

NAS8-37143
MMC-NLS-SR.001
January 1992

National Aeronautics and Space Administration
Marshall Space Flight Center
Michoud Assembly Facility



MARTIN MARIETTA
MANNED SPACE SYSTEMS

Book II - Part 1
Avionics & Systems

Cycle 0 (CY1991) NLS Trade Studies and Analyses Report

(NASA-CR-184472) CYCLE 0 (CY 1991)
NLS TRADE STUDIES AND ANALYSES,
BOOK 2. PART 1: AVIONICS AND
SYSTEMS Final Report, May 1991 -
Jan. 1992 (Martin Marietta Corp.)
~~254~~ p

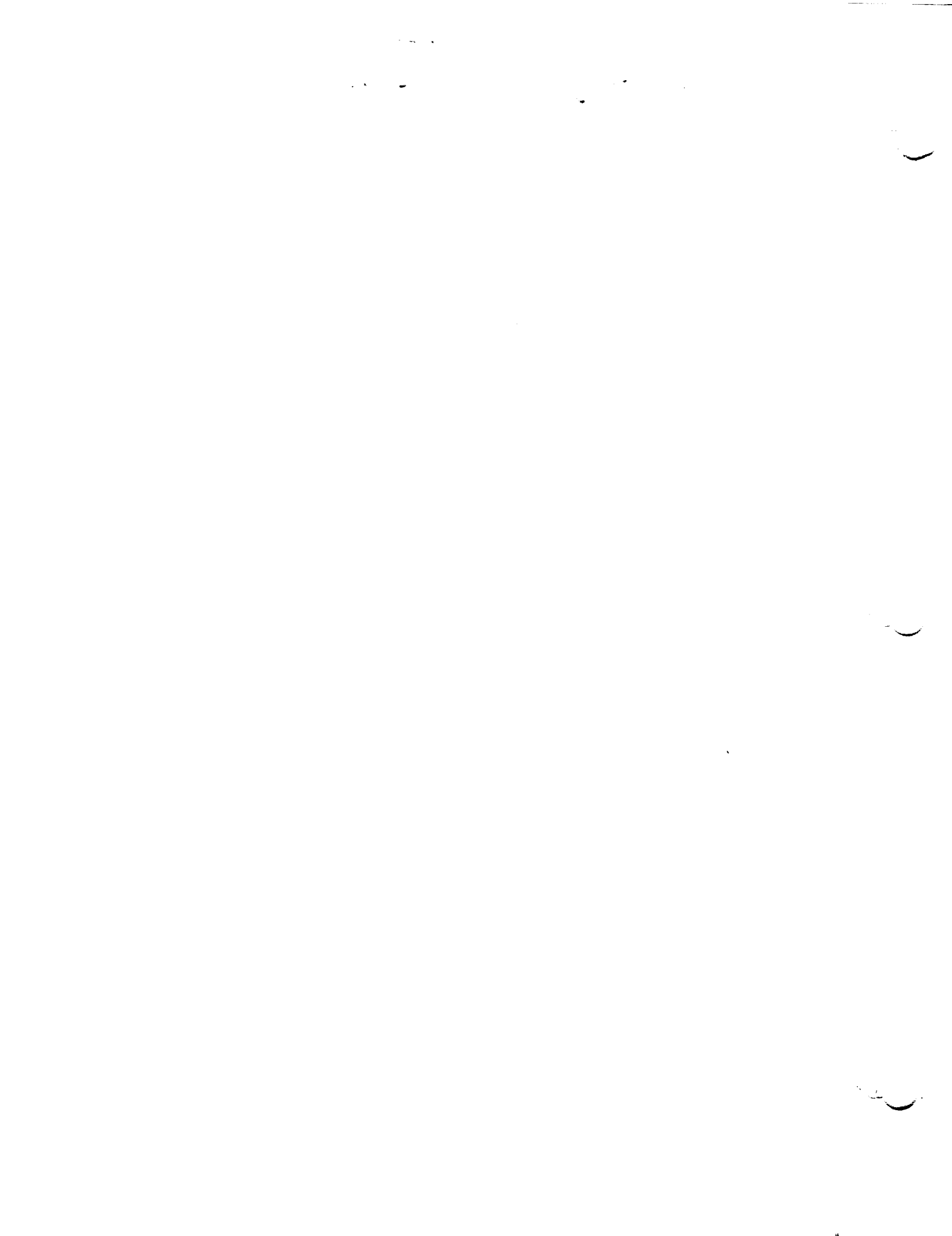
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260 p



FOREWORD

This document is Book 2, Part 1 of the Cycle Ø Study Report and documents the activities performed by MMC in support of the MSFC NLS Systems and Avionics Teams. The work was performed under NASA Contract NAS8-37143 between May 1991 and January 1992. This study report was prepared by Manned Space Systems, Martin Marietta Corporation, New Orleans, Louisiana for the NASA/Marshall Space Flight Center.

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2-4.0

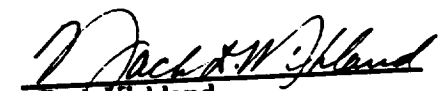
**NLS Cycle 1
System Architecture Options Analysis**

January, 1992

Distribution:
NLS / Shuttle-C Contracts (1)
NLS Technical Library (1)

Submitted By:


Richard Harris
Systems Analysis Manager


Zach Kirkland
Systems Engineering Director
NLS / Shuttle-C

2-4.0
Rev: Basic
Date: 1/92

FOREWORD

This report was prepared by Martin Marietta Manned Space Systems in New Orleans . The effort was conducted under Contract NAS8-37143 Shuttle-C for the period July 1991 through December 1991.

1.0 Summary

An assessment was conducted to determine the maximum LH2 tank stretch capability based on the constraints of the manufacturing, tooling and facilities at the Michoud Assembly Facility in New Orleans, Louisiana. The maximum tank stretch was determined to 5 ft with minor or no modifications, a stretch of 11 ft with some possible facility modifications and beyond 11 ft significant new facilities are required. A cost analysis was performed to evaluate the impacts for various stretch lengths. Cost impacts range from \$10 M to \$130 M depending on the tank length. For a tank stretch up to 11 ft, a cost impact of approximately \$30 M is realized.

2.0 Problem

The reference NLS vehicle configurations have been established to develop preliminary design data to determine potential concept risks and "show stoppers". The NLS 2 configuration is a thrust and propellant poor vehicle and as a result would like to have more propellant than the baselined 5 ft stretch in the LH2 tank currently configured. A system level trade study at Level II has requested the cost impacts of increasing the tank beyond the 5 ft baseline. A trade study will be conducted to recommend the vehicle propellant volume to optimize performance and cost.

3.0 Objective

The objective of this study is to determine manufacturing, tooling and facilities data base to support a cost impact analysis for MAF tank Stretch.

4.0 Approach

The approach for this study is to develop a parametric impact statement for tank stretch up to 25 ft in length. Manufacturing, tooling hardware and facilities impacts are evaluated beyond the 5 ft baseline stretch. A cost analysis has been performed considering current ET processes and technology and peak production rate of 3 HLLV's, 8 1.5 Stage's and 10 ET per year.

5.0 Results

The results of this study indicate the 5 ft stretch does not have an impact to the facilities. Tank stretch up to 11 ft is possible with modifications to the Cell E Internal LH2 Clean and Iridite, Cell A Core Tankage Vertical Stack, Cell P External Clean & Prime, LH2 Major Weld Assembly, and LH2 Proof Test in Building 451. Beyond the 11 ft stretch, a new proof test facility, a new Cell A at 12 ft and new cell E at 17ft are required.

6.0 Conclusions & Recommendations

The results of this study have been provided to the Level II studies to be integrated into the Task#4 System Architecture Options Study at JPO.

7.0 Supporting Data

The following attachments listed in Section 8.0 are included to provide detailed information relative to the Core Tank Stretch Study.

8.0 Attachments

Attachment 1 - NLS Core Tankage Tank Length Stretch Study, 22 November 1991

2-4.0 System Architecture options Analysis

**Attachment 1
NLS Core Tankage
Tank Length Stretch Study**

NLS Core Tankage Tank Length Stretch Study

- Tank Length vs Facility Impact
Trade Study Summary**
- MAF Facility Overview**
- Cost Impacts**

For Further Information/Questions Contact:

**Trade Study: Bob Simms(504-257-5344)
Cost Estimate: Brent Clayburn(504-257-2091)**

November 22, 1991

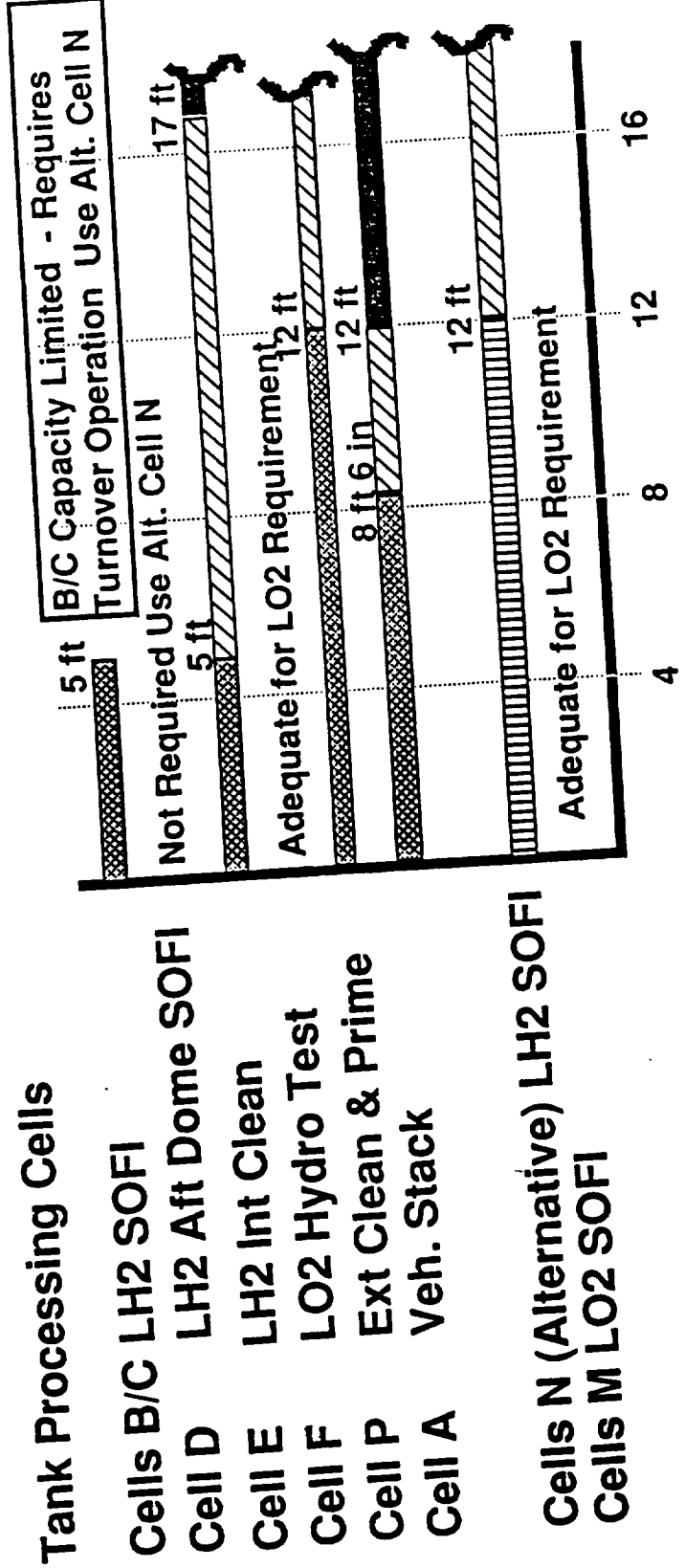
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3-S-008A
LH2 Tank Length vs Facility Impact
Trade Study Overview

Objective

***Assess External Tank Manufacturing Tooling and Facilities
to Determine the Impact of Increasing LH2 Tank Length***

Tank Length vs Facility Impact



- Achievable with Minor Tooling and Facility Mods
- Major Facility Mods - (ET Downtime Greater Than 9 Mo.)
- Modify Alternative Facility
- New Facility Required

Tank Length vs Facility Impact

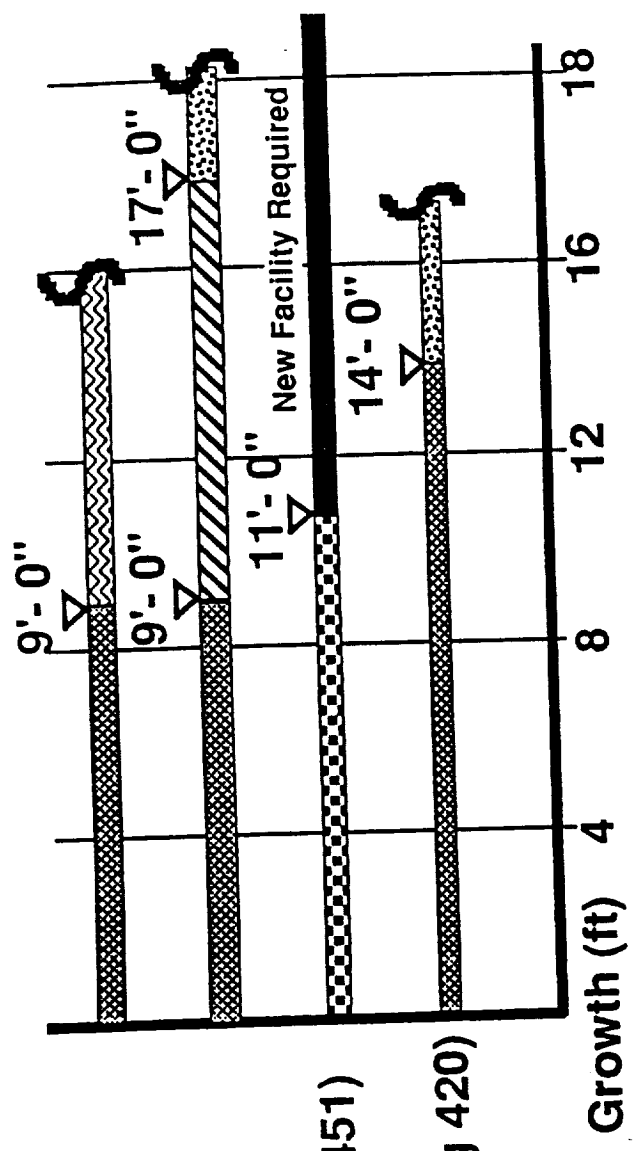
Assembly Impacts

LH2 Major Weld Assy

Final Assy (Bldg 103)

LH2 Proof Test (Bldg 451)

Test & Checkout (Bldg 420)



Achievable with Minor Tooling and Facility Mods

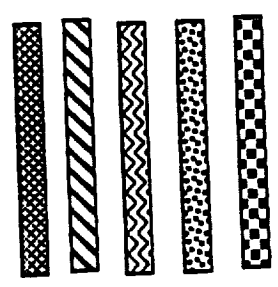
Facility Mods

Relocate Fwd Dome Attach Tooling

Extend Existing Bldg

LH2 Tank Proof Test(Pressure Only) up to 11 ft

(Applied Loads May Require New Facility)



Tank Length vs Facility Impact 3-S-008A

Summary

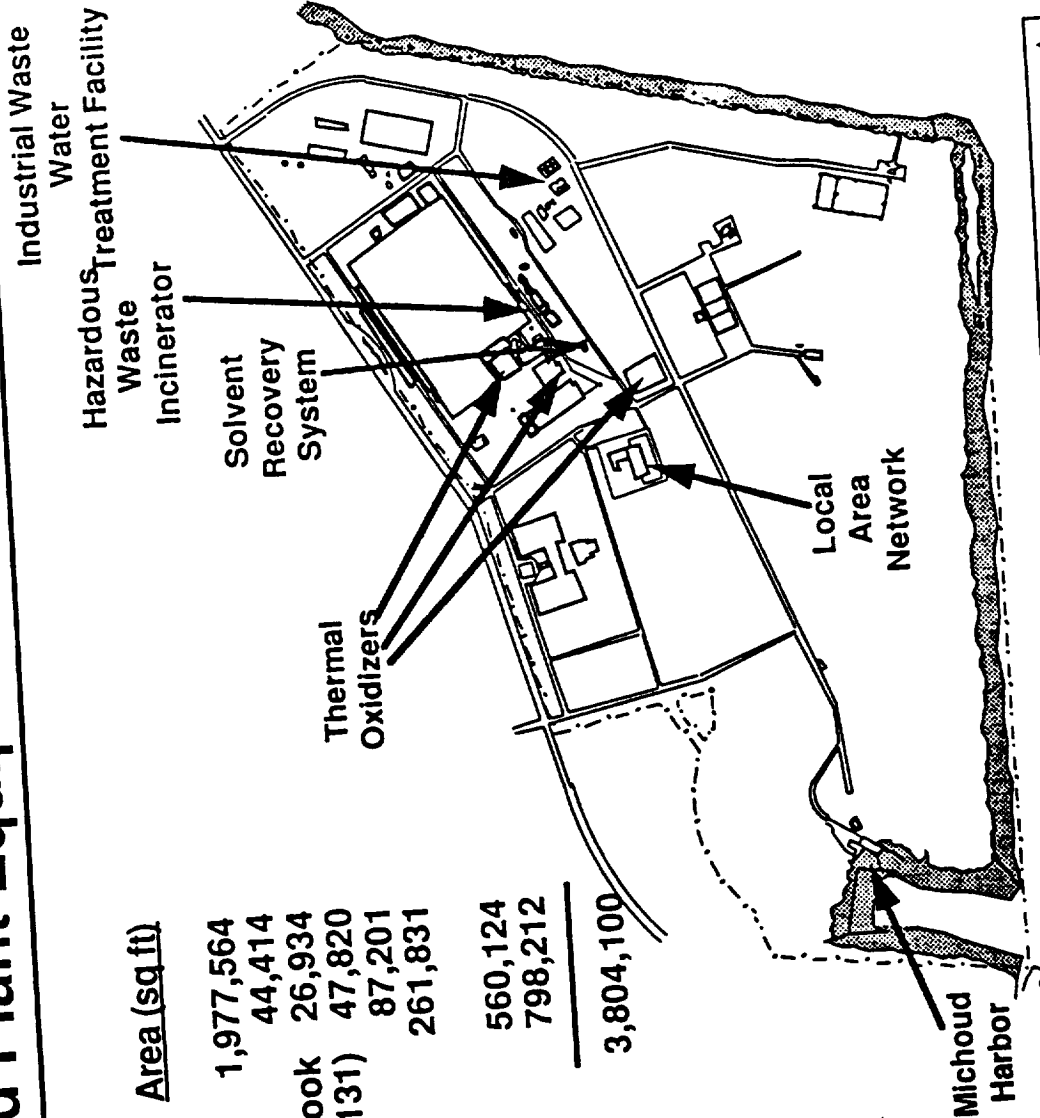
- Reference Configuration Tank Stretch Feasibility Re-Confirmed
 - 5 ft. Stretch Requires Minor or No Modifications
- Tank Stretch up to 11 ft. is Possible with Facility Modifications:
 - Cell E ~ Internal LH2 Clean & Iridite
 - Cell A ~ Core Tankage Vertical Stack
 - Cell P ~ External Clean & Prime
 - LH2 Major Weld Assy
 - LH2 Proof Test (Bldg. 451)
- New Facilities/Major Mods are Required Above 11 ft.
 - New Proof Test Facility @ 11 ft.
 - New VAB Cell A @ 12 ft.
 - New VAB Cell E @ 17 ft.

