid Hydrogen Tank. The liquid hydrogen tank shall include a cylindrical section, a forward bulkhead constructed with integral welds, insulation, and a common bulkhead with the liquid oxygen tank. The cylindrival section shall be an integral part of the basic vehicle structure.

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Table 3-6. Factors of Safety

General structure	
Yield factor of safety	1.10
Ultimate factor of safety	1.40
Vehicle propellant tanks	
Proof pressure	1.05 x limit pressure
Yield pressure	1.10 x limit pressure
Burst pressure	1.40 x limit pressure
Hydraulic or pneumatic systems	
Flexible hose, tubing and fittings less than 1.5 inch in diameter	
Proof pressure	2.00 x limit pressure
Burst pressure	4.00 x limit pressure
Flexible hose, tubing and fittings (including liquid oxygen and liquid hydrogen vent lines) 1.5 inch in diameter and greater	
Proof pressure	1.50 x limit pressure
Burst pressure	2.50 x limit pressure
Gas reservoirs	
Proof pressure	1.50 x limit pressure
Yield pressure	1.10 x preset pressure
Burst pressure	2.00 x limit pressure
Actuating cylinders, valves, filters, switches	
Proof pressure	1.50 x limit pressure
Burst pressure	2.50 x limit pressure
Liquid oxygen and liquid hydrogen feed lines and APS fill and drain lines	
Proof factor of safety	1.05 x limit pressure
Yield factor of safety	1.10 x limit pressure
Burst factor of safety	2.50 x limit pressure
Main liquid oxygen fill and drain line	
Proof factor of safety	1.05 x limit pressure
Yield factor of safety	1.10 x limit pressure
Burst factor of safety	1.40 x limit pressure
APS propellant tanks	
Proof pressure	1.50 x limit pressure
Yield pressure	1.10 x limit pressure
Burst pressure	2.00 x limit pressure

3.3.1.1.4.2 Liquid Oxygen Tank. The liquid oxygen tank shall be constructed of integral welded plates and shall include the common bulkhead defined in Paragraph 3.3.1.1.4.3 and aft bulkhead.

3.3.1.1.4.3 Common Bulkhead. The common bulkhead shall be the aft enclosure of the liquid hydrogen tank and the forward enclosure of the liquid oxygen tank.

3.3.1.1.4.4 Aft Skirt Structure. The aft skirt structure shall serve to transmit first-stage boost and second-stage thrust forces to the ESS body. The internal portions of this structure shall be provided with thermal protection from the heating produced by the firing of the main propulsion system engines and the orbital maneuvering system engines.

3.3.1.1.4.5 Forward Skirt Structure. The forward skirt assembly shall transmit part of the first stage boost loads to the ESS and shall transmit all thrust and vehicle maneuvering loads to the payload. The skirt structure shall include a bolting flange and mating face at station 856 for attachment of the payload adapter section.

3.3.1.1.4.6 Thrust Structure. The thrust structure assembly shall transmit main propulsion and orbital maneuvering engine thrust and actuation loads from the engine gimbal points to the aft skirt.

3.3.1.1.4.7 Not used

3.3.1.1.5 Insulation. The ESS design shall include a liquid hydrogen tank insulation which shall limit the heat input to the liquid hydrogen such that engine pump NPSH requirements as defined in 3.1.1.2.5.1 are met and the heat input is consistent with a 16.2 psia maximum vapor pressure during ground hold. The total heating mission is from initiation of tank pressurization to end of ESS main propulsion boost for the trajectories specified in Figures 3-14 through 3-19. The insulation shall be capable of withstanding stresses, induced by virtue of its attachment to the primary structure in combination with stresses resulting from natural and induced environments as defined in 3.1.2.4 and aerodynamic thermal environments.