Michoud Assembly Facility Overview

- MAF Facilities & Plant Equipment**
- Tooling Cost**
- Available Capacity**

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MAF Facilities and Plant Equipment Overview



Area (sq ft)

- Facilities
- Manufacturing 1,977,564
- Main Manufacturing (103) 44,414
- VAB (110) - 185' Hook 26,934
- High Bay TPS (114) - 86' Hook 47,820
- Horizontal Cleaning/TPS (131) 87,201
- TPS Components (318) 261,831
- Other Manufacturing

- Support Facilities 560,124
 - Offices 798,212
-
- 3,804,100

- Plant Equipment
- \$266M Replacement cost (91,599 Items)

- Real Property
- \$909M Replacement Cost

Facilities & Plant Equipment Replacement Value of \$ 1,175 M 1991 \$

Tooling Replacement Cost

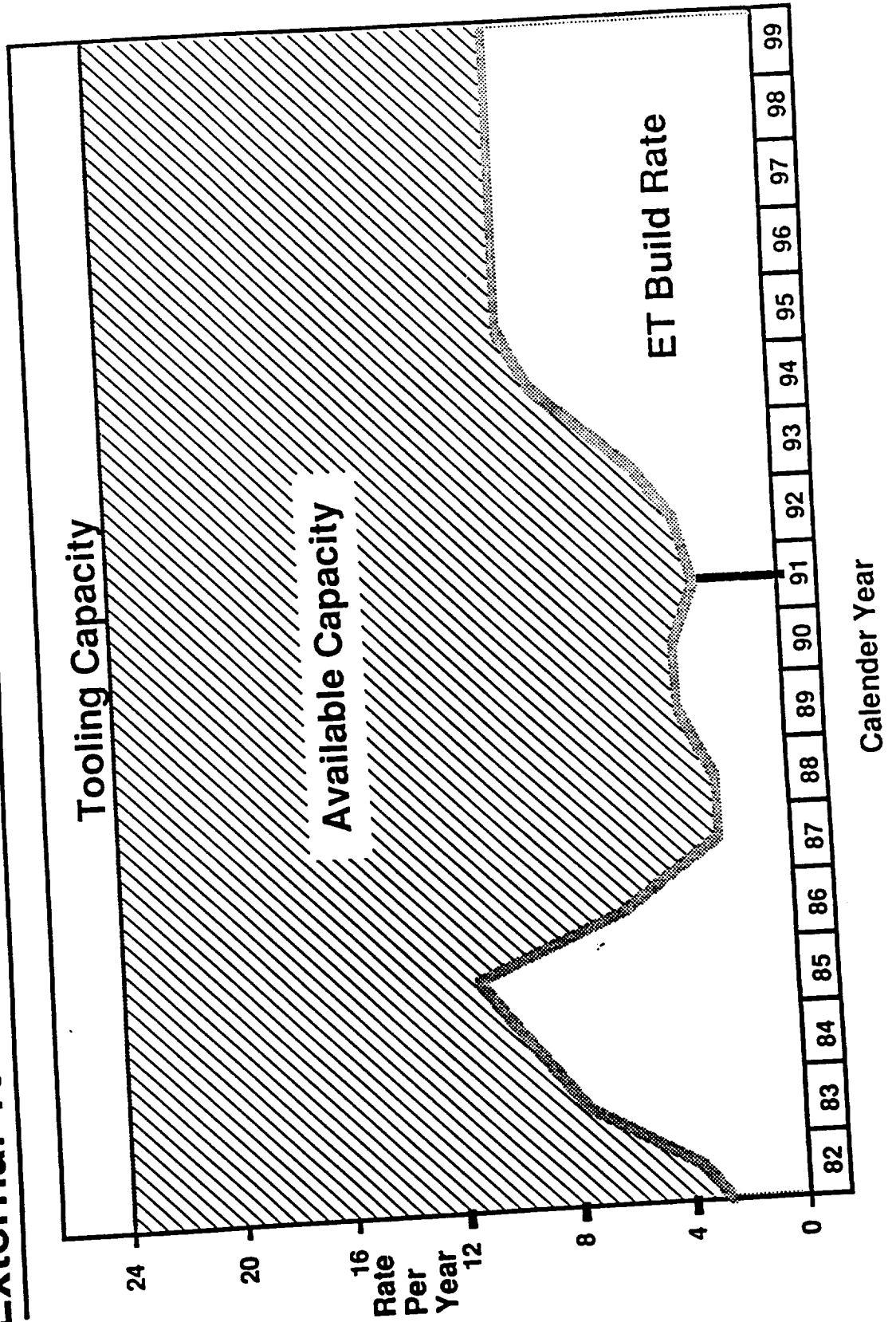
1991 Dollars in Millions

<u>Description</u>	<u>Tooling Quantity</u>	<u>Replacement Cost</u>
Dome Assembly	330	\$ 56.8
Ogive Assembly	119	26.8
Barrel Assembly	250	31.6
Ring Assembly	107	11.4
Intertank	296	25.8
Assembly	510	63.4
Major Weld	458	61.5
Clean & TPS	765	65.5
Final Assembly	3,569	132.3
Other *	<u>6,404</u>	<u>\$475.1</u>
Total		

* Includes Component Fabrication, Transportation & Handling, Rotational Offsite Support Equipment, and General Purpose Tooling

Use of MAF Offers Major Cost Avoidance

External Tank Build Rate (POP 91-1R1)



NLS Core Tankage Length vs Tooling and Facility Cost Impacts At MAF

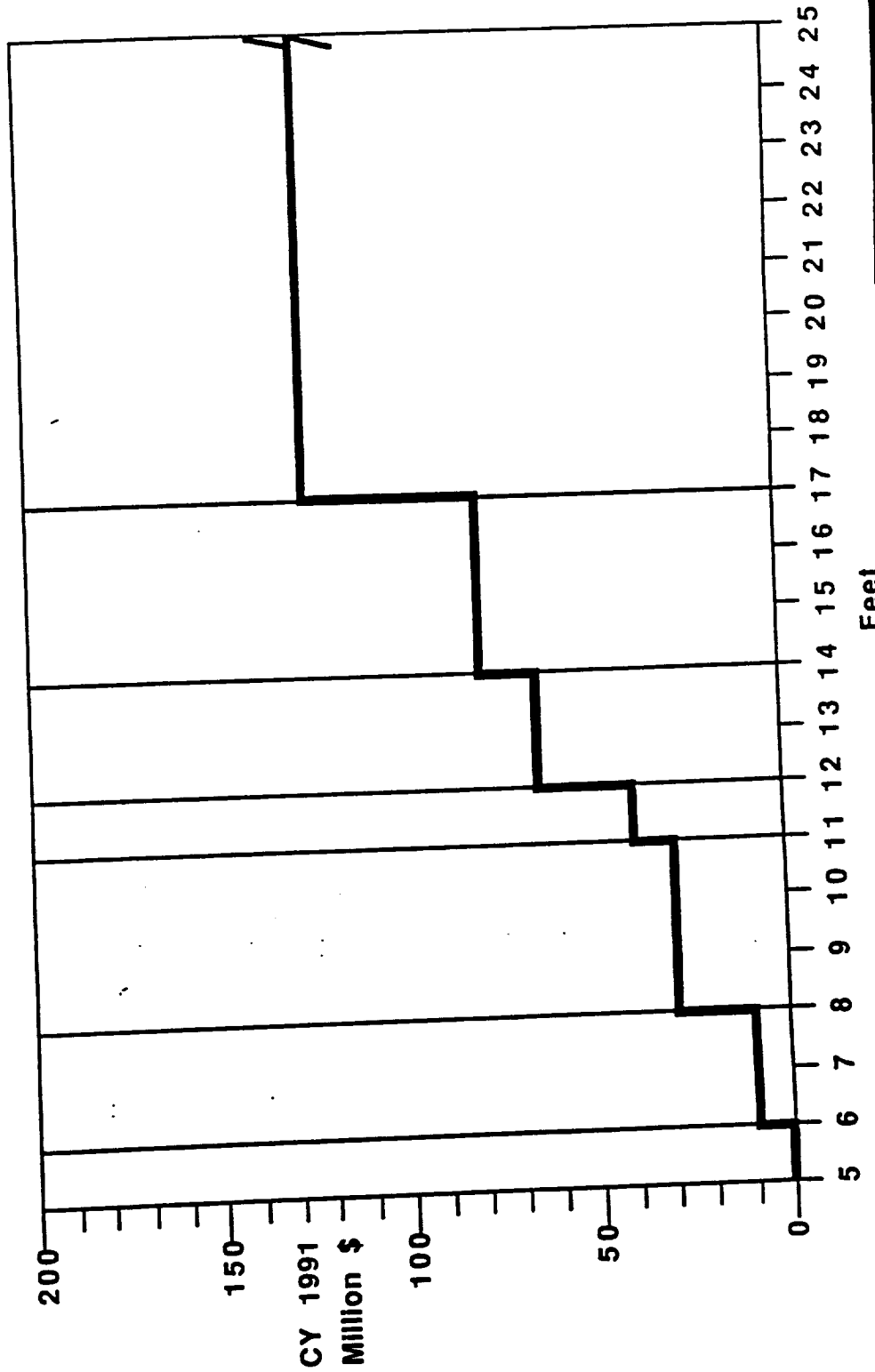
Harold T. Barrios
NLS Cost Estimating
(504) 257-0253
11/21/91
Revision 2

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Groundrules And Assumptions

- 1991 Dollars In Millions
- Delta Costs Are For Core Stage Vehicle
 - Tankage
 - Skirts
 - Propulsion Module
 - Avionics
 - IACO
- 5' Stretch Common Core Tankage Is Baseline
- Peak Production Rate - 3/8/10 (HLLV/1.5 Stage/ET)
- Current ET Processes And Technology
- NASA Program Management, Reserves and Contractor Fee Excluded
- Impact On ET Production Not Addressed

NLS Core Tankage Stretch Summary



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MARTIN MARIETTA PROPRIETARY DATA

Benefits of an ET-Derived Core at MAF

Facilities & Tooling

- **Proven Core Fabrication Facilities & Tooling Available**
 - 6404 Tooling & STE Items in Place
 - 3.8 Million Square feet of facilities in Place
 - 91,599 Plant Equipment items in Place
- **Highly Developed Infrastructure of Utilities, Environmental Systems, and Site Services**
 - Seven Environmental Permits in Place
 - 3 Tank Farms
 - 10 Manufacturing Processing Systems
 - General, Communications & Data Utilities Available
 - Security, Fire, Medical, Cafeteria & Child Care Services in Place
- **Roadway, Rail & Water Transport Available**
 - Michoud Harbor
 - Ocean-going Barges
- **Sharing of Support Base Possible at MAF**

**Software Sizing & Timing
3-A-028
and
Standard Software Language ADA
3-A-030**

**Martin Marietta Manned Space
Systems**

January, 1992

NLS AVIONICS FLIGHT SOFTWARE

Contract Report

NASA's National Launch System Launch Vehicle Level III SRD require the NLS Avionics to have a distributed processing system managed by the Avionics Flight computer. All Avionics Flight and Ground software is required to be developed according to a standard software lifecycle that is being defined in the Level III NLS Software Management Plan.

Also, the Data Management System is required to provide adequate margins for software requirements and design growth. These margins are required to be applicable to memory, CPU utilization, timing and throughput. As a minimum, at least 75 percent margin is required to be available at the end of the Flight Software PDR. At least 60 percent is required to be available at the end of the Flight Software CDR. At least 50 percent margin is required to be available at software acceptance.

Nine tasks were defined to perform trades and studies to determine the best approach to meet the NLS Avionics system requirements. The tasks are:

1. Independent Software Verification and Validation
2. Software Sizing and Timing
3. Ada Software Development Environments
4. Common Software Development Environments
5. Software Development Automation
6. Standard Software Language
7. Reusable Shuttle Software
8. Technologies For Eliminating Generic Software Faults
9. Software Policies and Standards

Each task was supported by Martin Marietta's Manned Space System in a lead or support role. In the tasks where lead role support was provided, supporting data was required and provided. In the other tasks, supporting data was also provided.

An average of three telecons per week was supported, and meetings were attended in Huntsville at MSFC in support of the NLS trades. Listed below is the data provided in support of NLS Avionics requirements definitions. Data is listed by the task supported. Also, attached support documentation is included.

- M-18S IRAD Presentation
- Ada Timing Data
- NLS Sizing Estimates
- NLS Avionics Functional Decompositions
- Artificial Intelligence ADAS Report
- MMMSS ESO Software Development Methodologies
- Software Productivity Consortium CASE Tool Evaluation

Supporting results and data provided was very informative, and used to develop and baseline NLS Avionics Software requirements.

Interoffice Memo

Date: January 7, 1992

To: Mark Hamer
Jon Patterson

From: Debra Hoyle

cc: Bill VanBeek

Subj: Software Productivity Consortium Evaluation of Automatic Code Generators

The attached document is the results of the evaluation of the capabilities and limitations of automatic code generators for real-time embedded avionics software. This evaluation was performed by SPC. Below is a brief summary of some of the key results.

Criteria	ALSCAT	MATRIX	GALA
Deterministic	+	+	+
Parameter Passing	+	+	+
Global References	+	+	+
Compiles Correctly	+	+	+
Efficiency	+	+	+
Reverse Engineering	-	-	-
2167A Document Std	+	-	-

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April 29, 1991

The following Software Productivity Consortium document is enclosed:

- 1990 Boeing Pilot Project Final Report
SPC-91095-MC, Version 01.00.01, April 1991

The 1990 Boeing Pilot Project Final Report describes the joint 1990 Boeing-Software Productivity Consortium pilot project which evaluated capabilities and limitations of current automatic code generation tools as they applied to the development of real-time, embedded avionics software and as they related to the Synthesis process.

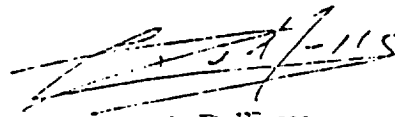
The primary purpose of this pilot project was to understand the capabilities and limitations of current automatic code generation technology present in products that specifically address the domain of control systems. Secondary project concerns were focused on the relationships between the control systems' domain products and other software development products, and on understanding how the evaluated products related to aspects of the Synthesis process.

Additionally, this pilot project developed an evaluation approach which consisted of establishing goals for the evaluations, selecting specific tools based on selection criteria, establishing an evaluation process, and using the evaluations to derive conclusions about the state of the technology of these tools.

Please contact Ms. Gerry Brewer, Administrator, Technology Transfer Clearinghouse, at (703)742-7211 if you have any questions or require further information regarding this delivery.

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* Cover letter only		

Sincerely,



Claude DeFosse
Vice President
Technology Transfer

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A		B		C		D		E	
NLS AVIONICS SIZING & TIMING									
BACKGROUND DATA FROM SHUTTLE-C ESTIMATES									
1	2	3	4	5	6	7	8	9	10
FUNCTION	SLOCS	KBYTES	FREQ. (HZ)						
1									
2									
3									
4									
5	4709	141	20						
6	3062	92	10						
7	1715	51	5						
8	792	24	20						
9	1807	54	5						
10	1276	38	5						
11	5391	162	10						
12	1130	34	1						
13	8726	262	1						
14	545	16	1						
15	10000	160	20						
16									
17									
18	39153	1034							
19	TOTALS								
20									
21									
22									
23									

*Include in contract report
 (W summary how it was used on NLS.*

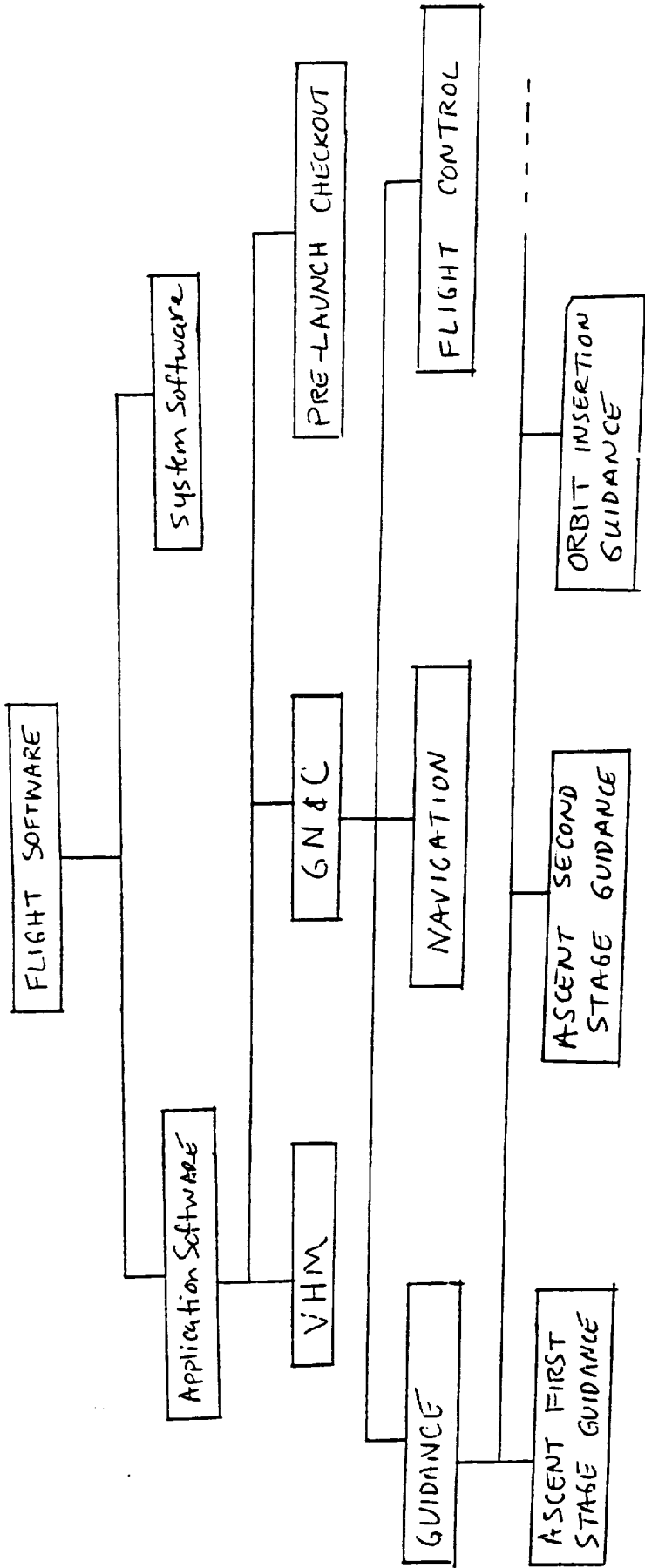
MARTIN MARIETTA
D. Hodges
12/4/91

Shuttle C Functions

A functional decomposition of these STS functions, Shuttle C SRD, redlined STS FSSRs, and HAL/S code were used in developing the Shuttle C estimates shown on the previous page.

1. Guidance
 - Staging
 - Insertion
 - Abort Targeting
2. Navigation
 - User Parameter Processing
 - State Propagation
3. Flight Control
 - Digital Autopilot
 - Steering
 - Attitude Processor
4. Sequencing
 - Launch Countdown
 - SSME Operations
 - Propellant Dump
5. Subsystem Operating Programs
 - MPS TVC
 - SSME
 - Rate Gyro
 - RCS Command
6. Redundancy Management
 - IMU
 - Rate Gyro

7. Systems Management
 - Data Acquisition
 - Fault Detection and Annunciation
 - Special Processes
8. Vehicle Utility
 - Data Acquisition
 - Launch Data Bus
 - Test Control Supervisor
9. Automated Crew Functions
 - Switch Activations
 - OPS 1 Load
10. Systems Control
 - System Initialization
 - Bus Management
11. Operating System
 - I/O Services
 - Multitasking Priority Preemptive Scheduling
 - Redundant Computer Operations



An Approach To Flight Software
Functional Decomposition

A Report
of
DIFFERENT SOFTWARE DEVELOPMENT PROCESS MODELS

Thu-Phong M. Nguyen
Martin Marietta Manned Space Systems
E.S.O 89619
October 12, 1990

Avionics Diagnostic System (ADS)

The ADS prototype demonstrates the application of knowledge-based system technology to the diagnosis and repair of avionic systems. ADS is meant to work with an automatic test equipment (ATE) but the current version queries the user for all status information.

Reasoning Methods for Automated Diagnostics

The ADS is an expanded version of the earlier Telemetry/Analysis and Diagnostic (TAD) program which used a rule-based reasoning approach. TAD used a backward chaining (goal-driven) rule-base for diagnosis and a forward-chaining rule-base to identify an appropriate problem solution.

Rule-based reasoning has some drawbacks which are most evident in a diagnostic application. First, rule-based diagnostic systems have a fixed range of capability beyond which novel fault situations cannot be handled. Secondly, the maintenance of a rule-base system becomes increasingly difficult as the size grows and electronic systems tend to require larger knowledge-bases.

One alternative to the difficulties of rule-based reasoning is a technique called Model-Based Reasoning. In this technique a model of the entire system is built which describes the functionality of all working components. To some extent this model can simulate the entire system, including system behavior under fault conditions. Diagnosis is achieved, in simple terms, by changing the simulation parameters to match the observed symptoms, at which point the model should correspond to the faulty state of the system.

Model-based reasoning can theoretically diagnose all error situations, even errors that have not been explicitly encoded in the program, thereby surpassing the fixed capability of rule-base systems. In addition, model-based reasoning can diagnose increasing larger systems without extensive rework of the knowledge-base. This follows from the fact the knowledge is stored as models of individual components; larger systems will require more component models but the models themselves remain unchanged.