3.3.1.1.6 Protrusions and Fairings. The ESS design shall be limited to the following protrusions.

Liquid hydrogen feed line fairing (2 fairings includes ACPS thrusters and docking port)
Liquid hydrogen return line fairing (1 fairing)
Systems tunnel (1 fairing)
Liquid oxygen vent valves fairing (1 fairing)
Liquid hydrogen fill and drain valve fairing (1 fairing)
Liquid oxygen fill and drain disconnect fairing (1 fairing)
Engine cutoff sensor and wiring fairing (2 fairings)
Liquid oxygen dispersion stringer fairing (2 fairings)
Liquid hydrogen tank instrumentation wiring fairing (3 fairings)
Leak-detection lines (fairings not required)
Upper umbilical disconnect panel (1 place)
Lower umbilical disconnect panel (1 place)
Forward insulation ramp fairing (144 fairings)
Liquid oxygen umbilical support brackets (2 fairings)
Liquid hydrogen vent valves (no fairings required)
Liquid hydrogen tank half insulation, Station 283 (no fairings required)
Aft skirt external insulation (no fairings required)
Main propulsion engine, airstream deflector (no fairings)

Protrusions and fairings shall be capable of withstanding design aerodynamic and thermal environments defined utilizing the design aerodynamic heat transfer trajectories given in Figures 3-14 through 3-19.

3.3.1.2 Not used

3.3.1.3 Propellant Densitites. The ESS shall be designed to provide propellant management based on liquid hydrogen density of 4.4 pounds per cubic foot at -423°F and liquid oxygen density 70.8 pounds per cubic foot at -297°F. Liquid hydrogen compressibility shall be assumed to be 6.42×10^{-4} per psi.

3.3.1.4 Engines

3.3.1.5 Pressurants. Nitrogen and helium pressurants shall conform to the requirements of Paragraph 3.2.1.5.2.3.

3.3.1.6 Conditioning

3.3.1.7 Flight Control

3.3.1.8 Electrical and Electronic

3.3.1.8.1 Lightning Protection. The ESS shall be designed to receive and discharge lightning within values or limits specified by Paragraph 3.7 of MIL-B-5087.

3.3.1.9 Propellant Dispersion

3.3.1.10 Leak Detection and Purge

3.3.1.10.1 Hazardous Gas Detection. Provisions for hazardous gas detection shall be provided in the engine compartment and the forward skirt of the ESS. These provisions shall comprise a 1/4-inch manifold mounted to the bottom of the thrust cone in the engine compartment and a similar 1/4-inch manifold mounted in the forward skirt. The hazardous gas detection support equipment shall be provided as GFE and shall interface with the ESS at the forward and aft umbilical carrier plate assemblies. Compatible disconnect assemblies shall be provided between the GSE and ESS.

3.3.1.11 Not used

3.3.2 Selection of Specifications and Standards. All specifications and standards applicable to the ESS shall be listed (see Paragraph 3.3.12). The order of precedence for selection of government specifications shall be in accordance with MIL-STD-143.

3.3.2.1 Drawings. The ESS drawings and associated lists shall be in accordance with MIL-D-70327.

3.3.3 Materials, Parts, and Processes. Materials, parts, and processes, shall conform to the applicable specifications and standards referenced in Section 2 and in Paragraph 3.3.12. NR process specifications to be employed in the design of the ESS shall be prepared in NR format and submitted to NASA for approval. The approved NR process specifications, including those imposed upon subcontractors shall supersede the applicable portions of the government specifications.

3.3.4 Standard and Commercial Parts. Government standards shall be used in all cases except as defined in the following paragraphs.

3.3.4.1 Nonfunctional Parts and Materials. Commercially available parts fabricated or procured in accordance with the contractors standard parts listing or procurement specifications may be used providing government standard parts are not adequate or are not available and the parts selected meet the applicable requirements of this specification.

3.3.4.2 Functional Parts. Functional parts, components, modules, and assemblies which are contractor designed and fabricated or commercially available, fabricated or procured in accordance with the contractors design standards or procurement specifications, may be used providing the government standard functional products are not available and the products are selected and controlled in accordance with criticality category rankings and meet the applicable requirements of this specification.

3.3.5 Moisture and Fungus Resistance. The ESS shall be designed to use fungus-resistant materials whenever possible. Fungus-nutrient materials that are used shall be treated so that the material will become fungus resistant. The treated material shall meet the fungus test in MIL-STD-810. Materials that are not fungus resistant may be used in hermetically sealed assemblies and other qualified uses such as paper capacitors and treated transformers.

3.3.6 Corrosion of Metal Parts. The ESS shall be designed to use metallic materials chosen for their corrosion resistance characteristics. Metal parts shall be protected from corrosion by stress-relieving, plating, anodizing, chemical coatings, organic finishes, and combinations thereof, as required. Finish specifications shall comply with criteria in MIL-STD-171.

3.3.6.1 Dissimilar Metals. The ESS design, insofar as practical, shall avoid the use of dissimilar metals in contact with one another. Dissimilar metals, as defined in MS33586, shall not be used in combination unless they are suitably coated to prevent electrolytic corrosion.

3.3.7 Interchangeability and Replaceability. The ESS shall be designed for ease of manufacture, assembly, inspection, and maintenance. Insofar as practicable, component parts shall be interchangeable or replaceable in accordance with MIL-I-8500. When practical, modular packaging of hardware, including modifications, shall provide interchangeability.

3.3.8 Workmanship. The ESS, including all parts and assemblies, shall be designed, constructed, and finished in a thoroughly workmanlike manner. Contractual specifications where applicable, shall be the governing criteria for workmanship. Areas involving workmanship not covered by contractual specifications shall be in accordance with manufacturing practices that will produce equipment free of defects. Special attention shall be given to neatness and thoroughness of assembly, wiring, marking of parts and assemblies, finishing, fitting, and freedom of parts from burrs, sharp edges, and protuberances.

3.3.9 Electromagnetic Interference

3.3.9.1 System Interference. The design requirements incorporated to assure electromagnetic interference-free operation shall be those specified by MIL-I-6181 for electromagnetic emission and susceptibility and MIL-B-5087 for electrical bonding. Details of these requirements shall be delineated in the MIL-E-6051-required Electromagnetic Interference Control Plan.

3.3.9.2 System Compatibility. The design requirements incorporated to assure total end item electromagnetic compatibility shall be those specified by MIL-E-6051. The details of these requirements shall be as delineated in the MIL-E-6051-required Electromagnetic Control Plan.

3.3.10. Identification and Marking. The ESS assemblies, subassemblies, units, sets, parts, and all items requiring identification shall be designed for marking in accordance with MIL-STD-130.

3.3.11 Storage. The ESS shall be designed to have a storage life of not less than five years when properly stored and shall have the capability of being restored to the requirements of this specification with proper processing at any time during the five year storage period. Hardware items and functional equipment shall be designed for operational usage without reconditioning, except as noted in Paragraph 3.1.2.3, after a maximum storage period of three years. Where limited storage is required due to life limit of materials used, such items shall be identified and controlled.

3.3.11.1 Not used

3.3.12 Design, Method and Material Documents. The design, method, and material documents that are not listed elsewhere herein, but are employed in the design of the ESS are listed in TBD; (the identification of applicable documents is deferred pending further development of the ESS design. Refer to Paragraph 3.3.12 of S-II CEI Specification CP621M0014A for a representative listing.)

4.0 QUALITY ASSURANCE PROVISIONS

The contractor shall perform testing in accordance with the requirements of safety, NPC 200-2, and for the verification of the Section 3 requirements. The contractor shall ensure that those test facilities under his control shall have good safety practices and that they are adhered to throughout testing. The contractor shall record and analyze the data necessary for verification of test results. Reports shall be generated at the conclusion of each test describing the test and testing results and shall be made available to the procuring agency upon request. Adherence to the requirements of NPC 200-2 shall be as defined in the basic contract. All primary design requirements and secondary design requirements of Section 3 shall be verified as required.