One drawback to model-based reasoning is the relatively long time required to find a solution. Because the model is effectively a simulation of the avionic system it requires a great amount of computation. Here the rule-based system has an advantage: because it explicitly lists all the known faults it can quickly concentrate the search effort to a likely problem area.

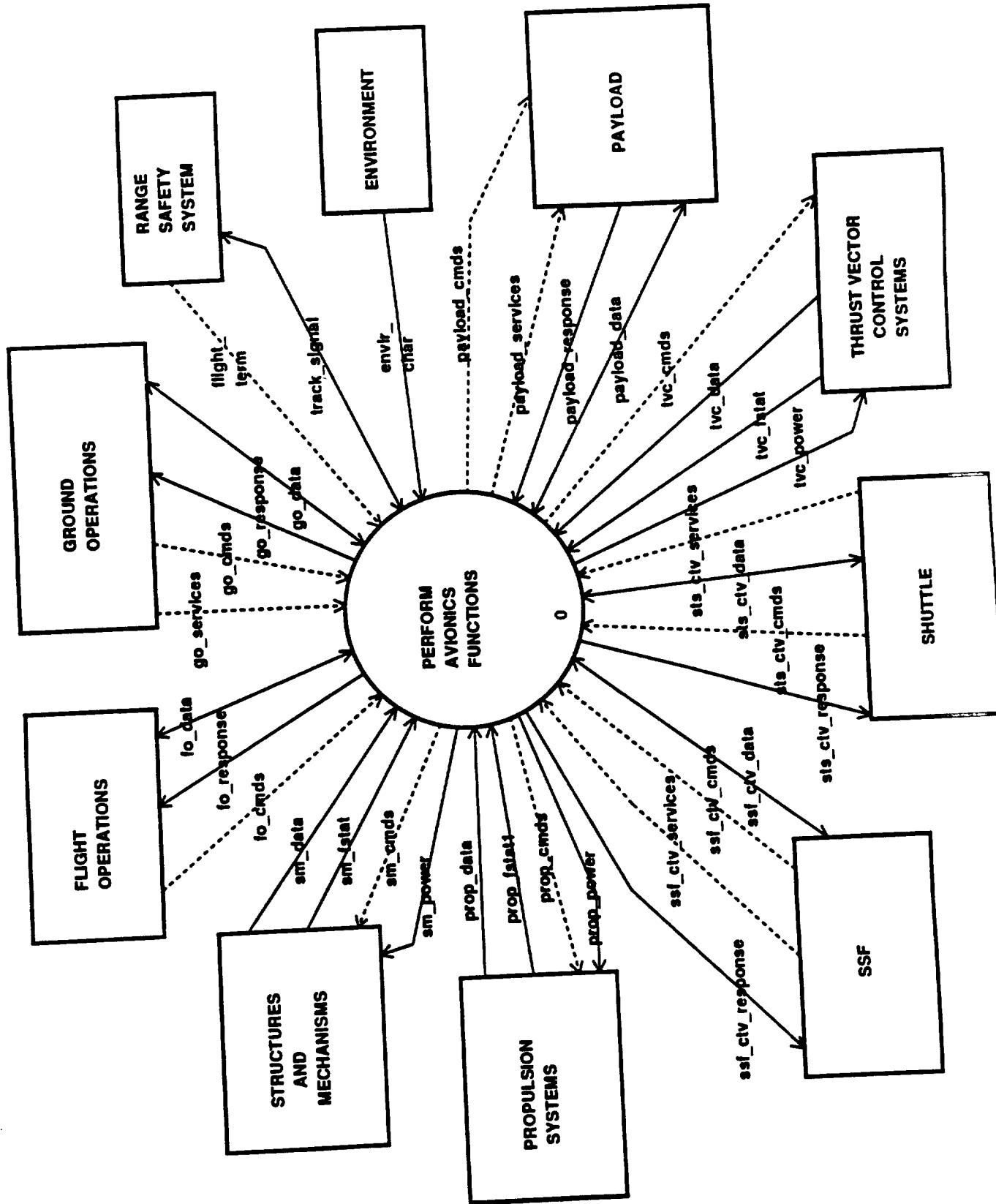
Fault-based Diagnostics

Fault-based diagnostics fall between model-based reasoning and rule-based reasoning. Individual components are modeled, but only with respect to causing or propagating fault symptoms. The avionics system is described in the computer as a network of component models. The connectivity of the model is analyzed to find all symptoms associated with particular faults and vice-versa.

In addition to the general fault-symptom connections, the fault-based system allows specific, rule-like connections from fault to symptom which correspond to expert knowledge about expected fault occurrences. These special connections speed up the diagnostic process for familiar problems, while allowing the general reasoning to operate for other faults which have not been explicitly described.

Implementation

The ADS prototype was written in Knowledge Craft on a Symbolics 3620 Lisp Machine. The program uses schemata to describe and components and their connectivity. The reasoning system was originally written in CRL-OPS (Knowledge Craft's version of OPS) but has been replace by a small Lisp program.



TERMINATOR DEFINITIONS (EXTERNAL I/Fs)

1.0 Flight Operations

The flight operations terminator includes all activities that interface with the NLS flight avionics functions after liftoff of the integrated launch vehicle. The interface between flight operations and the NLS flight avionics functions will be via RF links from either ground tracking stations, TDRSS, the SSF, or GPS. Flight operations functions will include mission control center operations, ground communication and data processing networks, tracking systems, the GPS, mission monitor and control activities on the SSF, and uplink of data loads/reloads including telemetry format changes and logic changes.

2.0 Ground Operations

The ground operations terminator includes all activities (except range safety) that interface with the NLS flight avionics functions prior to vehicle liftoff. These activities occur during individual stage manufacturing checkout, integrated launch vehicle assembly and test, preflight checkout, and countdown. They also include the ground portion of Vehicle Health Management.

The primary physical and electrical interface between ground operations and NLS launch vehicle avionics will be through one or more umbilical connectors. This interface will include a data bus/network connection for interchange of data and commands and cables for connection of ground electrical power. Direct or indirect RF communication may be performed during prelaunch checkout to verify RF communication capabilities.

3.0 Range Safety System

The range safety terminator includes all range safety activities that interface with the NLS flight avionics functions during ground assembly, integration, countdown, launch and the ascent mission phase prior to separation of the CTV/US from the core booster.

One of two interfaces between range safety and the NLS launch vehicle avionics will be through RF communication to a transponder on the launch vehicle which assists tracking radars. The second RF interface consists of the ground transmitter which issues the destruct commands. Additional vehicle health status information will be obtained from launch vehicle telemetry via ground/flight operations. During preflight tests, range safety functions will include verifying correct range safety component performance and safe/ar status.

4.0 Environment

Included are the natural phenomenon of wind, rain, lightening, temperatures, salt air, sand, cosmic radiation, and other radiations. It also includes a vacuum (or near vacuum), dynamic pressures during ascent, shock, vibration, thermal, angular acceleration, translational acceleration, sun presence, earth presence, etc.

5.0 Payload

The payload terminator includes all payload activities that interface with the NLS flight avionics functions during ground assembly, integration, countdown, launch and all mission phases prior to separation of the payload(s) from the CTV/US.

The primary physical and electrical interface between payload(s) and the NLS launch vehicle avionics will be through one or more umbilical connectors located on the payload carrier. This interface may include a data bus/network connection for interchange of data and commands and cables for connection of electrical power.

6.0 Thrust Vector Control Systems

The Thrust Vector Control Systems include the on-board hardware responsible for the physical change in STME and SSRB nozzle position. Included in the Thrust Vector Control Systems are the controllers and the actuators. The interface with the avionics includes a data bus and power bus.

7.0 Shuttle

The Shuttle terminator includes all Space Transportation System (STS) activities that interface with the CTV flight avionics functions when the CTV is berthed in the STS payload bay.

The primary physical and electrical interface between the STS and the CTV avionics will be through one or more umbilical connectors located on the CTV and in the STS payload bay. This interface may include a data bus/network connection for interchange of data and commands and cables for connection of electrical power.

8.0 SSF

The SSF terminator is the planned Space Station Freedom interfacing with the CTV for rendezvous and capture. The SSF provides electrical power to a berthed CTV and hardwire command and data links. (RF communication between the CTV and the SSF are considered a part of Flight Operations.

9.0 Propulsion System

The Propulsion System includes the STMEs, the SSRB engines, CTV engine(s), secondary propulsion systems, STME controllers, propellant management, and gases. The STME will interface via a data bus and power bus. The SSRBs will interface through an interface device in the core stage avionics. This interface will accommodate power and commands to the SSRBs and data for downlink from the SSRBs. This interface is predefined.

10.0 Structures and Mechanisms

The structures and mechanisms terminator includes all structures and mechanisms activities that interface with the NLS flight avionics functions during ground assembly, integration, countdown, launch and during all mission phases.

The avionics interface will consist of drivers for ordnance devices, solenoids, lights, sensors to measure structural conditions such as stress and temperature, as well as sensors to detect mechanism activation, etc.

The structures and mechanisms functions may include shroud jettison, stage separation, SSRB separation, and antenna deployment.

18:32:05 6 Nov 91 nls_avionics Data Dictionary Entry fo_cmds page 1

fo_cmds (control flow) =

Flight Operations Commands are all commands to the vehicle through RF link after liftoff. These commands may be sent with or without encryption or encoding, as required.

18:16:50 6 Nov 91 nls_avionics Data Dictionary Entry fo_response page 1

fo_response (data flow) =

Flight Operations Response includes responses to Flight Operations Commands.

16:55:08 6 Dec 91 nls_avionics Data Dictionary Entry fo_data page 1

fo_data (data flow) =

Flight Operations Data includes data being sent to the vehicle, as well as data coming from the vehicle. Data being sent to the vehicle includes GPS data and table loads/reloads for any purpose to CTV or Upper Stage. These data loads may also be telemetry format changes and logic changes to some on-board processor (including memory loads). Data coming from the vehicle will consist of vehicle data, and may include payload telemetry data. The vehicle data may include flight critical data, operational flight instrumentation data, and development flight instrumentation data.

18:17:19 6 Nov 91 nls_avionics Data Dictionary Entry prop_cmds page 1

prop_cmds (control flow) =

Propulsion Commands are all commands to the STME Engine Controllers, to the ASRBs, to the secondary propulsion systems, and to the propulsion valves of the attitude control, or Reaction Control System. Propulsion Commands also includes all commands for fluid and gas management.

18:17:36 6 Nov 91 nls_avionics Data Dictionary Entry prop_data page 1

prop_data (data flow) =

Propulsion Data consists of all health, status, mode, and all other data to be included in the vehicle RF downlink telemetry.

18:17:49 6 Nov 91 nls_avionics Data Dictionary Entry prop_fstat1 page 1

prop_fstat1 (data flow) =

Propulsion Fault Status includes all pertinent fault-related data generated by the health monitoring function of the various propulsion subsystems.

17:47:28 4 Dec 91 nls_avionics Data Dictionary Entry prop_power page 1

prop_power (data flow) =

Propulsion Power is electrical power provided by the avionics system to the propulsion systems.

18:18:05 6 Nov 91 nls_avionics Data Dictionary Entry sm_cmds page 1

sm_cmds (control flow) =

Structures and Mechanisms Commands include all ordnance commands, latch commands, and all commands to control docking lights.

18:18:18 6 Nov 91 nls_avionics Data Dictionary Entry sm_data page 1

sm_data (data flow) =

Structures and Mechanisms Data includes separation data, ordnance data, position data, and all other data to be included in the vehicle RF downlink telemetry.

18:18:29 6 Nov 91 nls_avionics Data Dictionary Entry sm_fstat page 1

sm_fstat (data flow) =

Structures and Mechanisms Fault Status data includes all pertinent fault-related data generated by any health monitoring function of a vehicle structure, mechanism, or ordnance.

17:42:18 4 Dec 91 nls_avionics Data Dictionary Entry sm_power page 1

sm_power (data flow) =

Structures and Mechanisms Power is electrical power provided by the avionics system to structures, mechanisms or ordnance.

18:18:58 6 Nov 91 nls_avionics Data Dictionary Entry sts_ctv_cmds page 1

sts_ctv_cmds (control flow) =

***STS CTV Commands are all hardwired commands from the STS to the CTV.
(Note: RF commands are considered to be Flight Operations Commands).***

18:19:13 6 Nov 91 nls_avionics Data Dictionary Entry sts_ctv_respo page 1

sts_ctv_response (data flow) =

STS CTV Response includes responses to STS CTV Commands.

18:19:26 6 Nov 91 nls_avionics Data Dictionary Entry sts_ctv_data page 1

sts_ctv_data (data flow) =

***STS CTV Data is all hardwired data from CTV to the STS, or from STS
to the CTV.***

18:19:39 6 Nov 91 nls_avionics Data Dictionary Entry sts_ctv_servi page 1

sts_ctv_services (control flow) =

***STS CTV Services are any services, following berthing of the CTV with
the Shuttle, which may be required to provide power to CTV subsystems,
or to effect other actions necessary to modify the CTV environment.***

18:19:57 6 Nov 91 nls_avionics Data Dictionary Entry ssf_ctv_cmds page 1

ssf_ctv_cmds (control flow) =
*SSF CTV Commands are all hardwired commands from the SSF to the CTV.
(Note: RF commands are considered Flight Operations Commands).*

18:20:14 6 Nov 91 nls_avionics Data Dictionary Entry ssf_ctv_respo page 1

ssf_ctv_response (data flow) =
SSF CTV Response includes responses to SSF CTV Commands.

18:20:32 6 Nov 91 nls_avionics Data Dictionary Entry ssf_ctv_data page 1

ssf_ctv_data (data flow) =
SSF CTV Data is all hardwired data from the CTV (including payload, if applicable) to the SSF, or from SSF to the CTV.

18:20:57 6 Nov 91 nls_avionics Data Dictionary Entry ssf_ctv_servi page 1

ssf_ctv_services (control flow) =
SSF CTV Services are any services, following berthing of the CTV with the SSF, which may be required to provide power to CTV subsystems, or to effect other actions necessary to modify the CTV environment.

18:24:34 6 Nov 91 nls_avionics Data Dictionary Entry tv_c_cmds page 1

tv_c_cmds (control flow) =

*The TVC Systems include the TVC Subsystems for all NLS gimbaled engines (e.g., STME, ASRB, etc.). A TVC Subsystem consists of the controller(s) and the actuator(s).

TVC Commands are all commands to the TVC controllers. These include commands to gimbal the engines to specific positions, mode commands, etc..*

18:21:34 6 Nov 91 nls_avionics Data Dictionary Entry tv_data page 1

tv_data (data flow) =

TVC Data includes, but is not limited to, the following: all TVC measurements which are to be included in the vehicle RF downlink or hardwired telemetry, data necessary for performance assessment, checkout data.

18:21:54 6 Nov 91 nls_avionics Data Dictionary Entry tv_fstat page 1

tv_fstat (data flow) =

TVC Fault Status includes all pertinent fault-related data generated by the health monitoring function of the various TVC Subsystems.

17:47:03 4 Dec 91 nls_avionics Data Dictionary Entry tv_power page 1

tv_power (data flow) =

Thrust Vector Control Power is electrical power provided by the avionics system to the TVC systems.

18:06:55 6 Nov 91 nls_avionics Data Dictionary Entry envir_char page 1

envir_char (data flow) =

Environmental Characteristics are all environmental characteristics used by the Avionics System in performing its various functions. These characteristics may be any of the following: temperatures, pressures, acceleration, changes in attitude, wind, shock, vibration, in and out of sun, etc.. This data may also be included in RF or hardwired downlink telemetry.

18:09:48 6 Nov 91 nls_avionics Data Dictionary Entry flight_term page 1

flight_term (control flow) =

Flight Termination is a pair of commands to destroy the NLS elements (core, ASRB, CTV, US), as applicable. The commands are sent to the on-board Range Safety System via its own RF link.

17:53:17 4 Dec 91 nls_avionics Data Dictionary Entry track_signal page 1

track_signal (data flow) =

Tracking Signal is a tracking beacon/signal generated by the on-board Range Safety System during ascent in response to a ground-generated signal. The Tracking Signal assists the ground Range Safety function in determining whether the vehicle is violating trajectory limits.

18:22:20 6 Nov 91 nls_avionics Data Dictionary Entry payload_cmds page 1

payload_cmds (control flow) =

Payload Commands are all commands from an NLS element to an attached payload.

18:22:35 6 Nov 91 nls_avionics Data Dictionary Entry payload_respo page 1

payload_response (data flow) =

Payload Response is a response from the payload as a direct consequence of having received a Payload Command.

18:22:46 6 Nov 91 nls_avionics Data Dictionary Entry payload_data page 1

payload_data (data flow) =

Payload Data includes data being sent to the payload, as well as data coming from the payload. Data being sent to the payload may include navigation updates. Data coming from the payload may include flight critical data, operational flight instrumentation data, and development flight instrumentation data.

18:22:58 6 Nov 91 nls_avionics Data Dictionary Entry payload_servi page 1

payload_services (control flow) =

Payload Services include all services which may be required by the payload. These may include electrical power, environmental control, and discretes which may be used by the payload to effect various functions.

18:30:42 6 Nov 91 nls_avionics Data Dictionary Entry go_cmds page 1

go_cmds (control flow) =

Ground Operations Commands are all commands, including simulated commands, to the vehicle whether by RF-link, special cable, or via a test connector. These commands may be sent with or without encoding or encryption.

18:27:39 6 Nov 91 nls_avionics Data Dictionary Entry go_response page 1

go_response (data flow) =

Ground Operations Response includes command responses and is effected via a copper path or test cable/plug during manufacturing checkout and prelaunch checkout (not on-pad checkout).

18:14:09 6 Nov 91 nls_avionics Data Dictionary Entry go_data page 1

go_data (data flow) =

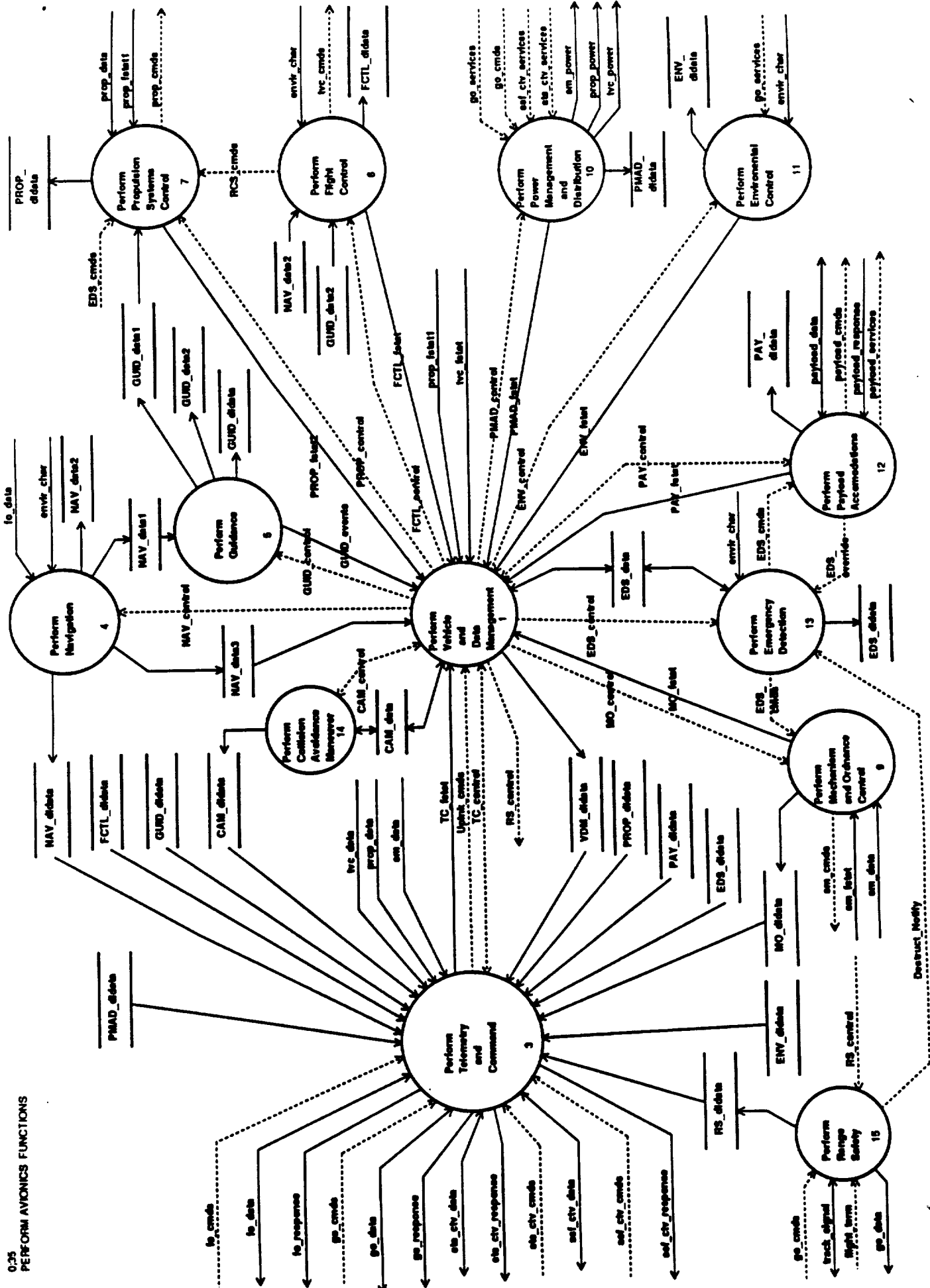
Ground Operations Data includes data being sent to the vehicle, as well as data coming from the vehicle. Data being sent to the vehicle includes data loads for any purpose - day-of-launch wind profiles, programmable telemetry formats, mission or test characteristics and limits, or logic changes normal to any on-board processor (including memory loads). Normal data coming from the vehicle may include flight critical data, operational flight data, or development flight instrumentation data. The data will be in the selected programmable format as commanded (loaded) and set in the Telemetry and Command subfunction.