4.1 Phase I Test/Verification. This section specifies the requirements and methods for formal verification of performance, design, and construction requirements of Section 3.

4.1.1 Verification. The tests/verification performed to verify the requirements of Section 3 shall include the following:

4.1.1.1 Inspection

4.1.1.1.1 Inspection for Manufacturing. Where applicable, inspections shall be conducted to the required degree necessary at each location/activity throughout the life of the stage. Inspection is defined for operations up to and including those of Paragraph 4.1.3.4 to include those for inspection of materials, parts, and processes, standard and commercial parts, workmanship, and identification and marking. The contractor shall conduct an in-process inspection of materials, parts, and processes. The contractor shall perform visual inspection of standard and commercial parts to verify Paragraph 3.3.4 requirements as defined by engineering documentation. The contractor shall perform inspection on parts in process to verify workmanship requirements specified in Paragraph 3.3.8. The contractor shall perform inspection to verify requirements for inspection and marking specified in Paragraph 3.3.10.

4.1.1.1.2 Inspection for MTF and KSC. Where applicable, inspection for Paragraph 4.1.3.2 and subsequent is defined as visual inspection for damage. Additionally, for Paragraph 4.1.1.1.1, inspection is defined as inspection necessary for new installation, replacement, and/or repair activity.

4.1.1.2 Demonstration. Where applicable, the requirements of Section 3 verified by methods which involve actual accomplishment of activities, i.e., observable physical actions, such as transportation and access to equipment compartments, shall be defined as demonstration.

4.1.1.3 Test. Where applicable, the completely assembled end item and subsystems therein shall be tested to verify that each applicable design requirement in Section 3 has been met. All subsystems and systems shall be compatible to each other and to external interfacing systems and/or facilities. Equipment simulating interface functions will be provided as necessary for such verification. Tests shall be accomplished in a logical sequence of ascending complexity with subsequent tests building on the results of the previous test. Such tests shall be performed with automatic checkout and/or manual checkout where required.

4.1.1.4 Analysis. Where applicable, the design criteria requirements of Section 3 shall be verified by review of analytical data. These analyses shall be updated to include empirical supporting data that become available from tests performed.

4.1.2 Engineering Test and Evaluation. The contractor shall perform the necessary tests and evaluations to support the design and development of the ESS wherein supporting test programs are required to verify Section 3 requirements. The contractor must perform other engineering development tests, as required, in support of the ESS Program.

4.1.3 Flight Systems Acceptance Testing. The contractor's flight systems acceptance tests on the CEI shall demonstrate or verify that the requirements of Section 3 are satisfied as specified in the Part II. These tests shall be conducted in the environment present during the test and shall only verify those requirements that can be verified in that environment.

4.1.3.1 Manufacturing Checkout. This testing phase is defined to be those tests performed on the CEI at the Seal Beach Facility, starting at the subsystem level, through integrated systems test. For those tests where either automatic or manual capability is available, the primary test method shall be automatic.

4.1.3.2 Prestatic Checkout. This testing phase is defined to be a series of functional tests that shall be performed on the first two flight stages to verify the functional configuration and readiness prior to static-firing tests. These tests shall include automatic and/or manual checkout of subsystems, integrated systems verification tests, and propellant loading tests to verify the requirements of Section 3.

4.1.3.3 Static-Firing Tests. The first two flight stages will undergo static firing testing. Flight systems installed will be functionally operated during static-firing to verify requirements of Section 3. Firing durations will be sufficient to assure stability to the overall systems in terms of static-firing environment.

4.1.3.4 Post Static-Firing Tests. These tests are defined to be those subsystems and integrated systems tests necessary to be performed on the first two flight stages to verify the functional configuration and readiness prior to shipment to KSC.