18:15:35 6 Nov 91 nls_avionics Data Dictionary Entry go_services page 1

go_services (control flow) =

Ground Operations Services are those services including electrical power, air or GN2 purge, and air conditioning needed before launch.

0.25
PERFORM AVIONICS FUNCTIONS



1. VEHICLE AND DATA MANAGEMENT

1 Mode Control
(Test Control
and Sequencing)
12Kbytes/50Hz

2 Command
Processing
and Distribution
2Kbytes/50Hz

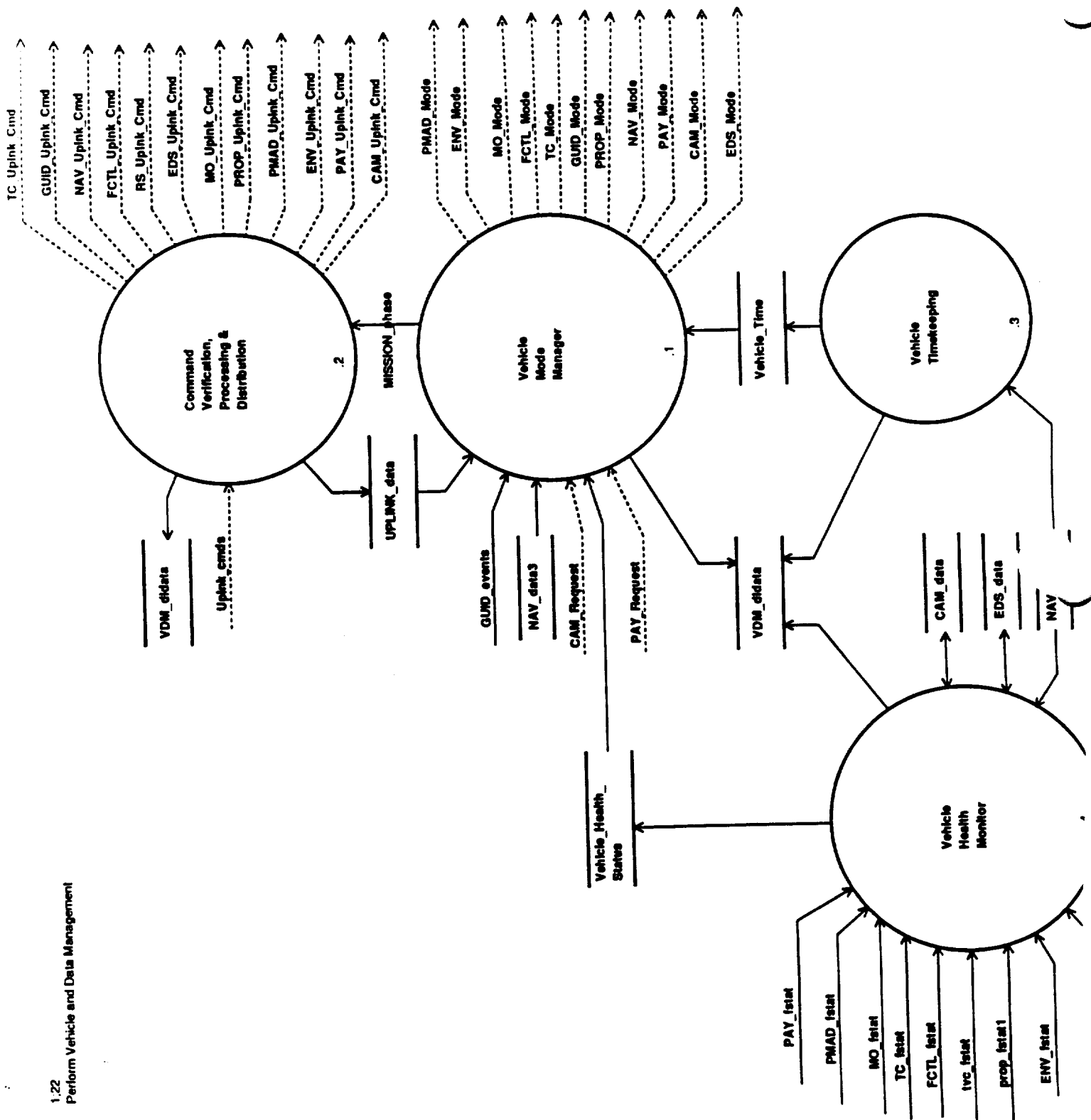
3 Vehicle
Timekeeping
1Kbytes/50Hz

4 Vehicle
Health
Monitor
30Kbytes/50Hz

5 Operating
System
Services
100Kbytes/50Hz

6 Bus
Management
5Kbytes/50Hz

1.22 Perform Vehicle and Data Management



3.1.1 Vehicle and Data Management

The Vehicle and Data Management function performs executive monitoring and control of the on-board functions. The V&DM function shall control the operational mode of all other on-board functions. The on-board system service functions are considered part of V&DM. V&DM performs its own health monitoring and self-test.

3.1.1.1 Mode Control (Test Control and Sequencing)

Mode control defines the vehicle mode or mission phase of the vehicle software (test, prelaunch, launch, ascent, separation, coast, payload insertion, on-orbit checkout, rendezvous, capture, deorbit, etc.), issues sequential commands from the appropriate data load(s) and issues time dependent commands. Mode control is responsible for CAM enable/disable and is the basic control mode and software for all vehicle operations.

3.1.1.2 Command Processing and Distribution

Command Processing and Distribution verifies that commands received from external sources (including stored program commands) are valid for the current vehicle mode or mission phase. Commands which would result in a vehicle mode change are then passed to the Vehicle Mode Manager subfunction. Other commands are interpreted and either sent to the functions (destinations) for which they are intended or executed as appropriate

3.1.1.3 Vehicle Timekeeping

Vehicle timekeeping monitors the master time pulse and maintains and updates as necessary the current time for the vehicle. This function is also responsible for synchronizing the other timing functions including other processors to assure the vehicle units do not become skewed.

3.1.1.4 Vehicle Health Monitor

Vehicle Health Monitor correlates the vehicle health status from all subfunctions, remains cognizant of the status of similar signals from the terminators, and relays information to other subfunctions that may be affected. Vehicle Health Monitor is also responsible for hazard detection. It shall determine failure condition and shall notify other functions or subfunctions that a hazard has been detected. The Vehicle Health Monitor

also remains cognizant of the VDM hardware and software and notifies mode control when a failure is detected.

3.1.1.x Operating System Services

3.1.1.y Bus Management

3. TELEMETRY AND COMMAND

1
Formatting
Telemetry
10Kbytes/50Hz

2
Storage
8Kbytes/50Hz

3
Receive

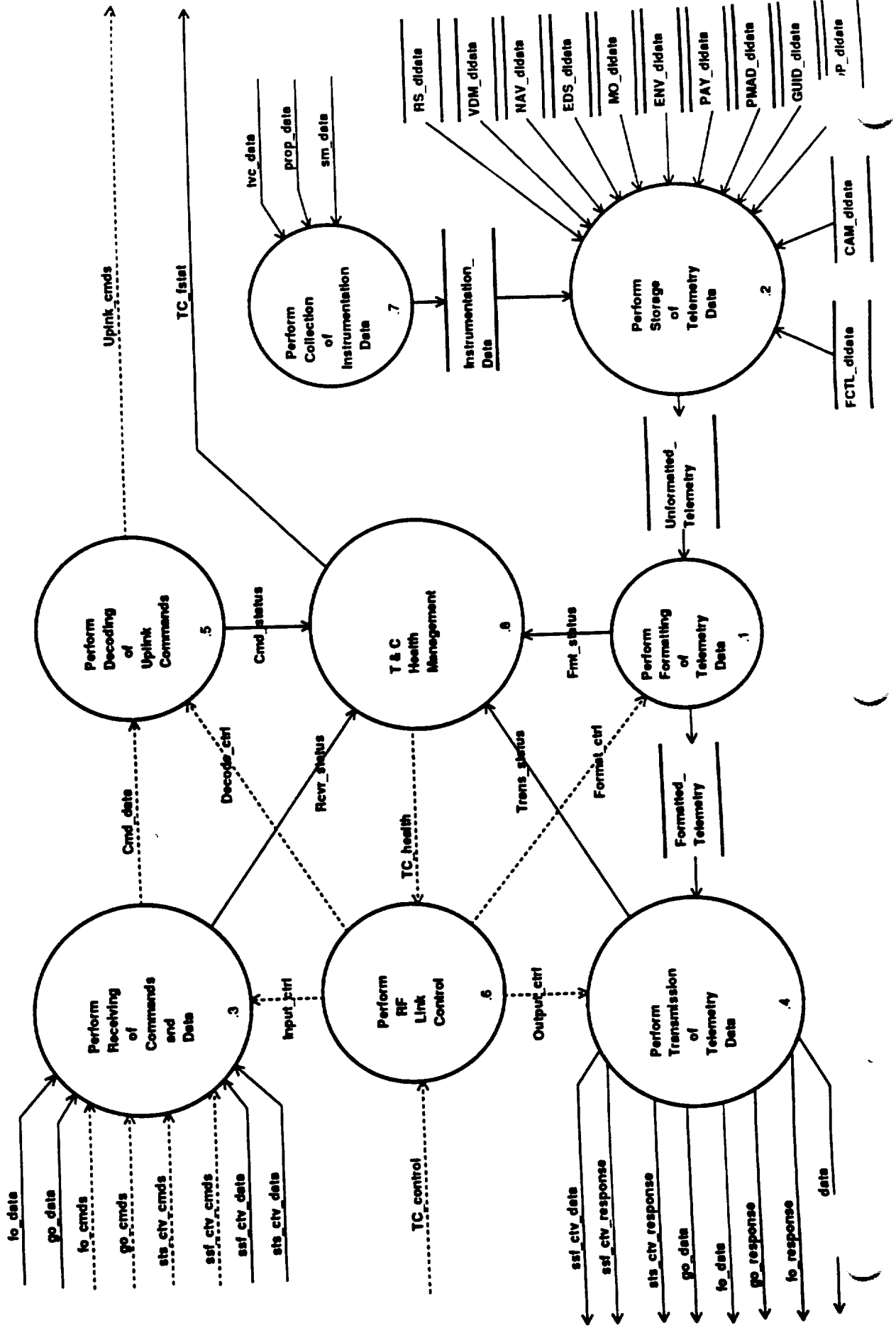
4
Transmit

5
Decode
1Kbytes/50Hz

6
RF Link
Control
1Kbytes/2Hz

7
Instrumentation
5Kbytes/50Hz

8
Telemetry and
Command
Health Management
4Kbytes/50Hz



3.1.3 Telemetry and Command

The Telemetry and Command (T&C) function shall provide timely, accurate and secure exchange of command data to the vehicle from the external interfaces and the transmission of telemetry data to these external interfaces, i.e. all uplink and downlink. The function shall control all RF links except range safety and GPS. The function shall perform its own health monitoring and self-test.

3.1.3.1 Formatting Telemetry

The formatting telemetry subfunction transforms the instrumentation and computer-generated signals for downlink. This formatting is based on the or programmable format that has been commanded by the VDM or an external interface (STS, SSF, ground).

3.1.3.2 Storage

Storage is the on-board medium (hardware and software) for storing data as it is received by the Telemetry and Command function. The storage subfunction stores all vehicle telemetry data until required by the telemetry formatting function. This subfunction acquires data from the various systems by monitoring the data bus(es). This function also gets data from the instrumentation function. Commands which are uplinked for later execution are also stored.

3.1.3.3 Receive

The receive subfunction demodulates the RF signals from an external source and does a hardware check for validity.

3.1.3.4 Transmit

The transmit subfunction modulates the formatted telemetry downlink data for transmission by cable or RF link. The transmit subfunction also performs data encryption and encoding if required.

3.1.3.5 Decode

The decode subfunction removes encoding on uplink data received, and if required, also does decryption. This subfunction also does error detection and correction. The data is then forwarded to the addressed function via the VDM.

3.1.3.6 RF Link Control

The RF link control subfunction configures the on-board transmitters.

3.1.3.7 Instrumentation

The instrumentation subfunction collects sensor data and performs signal conditioning as required to process and distribute all onboard instrumentation data.

3.1.3.8 T&C Health Management

The T&C Health Management subfunction assesses the health of and reconfigures, if required, the T&C Function. The T&C health status is reported to the VDM function.

4. NAVIGATION

1

Inertial
Measurement

2

Sensor
Compensation
6Kbytes/50Hz

3

State Vector
Computation/
Update
6Kbytes/50, 2Hz

4

GPS Processing
30Kbytes/2Hz

5

On-Pad
Alignment
and Sensor
Bias Estimation
16Kbytes/100Hz

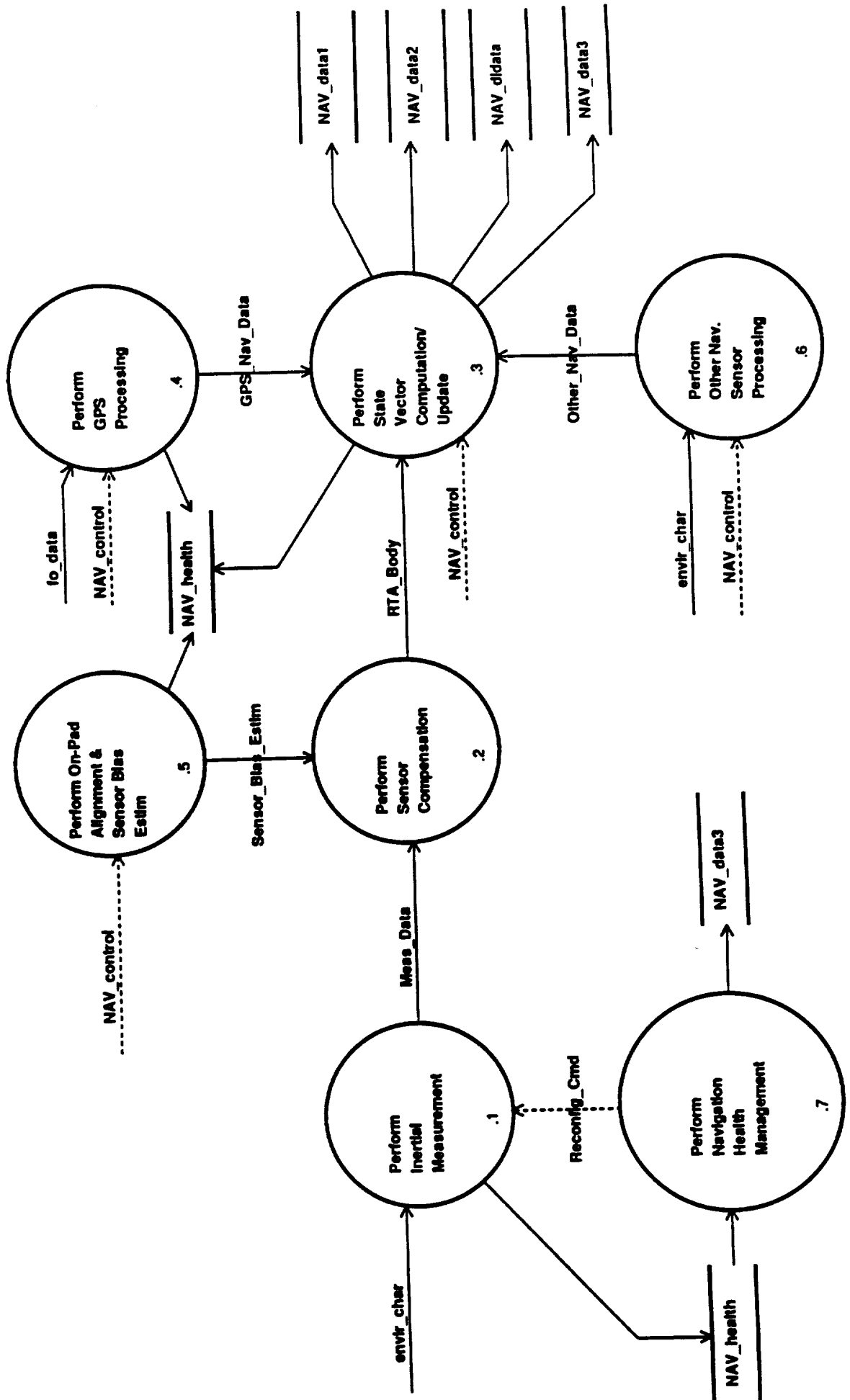
6

Other
Navigation Sensor
Processing
30Kbytes/50Hz

7

Navigation
Health
Management
12Kbytes/2Hz

4:14 Perform Navigation



3.1.4 Navigation

The Navigation function shall determine the rotational and translational states of the vehicle during all mission phases. The navigation function shall have the ability to update these states.

3.1.4.1 Inertial Measurement

The inertial measurement subfunction measures inertial angular and translational accelerations.

3.1.4.2 Sensor Compensation

Sensor compensation converts raw inertial measurement acceleration information into acceleration in engineering units, which is aligned to the sensor coordinate frame. Raw inertial measurement data is multiplied by a scale factor, added to a bias, added to acceleration dependant correction, and corrected for measured manufacturing misalignments of sensors. This is done for both translational and rotational data. The rotational data is also corrected for sculling effects and coning effects. The gyro biases are updated based on the pad alignment process.

3.1.4.3 State Vector Computation/Update

The state vector computation/update subfunction updates the vehicle states with IMU compensated sensor data, GPS navigation data and other navigation sensor data as applicable. The translational state vector is updated by converting the compensated data to inertial coordinates and adding it to the existing inertial state vector. The rotational states are updated by incrementing the current states with the compensated data.

3.1.4.4 GPS Processing

The GPS processing subfunction contains the Global Positioning System (GPS) antennae, pre-amplifiers and receiver. These elements perform the acquisition and tracking of the GPS. The GPS data is processed and provided for state vector computation/update.

3.1.4.5 On-Pad Alignment and Sensor Bias Estimation

The on-pad alignment and sensor bias estimation subfunction performs acceleration coupled leveling and azimuth alignment needed to initialize the vehicle rotational states. (During pad alignment, the steady state angular rate on the IMU is earth rate. Alignment measurements different from earth rate are due to gyro bias error, so the gyro bias compensation

utilized during flight is updated to correct for this known error.) This subfunction also determines the correct navigation element biases and updates the sensor compensation biases utilized during flight. This subfunction also supports the health management subfunction by facilitating IMU performance monitoring on the launch pad.

3.1.4.6 Other Navigation Sensor Processing

The other navigation sensor processing subfunction includes other navigational sensors (e.g. sun sensors, star trackers, horizon sensors).used to update the rotational states for execution of all CTV operations. The sensor data is processed and provided for state vector computation/ update.

3.1.4.7 Navigation Health Management

The Navigation Health Management subfunction provides continual management of the IMU, GPS Receiver and antennae, CTV Operations, and the navigation software tasks. The Navigation health status is reported to the VDM function.

5. GUIDANCE
35Kbytes/2Hz

1

Guidance
Prediction
and Analysis

2

Engine
Cut Off
Timing

3

Translational
Thruster
Firing

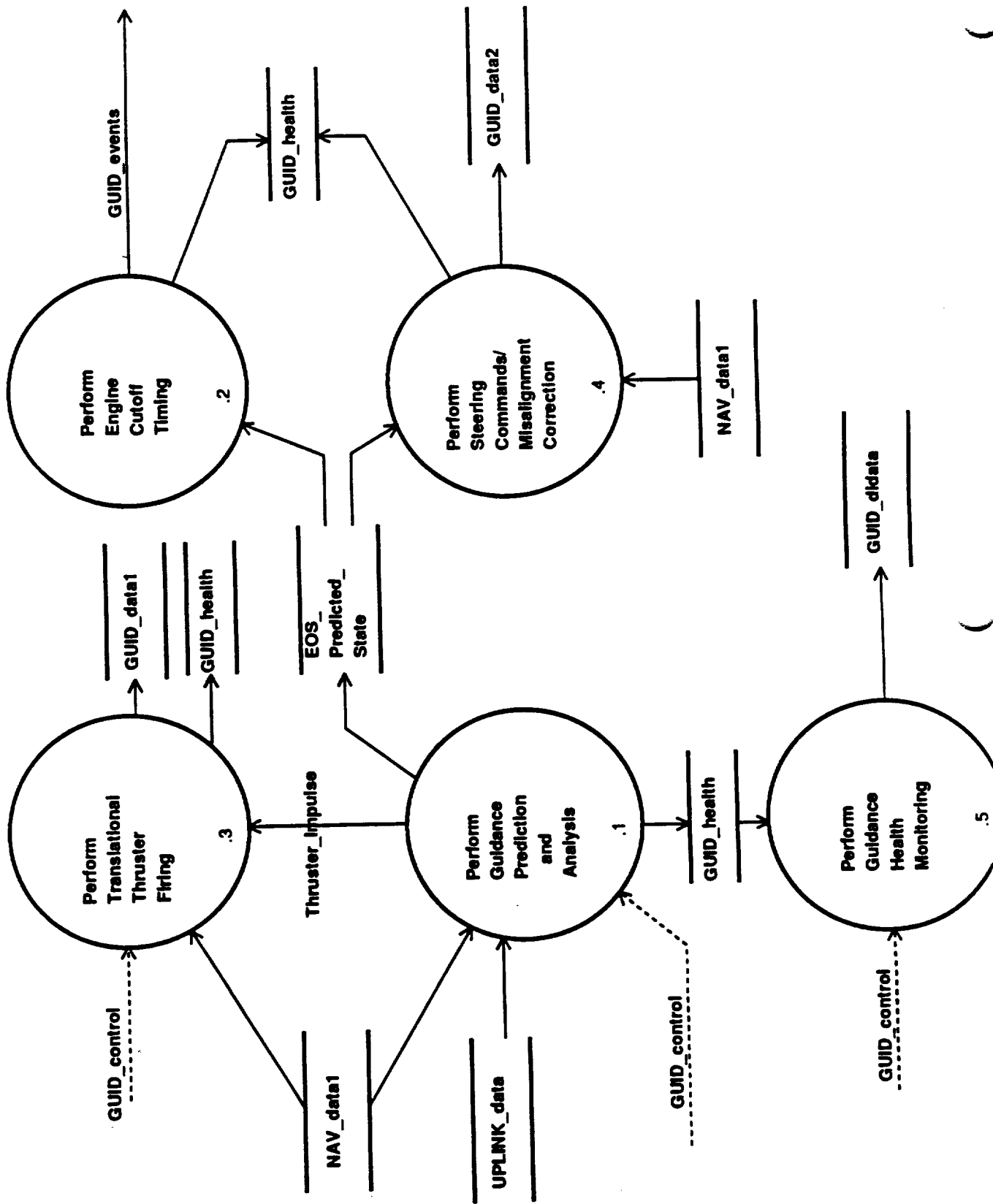
4

Steering/
Misalignment
Corrections

5

Guidance
Health
Monitor

5.6 Perform Guidance



(

(

(

3.1.5 Guidance

The Guidance function shall generate flight steering data based upon navigational inputs. The guidance function shall perform the calculations required to achieve the predetermined orbit, orbital maintenance, and rendezvous. The Guidance function shall be responsible for trajectory modifications in response to propulsion system performance. Guidance shall perform its own health monitoring and self-test.

3.1.5.1 Guidance Prediction and Analysis

The Guidance Prediction and Analysis subfunction predicts the end-of-stage state vector based on current state vector and expected performance to the end of the burn. For the open loop unguided portion of a mission, open loop pitch and yaw commands are extracted from memory and used to determine pitch and yaw rates. For the closed loop guidance portion of flight, predicted end of stage conditions are predicted for the Engine Cutoff Timing subfunction and the Steering Commands/Misalignment Corrections subfunction.

3.1.5.2 Engine Cut Off Timing

Based on the predicted end of stage conditions from the Guidance Prediction and Analysis subfunction, the engine cutoff timing will be determined by this subfunction.

3.1.5.3 Translational Thruster Firing

The Translational Thruster Firing subfunction generates thruster on-times required for on-orbit operations. These translational delta velocity burns are required for CTV orbit adjust, proximity operation, and deorbit.

3.1.5.4 Steering/Misalignment Corrections

The Steering/Misalignment Corrections subfunction generates steering data based on Guidance Prediction and Analysis subfunction results. It performs steering misalignment correction to remove bias errors from the steering data. Based on the end-of-stage stage vector and the current state, this routine determines the optimal steering to remove the error by the stage end time.

3.1.5.5 Guidance Health Monitor

The Guidance Health Monitor subfunction collects guidance health status to be used by the VDM function.

6. FLIGHT CONTROL
141Kbytes/25Hz

1
Gain
Computation

2
Sensor Data
Acquisition
and Filtering

3
Compensation
Filtering

4
Compute Gimbal
Angle Commands
(Autopilot)

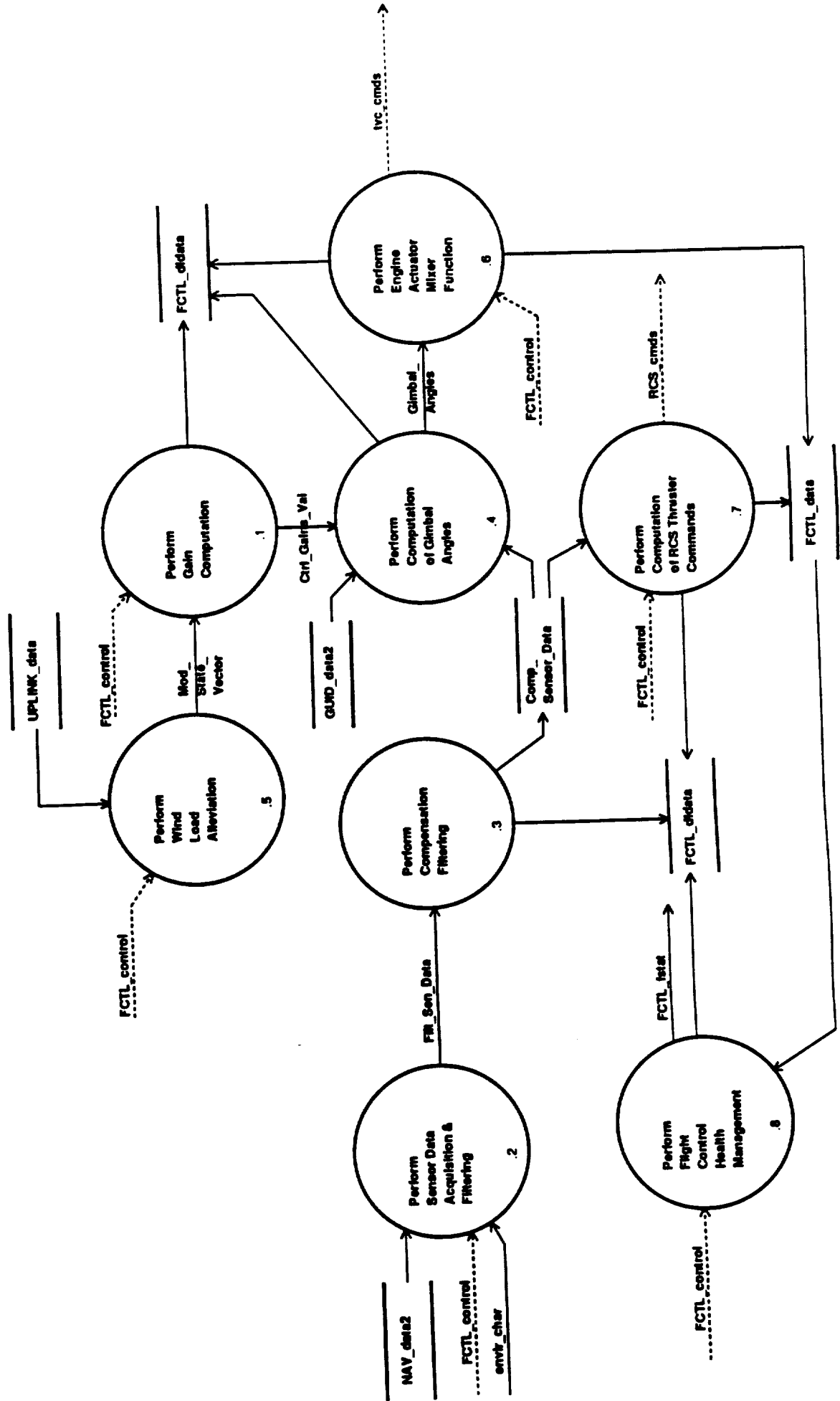
5
Wind Load
Alleviation

6
Engine
Actuator Mixer
(TVC Commands)

7
Compute RCS
Commands
(Autopilot)

8
Flight Control
Health
Management

6.13 Perform Flight Control



3.1.6 Flight Control

The Flight Control function shall maintain vehicle stability, provide adequate command response, and provide active loads reduction. The Flight Control function shall generate commands for the control effectors and thrusters using guidance steering data and flight control sensors. Flight Control shall also control and monitor the operation of the thrust vector control actuators. Flight control shall perform its own health monitoring and self-test.

3.1.6.1 Gain Computation

The Gain Computation subfunction consists of algorithms that select, using sensed vehicle velocity, acceleration, position, and time, current value of gains and filter parameters for use in other Flight Control subfunctions.

3.1.6.2 Sensor Data Acquisition & Filtering

The Sensor Data Acquisition and Filtering subfunction acquires flight control sensor data. These data and navigation function outputs are filtered to reduce noise and prevent aliasing.

3.1.6.3 Compensation Filtering

The Compensation Filtering subfunction modifies autopilot signals to achieve control system requirements.

3.1.6.4 Compute Gimbal Angle Commands (Autopilot)

The Compute Gimbal Angle Commands subfunction combines gain computation, compensation filtering, wind load alleviation, sensor filtering, and engine actuator mixer to compute necessary gimbal angles.

3.1.6.5 Wind Load Alleviation

The Wind Load Alleviation subfunction consists of algorithms which reduce structural loads and gimbal angles in the presence of winds aloft.

3.1.6.6 Engine Actuator Mixer (TVC Commands)

The Engine Actuator Mixer subfunction converts body axis engine commands to engine axis commands, taking into account individual engine and propulsion module status.

3.1.6.7 Compute RCS Commands (Autopilot)

The Compute RCS Commands subfunction performs the thruster selection

3.1.6.8 Flight Control Health Management

The Flight Control Health Management subfunction subfunction determines the health of the Flight Control system including any reconfiguration.

7. PROPULSION CONTROL
37Kbytes/25, 1Hz

1

**Engine
Controller
Commands**

2

**Manage
Fluids
(Pressure/Tanking)**

3

**Manage
Gases**

4

**Secondary
Propulsion
Control**

5

**Propulsion
Health
Management**

7.5 ENGINE CONTROL

1

Monitor
Sensors

2

Effector
Control

3

Thrust
Control

4

Engine
Conditioning
(Start up/Shut down)

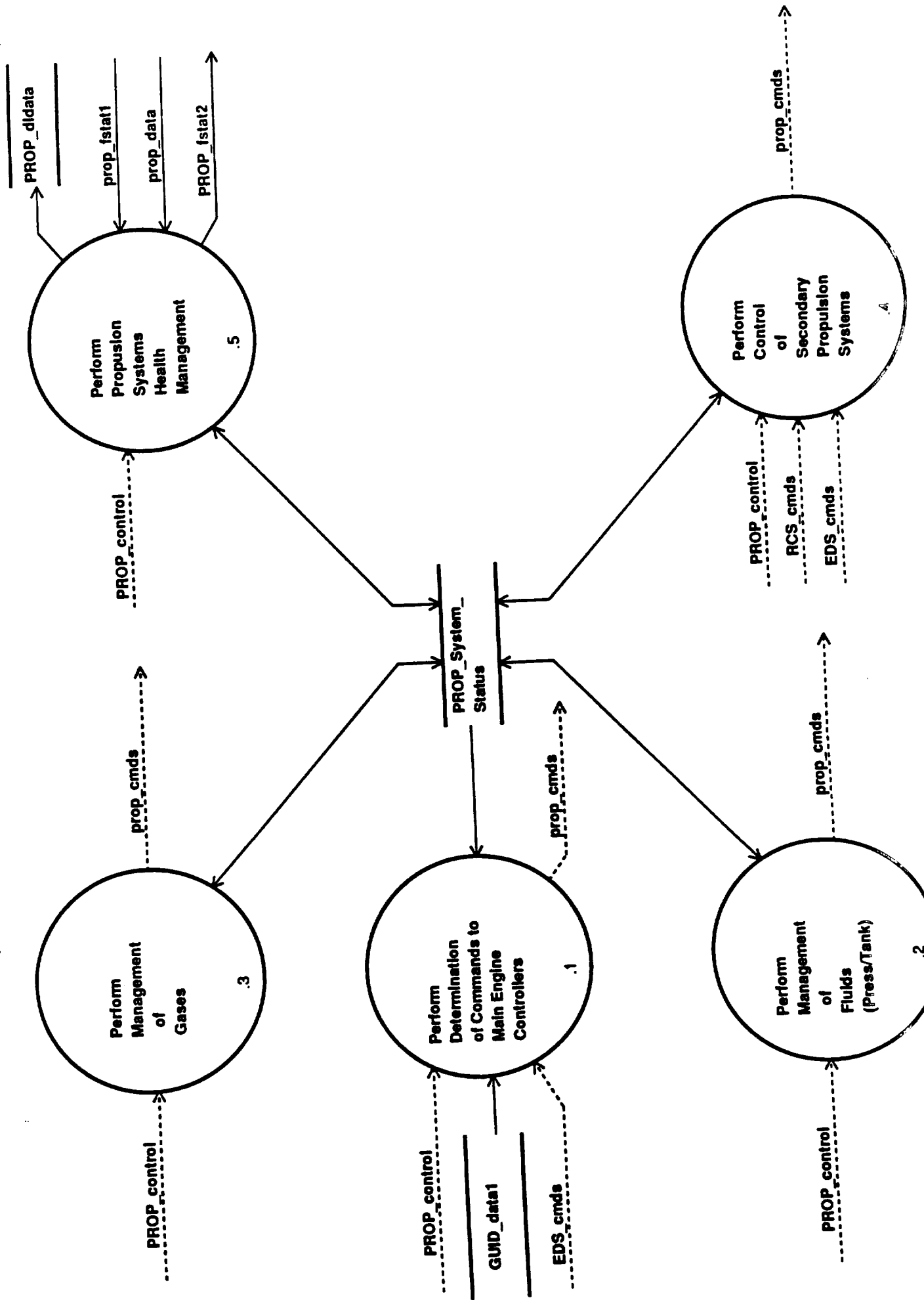
5

Vehicle
Communication

6

Engine Control
Health
Management

7.6 Perform Propulsion Systems Control



3.1.7 Propulsion Control

The Propulsion Control function shall control and monitor the propulsion systems. This function shall include engine start-up, shut down, thrust level setting events; propellant management; gas system management; and thruster valve control. Propulsion Control shall perform its own health monitoring and self-test.

3.1.7.1 Engine Controller Commands

The Engine Controller Commands subfunction commands the engine controller to start, stop, select thrust level, and to inhibit shutdown etc. (The engine controller passes signals to the engine in the form of commands to control functions such as valves, igniters, etc. to start, stop, select thrust level, etc.) The engine controller command subfunction uses data from the Propulsion Health Management subfunction to determine required engine controller commands.

3.1.7.2 Manage Fluids (Pressure/Tanking)

The Manage Fluids subfunction receives commands from the VDM function to actuate valves for prelaunch, engine conditioning and mission operation (fill/drain valves, pre-pressurization valves, etc.). This subfunction controls propellant tank pressurization and venting. Propellant pressures, temperatures and fluid level measurements are sent to the Propulsion Health Management subfunction, and to the T&C function for transmission to the ground.

3.1.7.3 Manage Gases

The Manage Gases subfunction receives commands to distribute helium for prelaunch purges during final launch countdown. This subfunction also manages the distribution of valve actuation gas for the main propulsion system as required during mission operations.

3.1.7.4 Secondary Propulsion Control

Upon command from the Flight Control function, the Secondary Propulsion Control subfunction arms/controls the secondary propulsion system. (Secondary propulsion consists of SSRBs, CTV engine(s) and controller(s), Upper Stage engine(s) and controller(s), RCS and deorbit engines.) Thruster, valve, pressure, and temperature status is provided to the Propulsion Health Management subfunction.

3.1.7.5 Propulsion Health Management

The Propulsion Health Management subfunction monitors the propulsion subsystems and assesses health of the propulsion system. This function monitors and evaluates engine controller status, valve open/closures, pressures, temperatures, fluid levels, and recognizes that an engine has been shut down by the engine controller. Propulsion status is provided to the VDM and the T&C functions.

9. MECHANISMS AND ORDNANCE CONTROL
2Kbytes/2Hz

1

Mechanisms

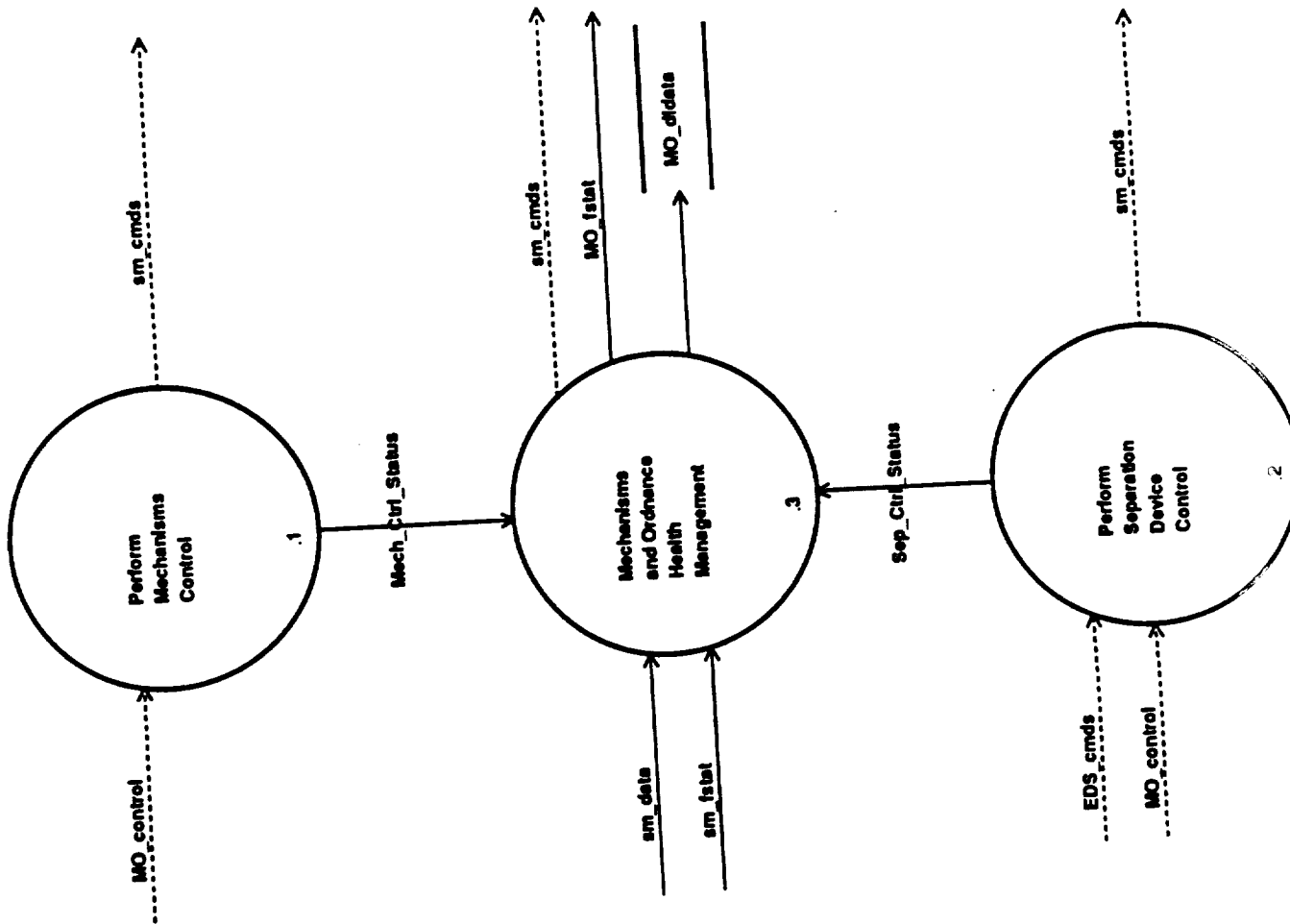
2

Separations

3

Mechanisms
and Ordnance
Health
Management

3.4 Perform Mechanism and Ordnance



3.1.9 Mechanisms and Ordnance Control

The Mechanisms and Ordnance Control function shall control vehicle mechanisms, verify vehicle interfaces, and initiate devices necessary for staging or other ordnance activated events. Mechanisms and Ordnance shall also control any interfaces between the vehicle and other vehicles with which it may rendezvous. Mechanisms and Ordnance shall perform its own health monitoring, self-test and related subsystems health monitoring.