4.1.3.5 End-Item Test Plan. An end-item test plan shall be submitted to define the objectives for all tests to be accomplished for the inspection, demonstration, testing, and/or analysis requirements.

4.1.4 Reliability Test and Analysis. Requirements for testing and analysis which are to be accomplished to verify requirements of Paragraph 3.1.2.1 are as follows: that testing to be accomplished specifically and solely to acquire reliability data shall be included herein and to the level of detail necessary to establish the scope and accuracy of the reliability data to be acquired and the scope of the test program.

4.1.4.1 Qualification Testing. Qualification testing of components shall be as specified in the Reliability Plan No. (TBD).

4.2 Phase II Test/Verification. Phase II tests/verifications shall be those which cannot be verified until the CEI is assembled into or used with other project or system equipment. Methods of test/verification consist of inspection as defined in Paragraph 4.1.1.1.2, demonstration as defined in Paragraph 4.1.1.2, tests as defined in Paragraph 4.1.1.3, and analysis as defined in Paragraph 4.1.1.4.

5.0 PREPARATION FOR DELIVERY

5.1 Preservation, Packaging, and Packing. The ESS shall be preserved, packaged, and packed for delivery to provide complete protection for the equipment against the handling, transportation, and storage environments specified in Paragraphs 3.1.2.4 and 3.1.2.5. Generalized methods to be used in preservation, packaging, and packing of the stage are covered in the following paragraphs.

5.2 Stage Protection During Transport and Storage

5.2.1 Transport. During all phases of transport, the ESS shall be installed on the stage transporter for maximum protection against the mechanical environment associated with handling and transportation.

5.2.2 Protection. During transport and storage, the stage forward skirt and engine compartment areas shall be protected from sand, dust, and moisture.

5.2.2.1 Stage Systems Preservation. The following measures shall be accomplished to ensure protection against deterioration of stage systems during transport and storage.

5.2.2.2 Sealing. All access doors and ports shall be sealed.

5.2.2.3 Protective Packaging. System components not hermetically sealed or otherwise inherently protected shall be covered with a flexible metal foil moisture barrier and sealed with tape.

5.2.2.4 Preservation. The hydraulic system shall be completely filled with operating fluid.

5.2.2.5 Surface Protection. All exposed critical surfaces shall be coated with corrosion-preventative compound.

5.2.2.6 Purging. The propulsion systems shall be purged with nitrogen gas.

APPENDIX B
SPECIFICATION NO. 76Z0500
ADDENDUM A
CODE IDENTIFICATION NO. 01470
SPACE SHUTTLE BOOSTER
CONTRACT END ITEM

This specification is an addendum to the space shuttle booster specification. The exact content of Specification 76Z0500, used as the basic document for this addendum, is dated March 26, 1971.

INTRODUCTION

1.0 SCOPE

1.1 Content. This addendum defines the required changes to Specification No. 76Z0500 to establish the performance, design, development, and test requirements for the space shuttle booster when the orbiting vehicle, including the payload, is the orbiter, as defined by Prime Item Development Specification for Space Shuttle, Orbiter Vehicle, CEI Part 1, No. CP613M0002, or an Expendable Second Stage (ESS), CEI Part 1, No. CP613M0003.

1.2 Organization of Document. This document permits a ready comparison of the exact relationship between two items by direct reference to the existing (76Z0500) specification on a paragraph-by-paragraph basis, identifying in the addendum specific reference to each paragraph, and noting addition, deletion, or change.

2.0 APPLICABLE DOCUMENTS. To contractor specifications, add: TBD.

3.0 REQUIREMENTS. The paragraphs of basic Specification 76Z0500 require no changes to specify the requirements of the orbiter and ESS space shuttle booster, except those stated herein. In the following list of paragraphs and figures, the only change required is to substitute "orbiter or ESS" for "orbiter."