3.1.9.1 Mechanisms

The Mechanisms subfunction consists of the automatic or manual operation of grappling devices on one vehicle required to attach it to or to release it from another vehicle with the appropriate docking adapter. This subfunction also operates any mechanical devices (such as latches) which exist on the integrated launch vehicle.

3.1.9.2 Separations

The Separations subfunction controls the opening or severance of holding devices and the activation of any forcing devices required to move a vehicle component into a planned position. The Separations subfunction initiates the following operations:

- (a) TO umbilical and holddown release
- (b) Booster separation
- (c) Shroud separation
- (d) Payload separation
- (e) CTV antenna deployment
- (f) Strongback deployment.

3.1.9.3 Mechanisms and Ordnance Health Management

The Mechanisms and Ordnance Health Management subfunction performs out of limit detection of mechanisms and ordnance health and status parameters, and if a problem occurs, automatically or by manual command isolates the problem from the system so that nominal mechanisms and ordnance operation continues. Mechanisms and ordnance health status is reported to the VDM function.

10. ELECTRICAL POWER AND DISTRIBUTION
15Kbytes/2Hz

1

Distribution

2

Source
Control

3

Power
Changeover
Control

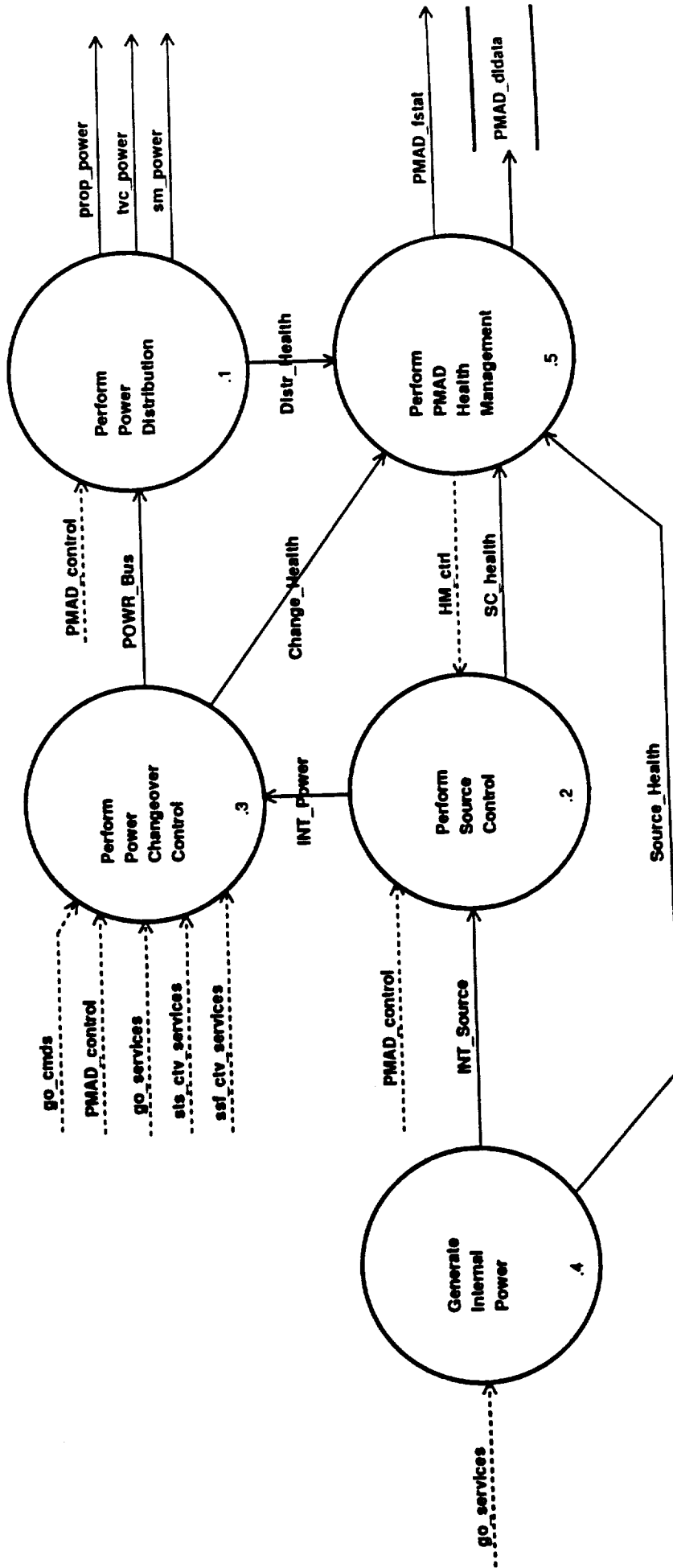
4

Source

5

EPD
Health
Management

10.5 Perform Power Management and Distribution



3.1.10 Electrical Power and Distribution (PMAD)

The PMAD function shall include the energy source and control and monitor the distribution of electrical power to vehicle electrical loads. It shall control and monitor energy sources as applicable, the transfer of electrical power between power sources, and the power-up and power-down sequencing. It shall provide necessary circuit protection and it shall meet and be compatible with the vehicle fault tolerance requirements. PMAD shall perform its own health monitoring and self-test.

3.1.10.1 Distribution

The Distribution subfunction shall apportion electrical power to the individual loads and shall have the ability to apply or remove power to individual loads.

3.1.10.2 Source Control

The Source Control subfunction shall apply or remove power to a bus as well as change power sources on the vehicle, i.e. primary battery to backup, or solar cell to battery, etc.

3.1.10.3 Power Changeover Control

The Power Changeover Control subfunction shall initiate and complete power transfer between individual sources such as ground power to vehicle power or CTV power to SSF power. It shall also provide any necessary sequencing.

3.1.10.4 Source

The Source subfunction provides the main power point of origin, i.e. batteries, ground power, fuel cells, etc.

3.1.10.5 EPS Health Management

The EPS Health Management subfunction determines if the power system is working properly and reports fault status to the VDM function.

11. ENVIRONMENTAL CONTROL
3Kbytes/2Hz

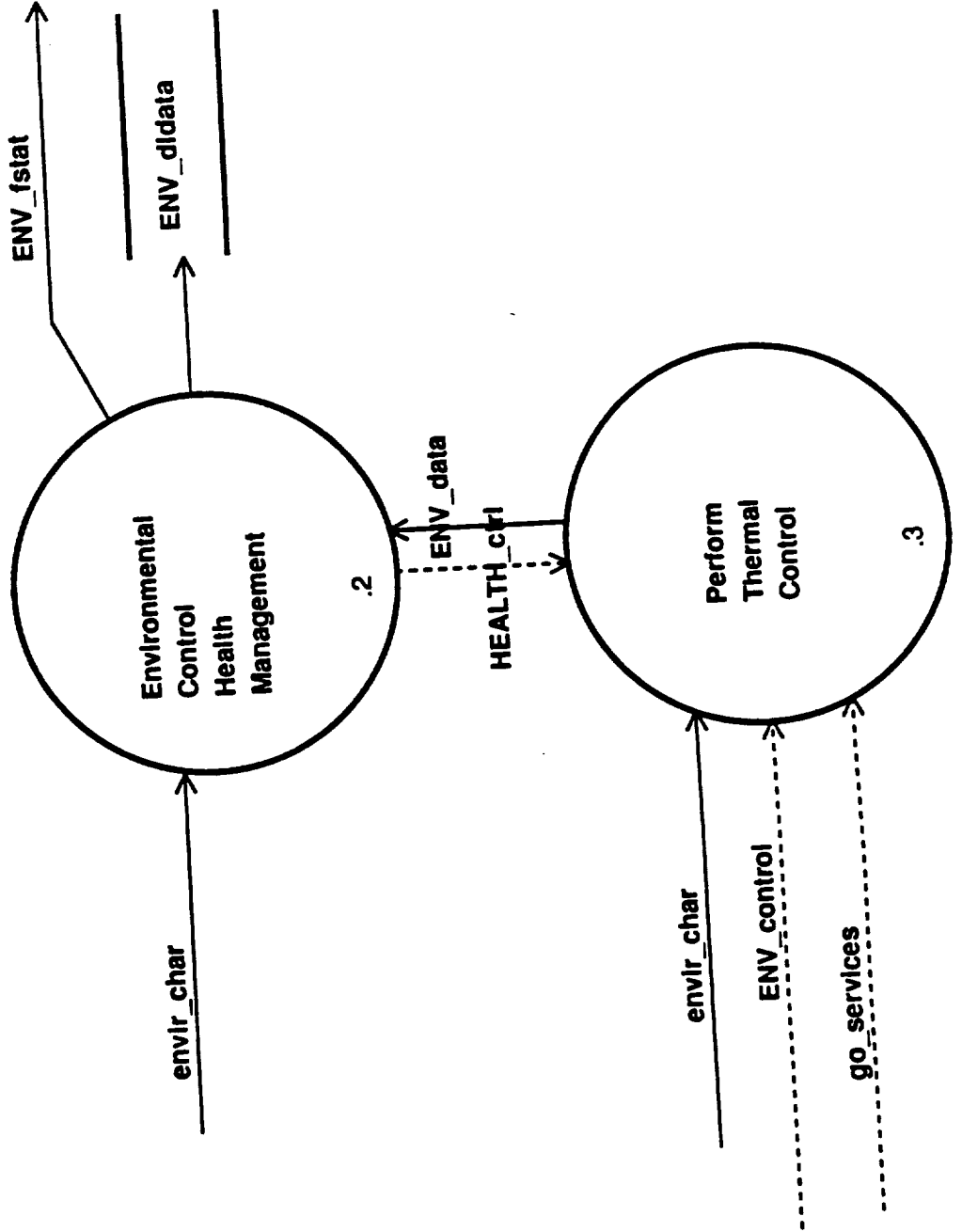
1

Thermal
Control

2

Environmental
Control
Health
Management

11.4
Perform Environmental Control



3.1.11 Environmental Control

The Environmental Control function shall respond to environmental conditions in order to ensure that the avionics is maintained within acceptable thermal limits. Environmental Control Shall perform its own health monitoring, self-test and related subsystems health monitoring.

3.1.11.1 Thermal Control

The Thermal Control subfunction monitors and provides control of avionics temperature during the mission. This will include both heating and cooling of the avionics systems.

3.1.11.2 Environmental Control Health Management

The Environmental Control Health Management subfunction determines if the Environmental Control system is working properly and reports fault status to the VDM function.

12. PAYLOAD ACCOMMODATIONS
2Kbytes/25Hz

1

Electrical
Power

2

Telemetry
Data
Collection

3

Thermal
Management

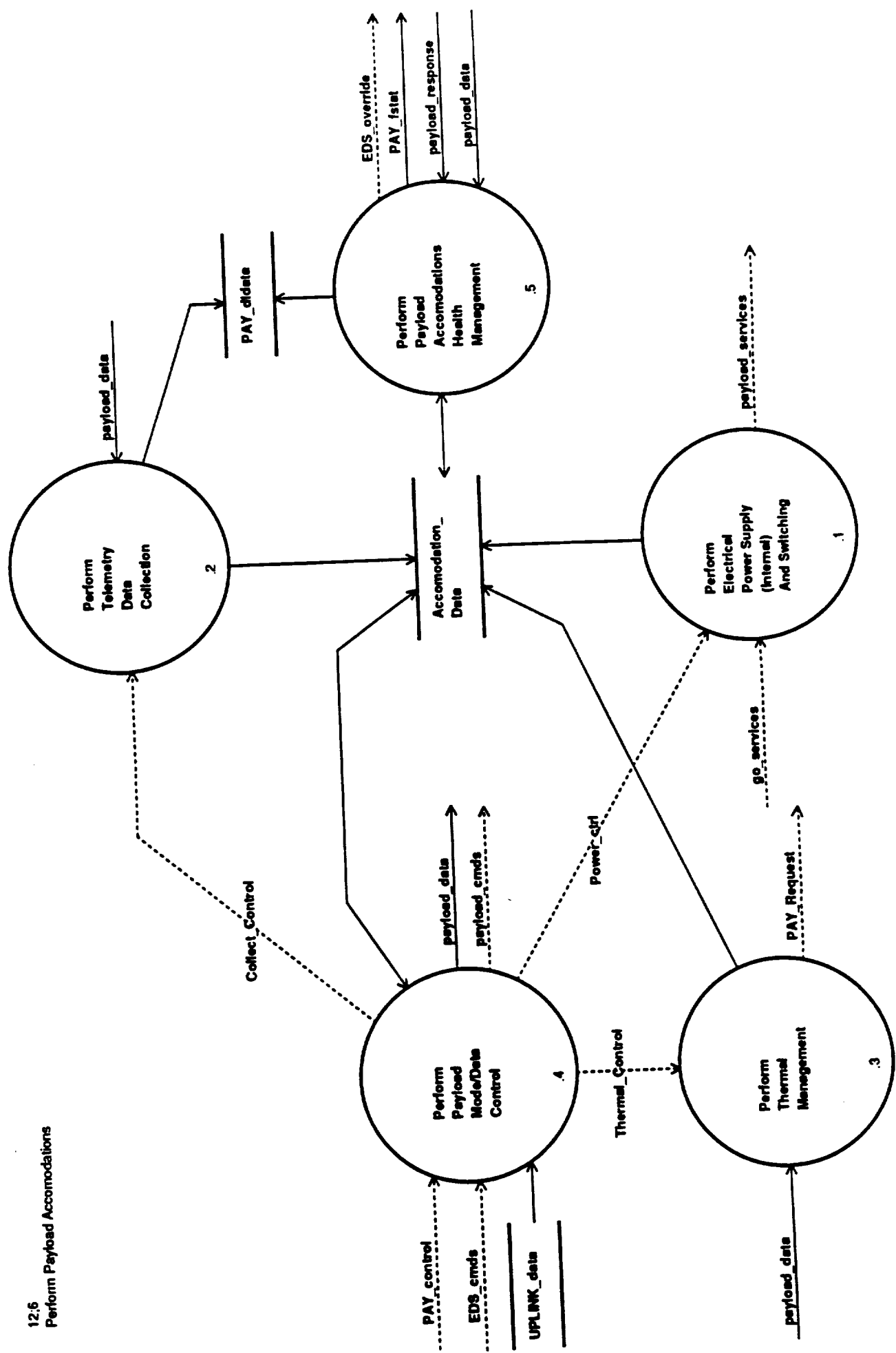
4

Mode
Control

5

Payload
Accommodations
Health
Management

12.6
Perform Payload Accommodations



3.1.12 Payload Accommodations

The Payload Accommodations function shall control the interface with the payload carrier. Special payload management or interfacing requirements are decoupled from the basic operation of the Core Stage or Upper Stage systems through the payload accommodations function. Requirements may include telemetry formatting, sensor monitoring, power source and power switching, and thermal management. The Payload Accommodations function shall provide its own health monitoring and self-test.

3.1.12.1 Electrical Power

The electrical power subfunction is the independent and electrically isolated power source dedicated to providing electrical power to the payload. This subfunction also transfers the power being provided to the payload from a ground source to an on-board source and turns the power source on or off.

3.1.12.2 Telemetry Data Collection

The Telemetry Data Collection subfunction provides the capability to receive a serial data stream and/or discrete analog and digital measurements from the payload and to transfer these measurements to the Core or Upper Stage telemetry data for downlink.

3.1.12.3 Thermal Management

The Thermal Management subfunction applies adequate payload thermal control by initiating vehicle roll maneuvers, etc. combined with proper protection of the payload from Core or Upper Stage thermal effects by using thermal blankets and heating/cooling.

3.1.12.4 Mode Control

The Mode Control subfunction issues commands to the payload which cause the payload to take an action.

3.1.12.5 Payload Accommodations Health Management

The Payload Accommodations Health Management subfunction provides monitoring and reconfiguration (if required) capability of the payload accommodations hardware/software upon the detection of anomalous behavior.

13. EMERGENCY DETECTION SYSTEM
5Kbytes/100Hz

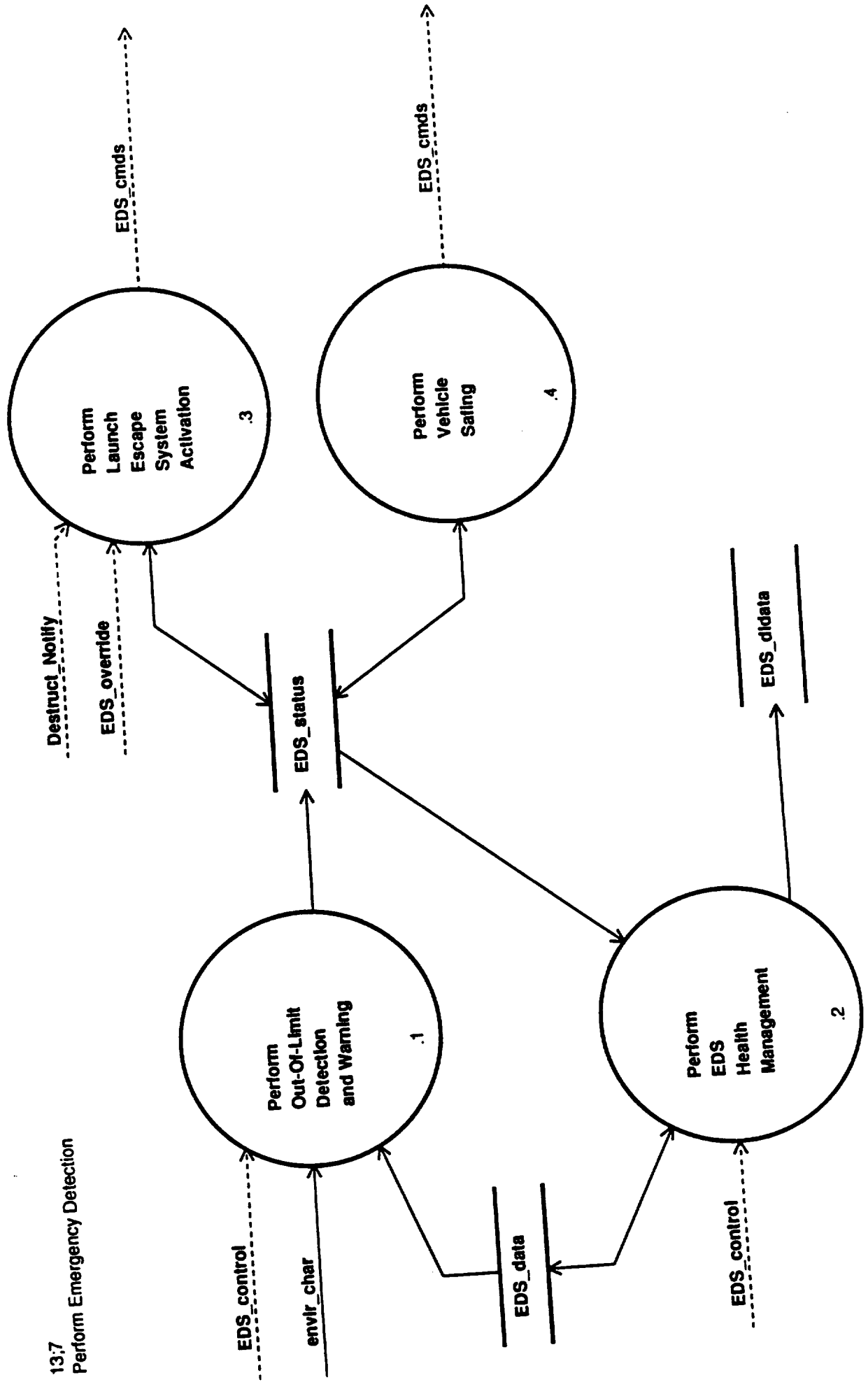
1
**Out of Limit
Detection
and
Warning**

2
**Launch
Escape System
Activation**

3
**Vehicle
Safing**

4
**EDS
Health
Management**

13.7 Perform Emergency Detection



3.1.13 Emergency Detection System

The EDS function shall independently monitor the overall operation of the Core Stage vehicle for any conditions that could be hazardous to a manned payload. If a hazardous condition is detected, the EDS function shall notify the crew. The crew then has the option to activate the Launch Escape System (LES). Some hazardous conditions may require that the EDS function be capable of automatically activating the LES. The EDS function is only required in the Core Stage when the payload is manned. The EDS function shall provide for its own health monitoring and self-test.