Paragraphs		Figures
3.1	3.7.9(i)	3.1.1-1(1.0), (5.0)
3.2.1.1	3.7.9.1.2	3.1.1.1-1
3.2.1.1.1.1.1	3.7.11(c)	3.1.1-5(5.4)
3.2.1.1.2	3.7.11.2.2 first sentence only)	3.2.1.1.1.1-5
3.2.2.4.2	3.7.13.2.4	3.7.1-1
3.2.5.2.1	4.2.2	3.7.1.2.8
3.7.1	4.2.5.3(a), (c)	3.7.1.2.8.1
3.7.8(e)	6.1	3.7.1.2.8.2
3.7.8.2.9		3.7.11.1-1

3.1.2 Interface Definition. Revise block "acceptance test, transport, ...maintenance..." by adding "...conversion to/from ESS configuration ..." after "...maintenance..." Add Item (k) as follows:

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Interface Control Document No.	Areas of Interface
(k) ICD S080-1001	Booster Vehicle and ESS Vehicle

3.1.2.1 Subsystem Interfaces. To Item 3.0 between the words "maintenance" and "repair" add "conversion to/from ESS configuration as required."

3.2.1.1 Perform Mission. Revise the second sentence to read as follows: "The performance of the booster during the mated ascent and staging is predicated on the use of an orbiter and payloads, described in Specification CP613M0002, and the use of an ESS and payloads, described in Specification CP613M0003."

Add a fourth sentence to read as follows: "The mass properties and other physical characteristics of the ESS-payload combination affecting the performance of the booster are described in Drawing S080-1001, booster ESS interface document."

3.2.1.1.1 Mated Ascent. After the second sentence, add the following: "The booster shall also be capable of boosting the ESS with the following payloads to the staging conditions noted:

	Altitude (ft)	Velocity (fps)	Flight Path Angle (deg)
Nuclear Stage	251,695	8,048	10.8
Space Station	278,509	9,044	4.7
Space Tug	251,529	10,059	3.3

Revise the fifth sentence as follows: "During ascent, the dynamic pressure-angle of attack ($q\alpha$) shall not exceed +2800 or -2900 degree-pound per square foot and the dynamic pressure-side slip angle ($q\beta$) shall not exceed 2400 degree-pound per square foot when boosting the orbiter, or 1600 degree-pound per square foot when boosting the ESS."

3.2.1.1.2 Booster/Orbiter or ESS Staging. In Figure 3.2.1.1.1.1-5, revise "voice and data" to read "voice (orbiter only) and data."

3.2.1.1.2.1 Performance Characteristics. Revise the first sentence to read as follows: "The CEI shall be capable of the flight performance specified in ICD SR 2.4.4-11186 and Specification CP613M0003.

3.2.2.2 Dimensions and Cube Limitations. Add Figure 3.2.2.2-4.

3.2.2.4.2 Design Loading. Add the following sentence: "The CEI shall also be capable of supporting a vertical unfueled ESS with payload and located (relative to the CEI) as shown in Drawing S080-1001, Appendix A, Volume VI, interface control document for the booster/ESS mated configuration."

3.2.4.1 Maintainability Requirements. Add the following sentence: "The characteristics of the modifications required to prepare the booster for an ESS mission after completing an orbiter mission and to convert back to the initial booster configuration after completion of an ESS mission shall not increase the two-shift, 5.5 working days requirement for the maintenance and refurbishment portion of the turnaround."

3.2.4.2 Maintenance and Repair Cycles. Revise the second sentence to read as follows: "Booster ground turnaround maintenance operations, including modifications required by ESS missions, shall be accomplished in 5.5 days (95th percentile)."

3.5.3 Facilities and Facility Equipment. Add "... including Addendum A."

3.7.1.2.5 Maximum Bending Loads. Revise to read as follows: "The body structure shall be capable of withstanding the maximum bending load specified in Table IV and the load intensities defined in interface control document S080-1001."

3.7.1.2.7 Maximum Axial Loads. Revise to read as follows: "The body structure shall be capable of withstanding the maximum axial loads specified in Table IV and the load intensities specified in interface control document S080-1001."

3.7.1.2.8.2 Mating. Add "... or the ESS is currently positioned as shown in interface control document S080-1001."

3.7.8.2.7 Aerodynamic Load Relief. Change "±2800 psf-deg" to "+2800 and -2900 psf-deg."

3.7.10.1 Interfaces. In Figure 3.7.11.1-1, change "two-way duplex voice" to "two-way duplex voice (orbiter only)."

3.7.11 Communications. In first sentence, after voice communications, add "... (orbiter only)."

4.0 QUALITY ASSURANCE PROVISIONS. No change.

5.0 PREPARATION FOR DELIVERY. No change.

6.1 Intended Use. Revise the first sentence to read: "The intended use of this CEI is to boost either an orbiter or an ESS vehicle..." Add the following sentence: "The modifications required to prepare the booster for an ESS mission after completion of an orbiter mission, or vice versa, shall be kept to a minimum."

APPENDIX 10. No change.

APPENDIX 20. No change.

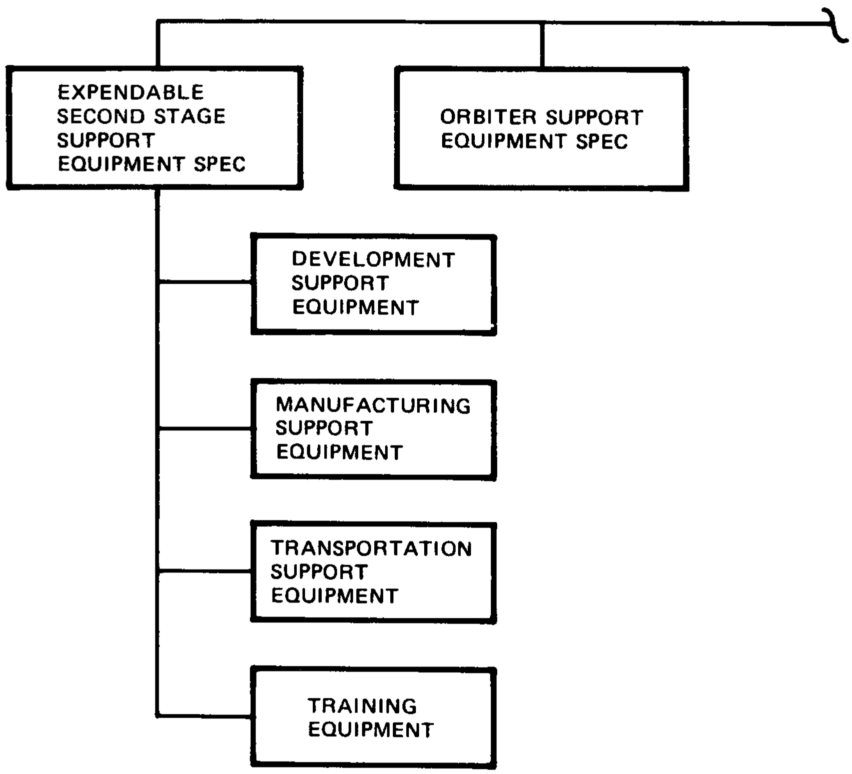
APPENDIX C
SPECIFICATION NO. 76Z0501
ADDENDUM A
GROUND SUPPORT SYSTEM
CONTRACT END ITEM

This specification is an addendum to the space shuttle ground support system specification. The exact content of Specification 76Z0501, used as the basic document for this addendum, is dated March 19, 1971.