3.1.13.1 Out of Limit Detection and Warning

The Out of Limit Detection and Warning subfunction determines if any EDS health and status parameter(s) is/are not within a nominal operating range, and if not, then notifies another vehicle function and/or ground personnel of this condition.

3.1.13.2 Launch Escape System Activation

The Launch Escape System Activation subfunction automatically or by manual command initiates an onboard sequence of events that cause people to be safely removed from the launch vehicle, either before or after launch, if an uncorrectable hazardous condition is detected.

3.1.13.3 Vehicle Safing

The Vehicle Safing subfunction inhibits all vehicle functions that may present any hazard to people. Hazardous functions may include the vehicle becoming propulsive or the performance of any ordnance event.

3.1.13.4 EDS Health Management

The EDS Health Management subfunction performs out of limit detection and warning of EDS health and status parameters, and if a problem occurs, automatically or by manual command isolates the problem from the system so that nominal EDS operation continues.

14. COLLISION AVOIDANCE MANEUVER
6Kbytes/25Hz

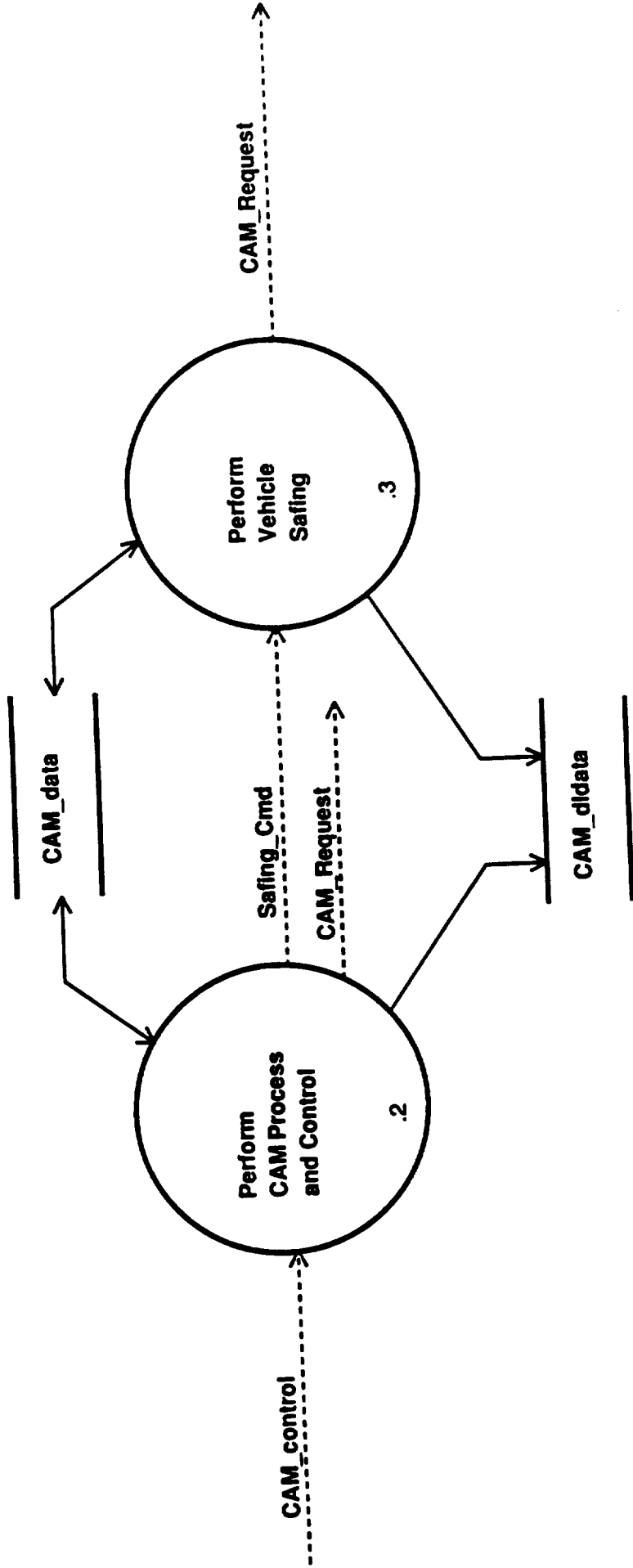
1

**CAM
Process
and Control**

2

**Vehicle
Safing**

14:6
Perform Collision Avoidance Maneuver



3.1.14 Collision Avoidance Maneuver

The CAM function shall monitor operation of the CTV when activated. When a hazardous condition is detected, or on command, the CAM function will intervene and maneuver the CTV to a safe position. The CAM function shall be an intervention level function.

3.1.14.1 CAM Process and Control

The CAM Process and Control subfunction will maneuver the CTV to a predetermined hold point which is at a safe distance from the target vehicle. The CTV will remain at the hold point sufficiently long for the ground/SSF controllers to decide if another proximity operation attempt is advisable. The CAM Process and Control subfunction can respond to a command for another attempt or it can respond to a command from the ground/SSF to move to a second point further from the target. Should no command be received within the designated period, the CTV CAM Process and Control subfunction will assume that a communication failure has occurred. The CAM Process and Control subfunction will automatically maneuver the CTV to the distant point.

3.1.14.2 Vehicle Safing

The Vehicle Safing subfunction sends a sequence of commands to the vehicle which will prevent it from actuating thrusters, ordnance or any other potentially dangerous functions. This subfunction occurs once the CTV is in a safe orbit which guarantees no recontact with the target vehicle. CAM functions are not disabled.

15. RANGE SAFETY
1Kbytes/100Hz

1

Tracking
Beacon
(or C-Band
Transponder)

2

Receive
Destruct
Commands

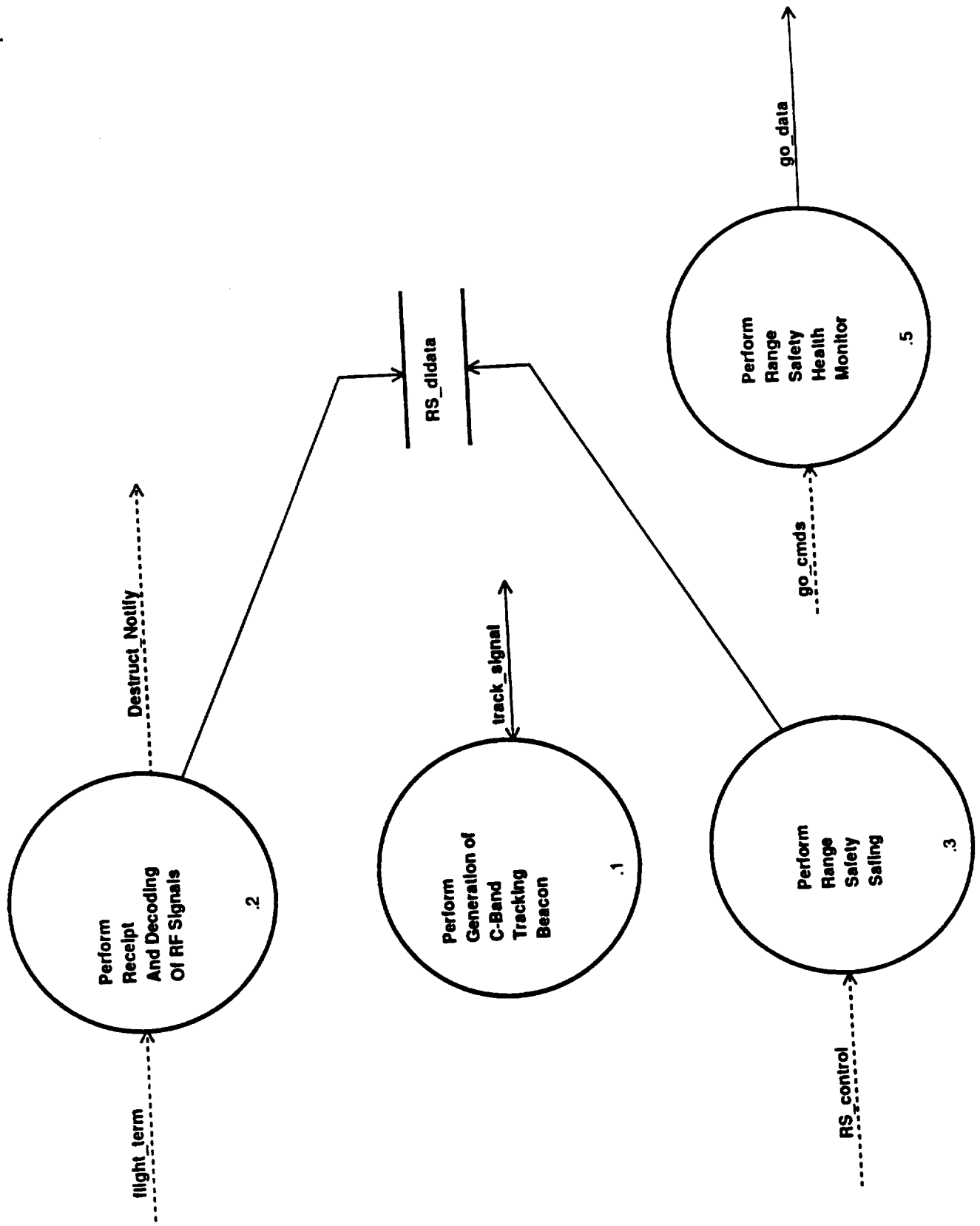
3

Range
Safety
Safing

4

Range
Safety
Health
Monitor

15:5
Perform Range Safety



3.1.15 Range Safety

The RS function shall ensure safe operation of the vehicle in the proximity of personnel or valuable capital assets. The RS communications shall be independent of the other avionics functions. RS shall provide for its own health monitoring and self-test.

3.1.15.1 Tracking Beacon (or C-Band Transponder)

The Tracking Beacon subfunction consists of a C-band transponder which is independent of all other NLS avionics functions, including Range Safety. The transponder receives signals from the range and replies.

3.1.15.2 Receive Destruct Commands

The Receive Destruct Commands subfunction receives a ground-issued destruct command and sends the appropriate hardware signals to the pyrotechnic devices for activation. If applicable, this subfunction also alerts the crew and the Emergency Detection System that the vehicle is about to be destroyed.

3.1.15.3 Range Safety Safing

The Range Safety Safing subfunction receives notification from the VDM function to safe the Range Safety Systems at appropriate times throughout the mission. The pyrotechnic devices are disabled and power is removed from the range safety hardware.

3.1.15.4 Range Safety Health Monitor

The Range Safety Health Monitor subfunction shall consist of built-in test equipment (BITE) for testing the pyrotechnic initiator controllers. This function only executes prelaunch.

16:20:22 3 Dec 91 nls_avionics Data Dictionary Entry TC_control page 1

TC_control (control flow) =
[TC_Uplink_Cmd | TC_Mode].

16:29:16 3 Dec 91 nls_avionics Data Dictionary Entry EDS_control page 1

EDS_control (control flow) =
[EDS_Uplink_Cmd | EDS_Mode].

16:30:55 3 Dec 91 nls_avionics Data Dictionary Entry PAY_control page 1

PAY_control (control flow) =
[PAY_Uplink_Cmd | PAY_Mode].

16:32:41 3 Dec 91 nls_avionics Data Dictionary Entry ENV_control page 1

ENV_control (control flow) =
[ENV_Uplink_Cmd | ENV_Mode].

16:35:19 3 Dec 91 nls_avionics Data Dictionary Entry PROP_control page 1

PROP_control (control flow) =
[PROP_Uplink_Cmd | PROP_Mode].

16:16:23 3 Dec 91 nls_avionics Data Dictionary Entry MO_control page 1

MO_control (control flow) =
[MO_Uplink_Cmd | MO_mode].

16:36:19 3 Dec 91 nls_avionics Data Dictionary Entry GUID_control page 1

GUID_control (control flow) =
[GUID_Uplink_Cmd | GUID_Mode].

16:37:07 3 Dec 91 nls_avionics Data Dictionary Entry NAV_control page 1

NAV_control (control flow) =
[NAV_Uplink_Cmd | NAV_Mode].

16:41:22 3 Dec 91 nls_avionics Data Dictionary Entry CAM_control page 1

CAM_control (control flow) =
[CAM_Uplink_Cmd | CAM_Mode | CAM_Request].

16:43:04 3 Dec 91 nls_avionics Data Dictionary Entry RS_control page 1

RS_control (control flow) =
[RS_Uplink_Cmd].

16:33:37 3 Dec 91 nls_avionics Data Dictionary Entry PMAD_control page 1

PMAD_control (control flow) =
[PMAD_Uplink_Cmd | PMAD_Mode].

16:34:26 3 Dec 91 nls_avionics Data Dictionary Entry FCTL_control page 1

FCTL_control (control flow) =
[FCTL_Uplink_Cmd | FCTL_Mode].

17:12:43 19 Nov 91 nls_avionics Data Dictionary Entry EDS_data page 1

data (store) =
_Fault_Status + VEH_Fault_Status.

11:15:41 18 Nov 91 nls_avionics Data Dictionary Entry NAV_data3 page 1

NAV_data3 (store) =
GPS_Time_Update + NAV_Fault_Status + VEH_Liftoff_Notification.

17:08:19 19 Nov 91 nls_avionics Data Dictionary Entry CAM_data page 1

CAM_data (store) =
CAM_Fault_Status + VEH_Fault_Status.

PROPOSED NLS AVIONICS PROCESSORS

- **Avionics System Computer (ASC)**
- **Command and Data Handling Unit (CDHU)**
- **Global Positioning System (GPS)**
- **Inertial Measurement Unit (IMU)**
- **Emergency Detection Processor (EDP)**
- **Range Safety Processor (RSP)**

	Proces. & S/W	Proces. Name	H/W	Common S/W	Common H/W	Sizing Kbytes	Timing Hz	Notes
Vehicle & Data Management								
• Mode Control	✓	ASC		?		12	50	
• Command Proces. & Distrib.	✓	ASC		✓		2	50	**
• Vehicle Timekeeping	✓	All Proces.	✓	✓	✓	1	50	h/w is MTU; s/w in ea. proc.
• Vehicle Health Monitor	✓	ASC		?		30	50	
• Operating System Services	✓	All Proces.	✓	✓	✓	100	50	
• Bus Management	✓	All Proces.	✓	✓	✓	5	50	
Telemetry & Command								
• Formatting Telemetry	✓	CDHU	✓			10	50	
• Storage	✓	CDHU	✓			8	50	
• Receive			✓					
• Transmit	✓	CDHU	✓			1	50	
• Decode	✓	CDHU	✓			1	2	
• RF Link Control	✓	CDHU	✓	✓	✓	5	50	
• Instrumentation						4	50	
• T&C Health Mgmt.	✓	CDHU	✓					

**Actual cmds. are data loads. Formats can be made common; executable can be made common.

	Proces. & S/W	Proces. Name	H/W	Common S/W	Common H/W	Sizing Kbytes	Firing Hz	Notes
Navigation								
• Inertial Measurement			✓		✓			
• Sensor Compensation	✓	IMU		✓		6	50	
• State Vector Computation/ Update	✓	ASC		✓		6	50, 2	
• GPS Processing	✓	GPS	✓	?		30	2	CTV: Unique; could be part of a common navigation package.
• On-Pad Alignment & Sensor Bias Estimation	✓	IMU	✓	✓	✓	16	100	
• Other Nav. Sensor Proces.	✓	ASC	✓	?		30	50	CTV: Unique; could be part of a common navigation package.
• Navigation Health Mgmt.	✓	ASC, GPS & IMU	✓	?		12	2	
Guidance								
						35	2	
• Guidance Product. & Analys.	✓	ASC		✓			2	
• Engine Cut Off Timing	✓	ASC		✓			2	
• Translational Thruster Firing	✓	ASC		✓			2	
• Steering/Misalign. Correc.	✓	ASC		✓			2	
• Guidance Health Monitor	✓	ASC		✓			2	

	Proces. & S/W	Proces. Name	H/W	Common S/W	Common H/W	Sizing Kbytes	Timing Hz	Notes
Flight Control								
• Gain Computation	✓	ASC		✓		141	25	
• Sensor Data Acquisition & Filtering	✓	ASC	✓	✓			25	
• Compensation Filtering	✓	ASC		✓			25	
• Compute Gimbal Angle Commands (Autopilot)	✓	ASC		?			25	Could be designed as a common package.
• Wind Load Alleviation	✓	ASC					25	
• Engine Actuator Mixer (TVC Commands)	✓	ASC		?			25	Could be designed as a common package.
• Compute RCS Commands (Autopilot)	✓	ASC		✓			25	Could be designed as a common package.
• Flight Control Health Mgmt.	✓	ASC	✓	?			25	
						37	25, 2	
Propulsion Control								
• Engine Controller Cmds.	✓	ASC					2	
• Manage Fluids	✓	ASC		?			2	
• Manage Gases	✓	ASC		?			2	
• Secondary Propulsion Ctrl.	✓	ASC		?			25	
• Propulsion Health Mgmt.	✓	ASC		?			2	

	Proces. & S/W	Proces. Name	H/W	Common S/W	Common H/W	Sizing Kbytes	Timing Hz	Notes
Mechanism & Ordnance Ctrl.								
• Mechanisms			✓	Not pertinent				
• Separations			✓					
• M&O Health Management	✓	ASC	✓					
Electrical Power & Distrib.								
• Distribution	✓	ASC	✓	✓		15	2	
• Source Control	✓	ASC	✓	✓				
• Power Changeover Control	✓	ASC	✓	✓				
• Source			✓					
• EPS Health Management	✓	ASC	✓	✓		4		

((

	Proces. & S/W	Proces. Name	H/W	Common		Sizing	Timing	Notes
				S/W	H/W			
Environmental Control								
• Thermal Control	✓	ASC	✓			3	2	
• Environ. Ctrl. Health Mgmt.	✓	ASC	✓					
Payload Accommodations								
• Electrical Power	✓	ASC	✓	✓		2	25	
• Telemetry Data Collection	✓	CDHU		✓				
• Thermal Management	✓	ASC	✓					
• Mode Control	✓	ASC		✓				
• Payload Accommodations Health Management	✓	ASC	✓	?				

	Proces. & S/W	Proces. Name	H/W	Common S/W	Common H/W	Sizing Kbytes	Timing Hz	Notes
Emergency Detection Sys.								
• Out of Limit Detection and Warning	✓	EDP	✓			5	100	
• Launch Escape System Activation	✓	EDP	✓					
• Vehicle Safing	✓	EDP	✓					
• EDS Health Management	✓	EDP	✓					
Collision Avoidance Maneuv.								
• CAM Process & Control	✓	ASC	✓			6	25	
• Vehicle Safing	✓	ASC	✓					
Range Safety								
• Tracking Beacon (C-band Transponder)			✓			1	100	
• Receive Destruct Commands	✓	RSP	✓					
• Range Safety Safing	✓	RSP	✓					
• Range Safety Health Monitor	✓	RSP	✓					

AVIONICS SYSTEMS COMPUTER

439 Kbytes, 3.521 MIPS

Operating System Services
100Kbytes/50Hz

State Vector Computation/Update
6Kbytes/50, 2Hz

Bus Management
5Kbytes/50Hz

Navigation Health Management
12Kbytes/2Hz

Other Nav. Sensor Processing
30Kbytes/50Hz

Sensor Data Acquisition and Filtering

Gain Computation

Compensation Filtering

Wind Load Alleviation

Compute RCS Commands (Autopilot)

Compute Gimbal Angle Commands (Autopilot)

Engine Actuator Mixer (TVC Commands)

Flight Control Health Management

141Kbytes/25Hz

Mode Control (Test Control and Sequencing)
12Kbytes/50Hz

Engine Controller Commands

Manage Gases

37Kbytes/25 & 2Hz

Command Processing and Distribution
2Kbytes/50Hz

Manage Fluids (Press./Tank.)