1.1 After "...space shuttle system," add "and expendable second stage on a reusable shuttle booster system."

1.2 Following "...orbiter..." in the last sentence, add "and expendable second stage."

To Figure 1.3-1, add the following:



3.1 Add "and ESS/RSB system" after "... shuttle system."

3.1.1 Add "and ESS/RSB system" after "The space shuttle..."

Add 3.1.1.3 <u>ESS Support Equipment Specification</u>. The ESS SE specification...

3.1.1.3.1 ESS Development Support Equipment Specification. The ESS SE...

3.1.1.3.2 ESS Manufacturing Support Equipment Specification. The manufacturing...

3.1.1.3.3 ESS Transportation Equipment Specification. The ESS...

3 1.1.3.4 ESS Training Support Equipment Specification. The training...

3.1.1.3.1 Change to 3.1.1.4.1 and add "The low bay of the KSC Vertical Assembly Building (VAB) shall be provided with the required support equipment to accomplish inspection, maintenance (Level 1), servicing, and checkout of the ESS."

3.1.1.3.2 Change to 3.1.1.4.2.

3.1.1.3.3 Change to 3.1.1.4.3.

3.1.1.3.4 Change to 3.1.1.4.4 and add "A service tower shall be provided at the launch pad to provide access and service to the ESS (see Figure 3.1-1)."

3.1.1.3.5 Change to 3.1.1.4.5.

3.1.1.3.6 Change to 3.1.1.4.6 and add "Does not apply to ESS."

3.1.1.3.7 Change to 3.1.1.4.7 and add "Does not apply to ESS."

3.1.1.3.8 Change to 3.1.1.4.8 and change the first sentence to read "...the orbiter vehicle and the ESS." Add to the last sentence "(orbiter only)."

3.1.1.3.9 Change to 3.1.1.4.9 and change to read "...and maintain the orbiter, booster, ESS, orbiter/booster, and ESS/booster."

3.1.1.4 Change to 3.1.1.5.

3.2.1.8 In the second sentence, add "(orbiter and booster only)" after "... horizontal flight test..."

3 2.1.9 Change first sentence to read "...performance of the orbiter, booster, ESS, orbiter/booster, and ESS/booster systems..."

3.2.2.2 Change second sentence to read "...and navigation aids (orbiter and booster only) such..."

3.3.1 Add "and in the expendable second stage on a reusable shuttle booster system, Specification SS613M0002, Paragraph 3.1.2."

3.3.2 Add "and ESS CEI Specification CP613M0003."

3.3.5 Add "and the expendable second stage on a reusable shuttle booster system, Specification SS613M0002."

3.4.1 Change to read, " ...booster, orbiter, and ESS, and to ..."

3.4.1.3 Change to read "...mated flights of orbiter/booster and ESS/booster, and..." And add "The ESS-required changes to the booster will not add more than three days to the normal turnaround cycle of the booster."

3.4.1.3.2.1 Change to read "...booster, orbiter, ESS, and payload ..." Add to (a) "or the ESS and LUT." Add to (c) "or prepare the ESS formatting to the booster and payload." Add to (d) "or load the payload on the ESS." Add to (f) "or raise the ESS and mate to booster." Add to (g) "or verify booster to ESS interfaces."

3.4.1.3.2.3 Change to read "...orbiter only."

3.4.1.3.2.4 Change to read "...booster, orbiter, ESS, and payload, change the payload (orbiter only), provide crew and passenger (orbiter only) ingress..."

3.4.1.3.3.1 At end of last sentence, add "(orbiter only)."

3.4.1.3.3.3 Change to read "...boosters, orbiters, and ESS's..."

3.4.1.3.5 Change to read "... orbiter and ESS operations."

3.4.2 Change to read "...booster, orbiter, and ESS..."

3.4.3.2 Add "(booster and orbiter only)."

3.4.6 Change to read "... SS613M0001 and SS613M0002."

3.6.1 Add "(booster and orbiter only)."

4.6(b) Change to read "...orbiter/booster and ESS/booster..."