Secondary Propulsion Control

Propulsion Health Management

ASC Time Update
1Kbytes/50Hz

Guidance Prediction and Analysis

Steering/Misalignment Corrections

Translational Thruster Firing

35Kbytes/2Hz

Engine Cut Off Timing

Guidance Health Monitor

Vehicle Health Monitor
30Kbytes/50Hz

Distribution

EPD Health Management

Source Control

Power Changeover Control

15Kbytes/2Hz

Environmental Control Health Management

3Kbytes/2Hz

Thermal Control

Electrical Power

Mode Control

Thermal Management

Pay. Accom. Health Management

2Kbytes/25Hz

Vehicle Safing

CAM Process & Control

6Kbytes/25Hz

COMMAND & DATA HANDLING UNIT

85 Kbytes, 1 MIP

Operating System Service 50Kbytes/50Hz	Bus Management 5Kbytes/50Hz	Formatting Telemetry 10Kbytes/50Hz	Storage 8Kbytes/50Hz	Decode 1Kbytes/50Hz
RF Link Control 1Kbytes/2Hz	Instrumentation 5Kbytes/50Hz	Telemetry and Command Health Management 4Kbytes/50Hz	Telemetry Data Collection ~0	CDHU Time Update 1Kbyte/50Hz

GLOBAL POSITIONING SYSTEM

98 Kbytes, 1 MIP

Operating
System
Services

50Kbytes/50Hz

Bus
Management

5Kbytes/50Hz

GPS Processing

30Kbytes/2Hz

Navigation
Health
Management

12Kbytes/2Hz

GPS

Time Update

1Kbyte/50Hz

INERTIAL MEASUREMENT UNIT

90 Kbytes, 2.25 MIPS

Operating System Services
50Kbytes/100Hz

Bus Management
5Kbytes/100Hz

Sensor Compensation
6Kbytes/50Hz

On-Pad Alignment and Sensor Bias Estimation
16Kbytes/100Hz

Navigation Health Management
12Kbytes/2Hz

IMU Time Update
1Kbyte/100Hz

EMERGENCY DETECTION PROCESSOR

61 Kbytes, 1.5 MIPS

Operating
System
Services
50Kbytes/100Hz

Bus
Management
5Kbytes/100Hz

EDP
Time Update
1Kbyte/100Hz

Out of Limit
Detection
and
Warning

Launch
Escape System
Activation

Vehicle
Safing

EDS
Health
Management

5KBytes/100Hz

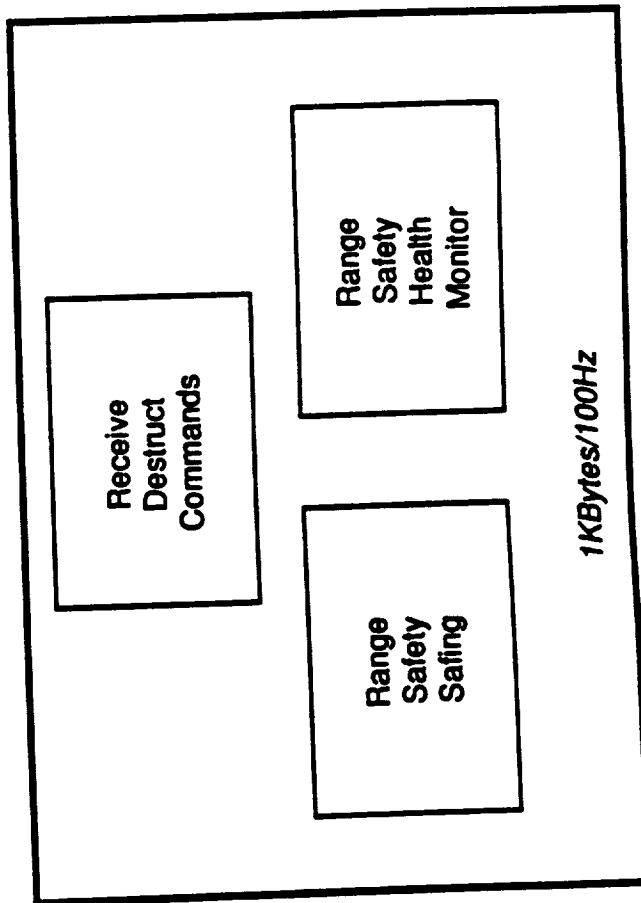
RANGE SAFETY PROCESSOR

57 Kbytes, 1.43 MIPS

Operating System Services
50Kbytes/100Hz

Bus Management
5Kbytes/100Hz

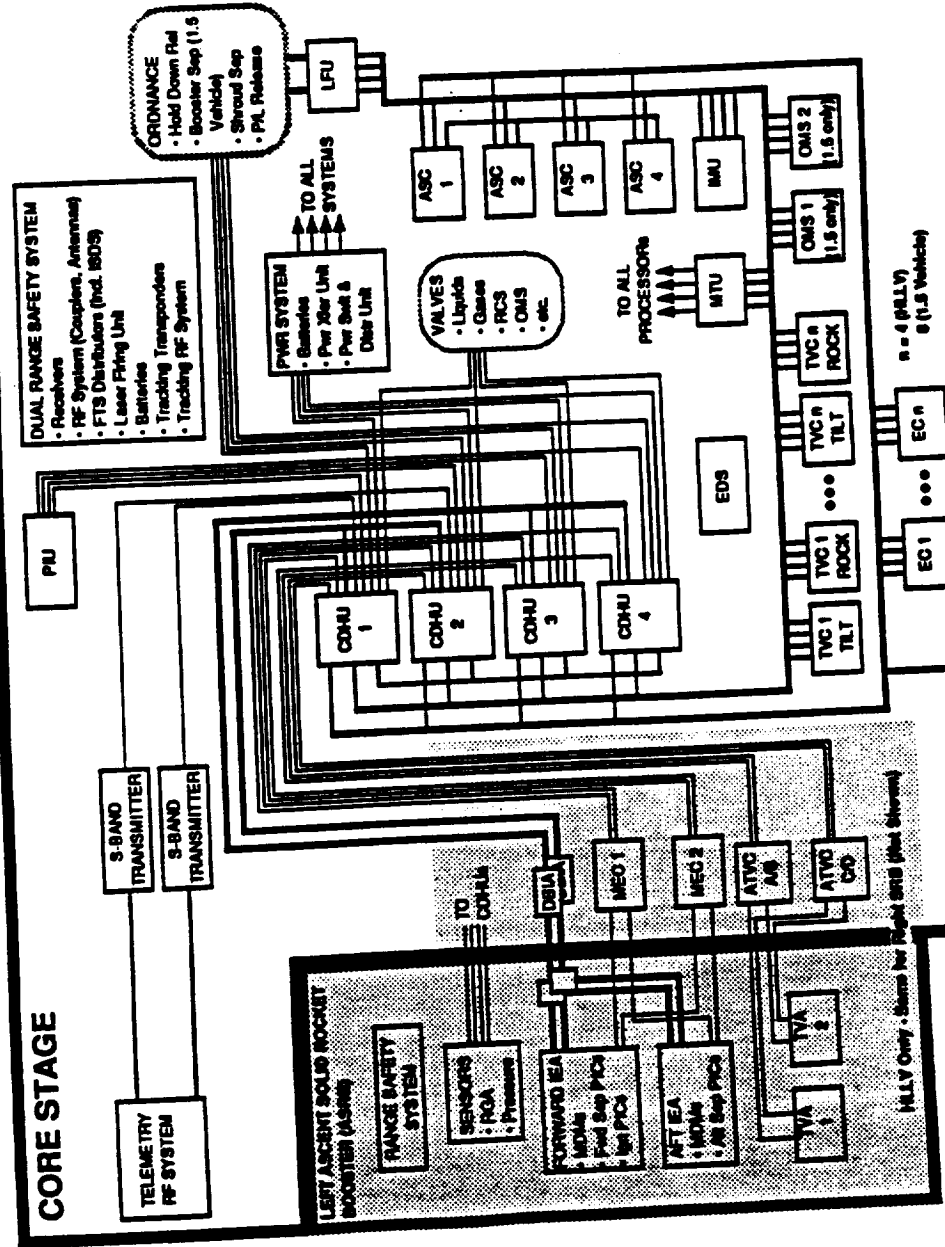
RSP Time Update
1Kbyte/100Hz



NLS Avionics Block Diagram - Core Stage

- PROPULSION CONTROL**
 - Engine Controller Cmds (ASC)
 - Manage Fluids (ASC)
 - Manage Gases (ASC)
 - Secondary Propulsion Control (ASC)
 - Propulsion Health Management (ASC)
- MECHANISMS & ORDNANCE CTRL**
 - Mechanisms
 - Separations
 - MEO Health Management (ASC)
- ELECTRICAL PWR & DISTRIBUTION**
 - Distribution (ASC)
 - Source Control (ASC)
 - Power Changeover Control (ASC)
 - Source
 - EPS Health Management (ASC)
- ENVIRONMENTAL CONTROL**
 - Thermal Control (ASC)
 - Environ Control Health Mgmt (ASC)
- PAYLOAD ACCOMMODATIONS**
 - Electrical Power Control (ASC)
 - Telemetry Data Collecting (CDHU)
 - Thermal Management (ASC)
 - Mode Control (ASC)
 - Payload Accom Health Mgmt (ASC)
- EMERGENCY DETECTION**
 - Out of Limit Detect & Warning (EDP)
 - Launch Escape Sys Activation (EDP)
 - Vehicle Saling (EDP)
 - EDS Health Management (EDP)
- RANGE SAFETY**
 - Tracking Beacon
 - Receive Desirud Commands (RSP)
 - Range Safety Saling (RSP)
 - Range Safety Health Mgmt (RSP)

- VEHICLE & DATA MANAGEMENT**
 - Mode Control (ASC)
 - Command Process & Disinb (ASC)
 - Vehicle Tracking (MTU)
 - Vehicle Health Monitor (ASC)
 - Operating System Services (ASC)
 - Bus Management (ASC)
- TELEMETRY & COMMAND**
 - Formatting Telemetry (CDHU)
 - Storage (CDHU)
 - RF Link Control (CDHU)
 - Instrumentation (CDHU)
 - T&C Health Management (CDHU)
- NAVIGATION**
 - Inertial Measurement
 - Sensor Compensation (IMU)
 - State Vector Update Comp (ASC)
 - On Pad Align & Sensor Bias Est (ASC)
 - Other Flaw Sensor Processing (ASC)
 - State Vector Update Data Acq (ASC)
 - Navigation Health Mgmt (ASC/IMU)
- GUIDANCE**
 - Guidance Predict & Anal (ASC)
 - Engine Cut-Off Timing (ASC)
 - Translational Thruster Firing (ASC)
 - Steering/Misalign Correction (ASC)
 - Guidance Health Management (ASC)
- FLIGHT CONTROL**
 - Gain Computation (ASC)
 - Sensor Acquisition Filtering (ASC)
 - Compensation Filtering (ASC)
 - Compute Global Angle Cmds
 - Autopilot (ASC)
 - Wind Load Alleviation (ASC)
 - Engine Actuator Mixer - TVC
 - Commands (ASC)
 - Compute RCS Cmds - Autopilot (ASC)
 - Flight Control Health Mgmt (ASC)



- Hold Down Rail
- Booster Sep (1.5 Vehicle)
- Shroud Sep
- PL Release

- Receivers
- RF System (Couplers, Antennas)
- FTS Distributors (Ind. BDU)
- Laser Firing Unit
- Batteries
- Tracking Transponders
- Tracking RF System

- Liquids
- Gases
- RCS
- etc.

- Batteries
- Pwr Xbar Unit
- Pwr Split & Dir Unit

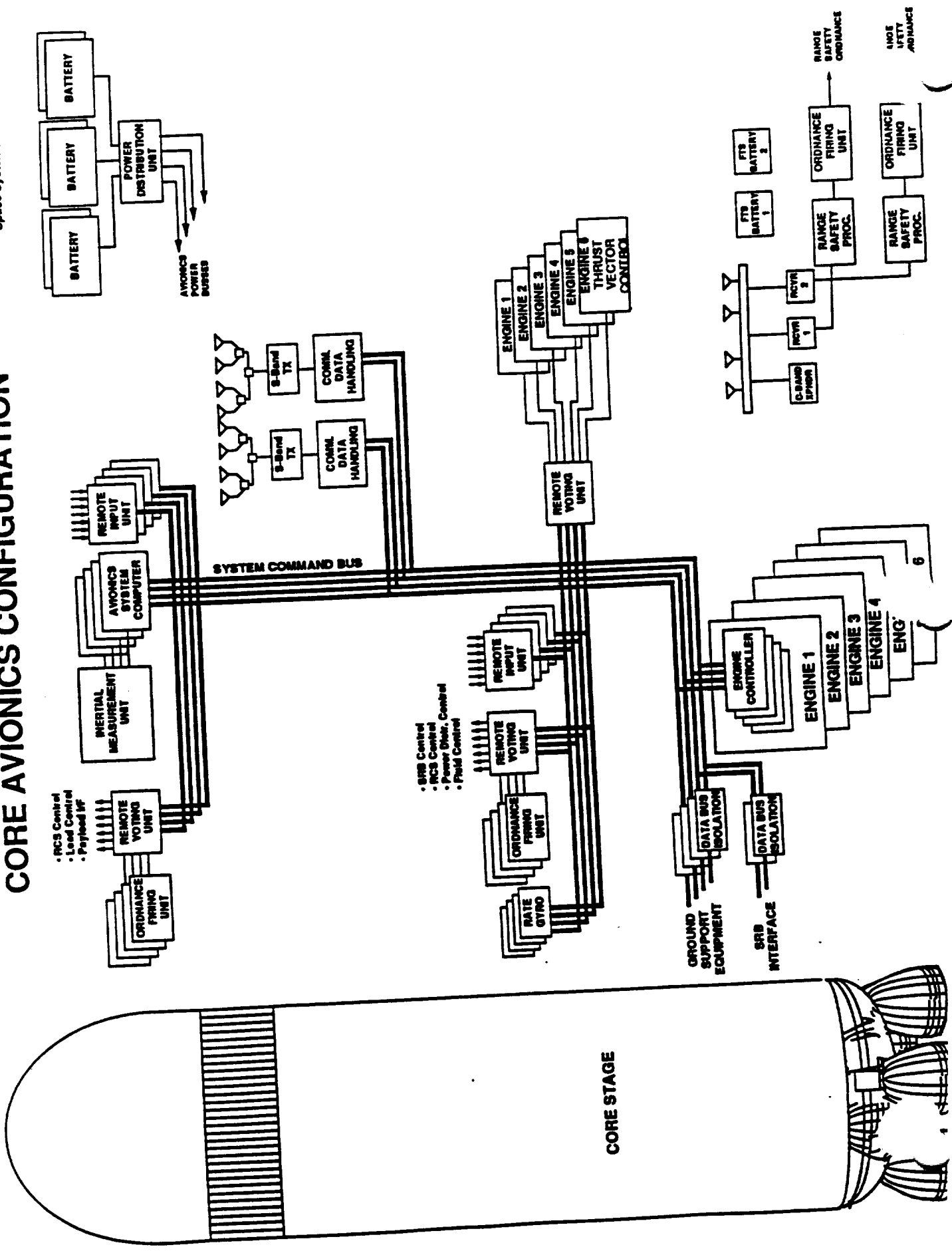
- Master Timing Unit
- Orbital Maneuver System
- Payload Interface Unit
- Range Safety Processor
- Thrust Vector Controller

- Avionics System Computer
- Ascent Thrust Vector Controller
- Command & Data Handling Unit
- Data Bus Isolation Amp
- Engine Controller

- Emergency Detection Processor
- Emergency Detection System
- Integrated Electronics Assembly
- Inertial Measurement Unit
- Laser Firing Unit
- Master Events Controller

- n = 4 (RLV)
- 8 (1.5 Vehicle)

CORE AVIONICS CONFIGURATION

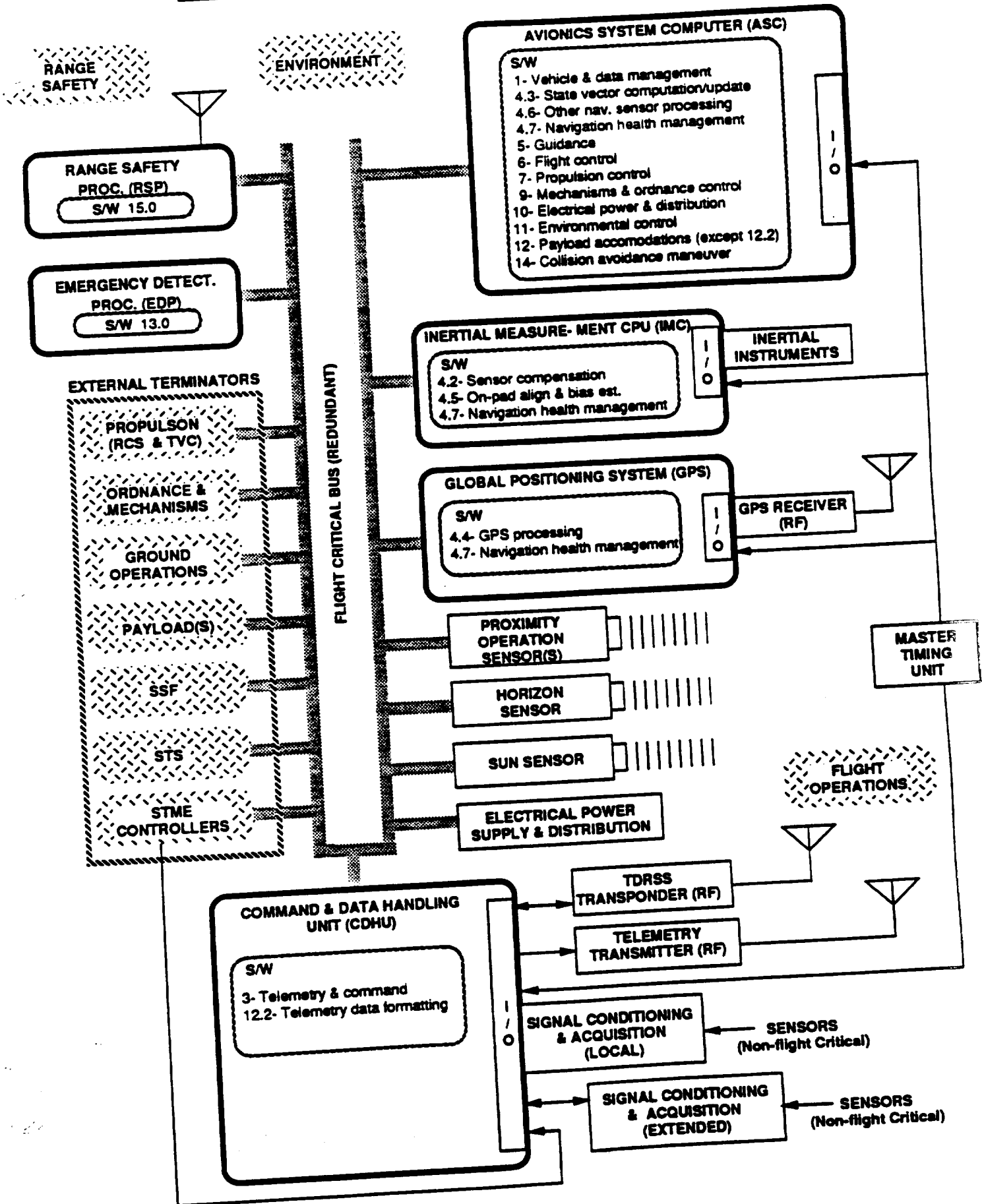


- RCS Control
- Lead Control
- Payload M

- SRB Control
- RCS Control
- Power Distr. Control
- Field Control

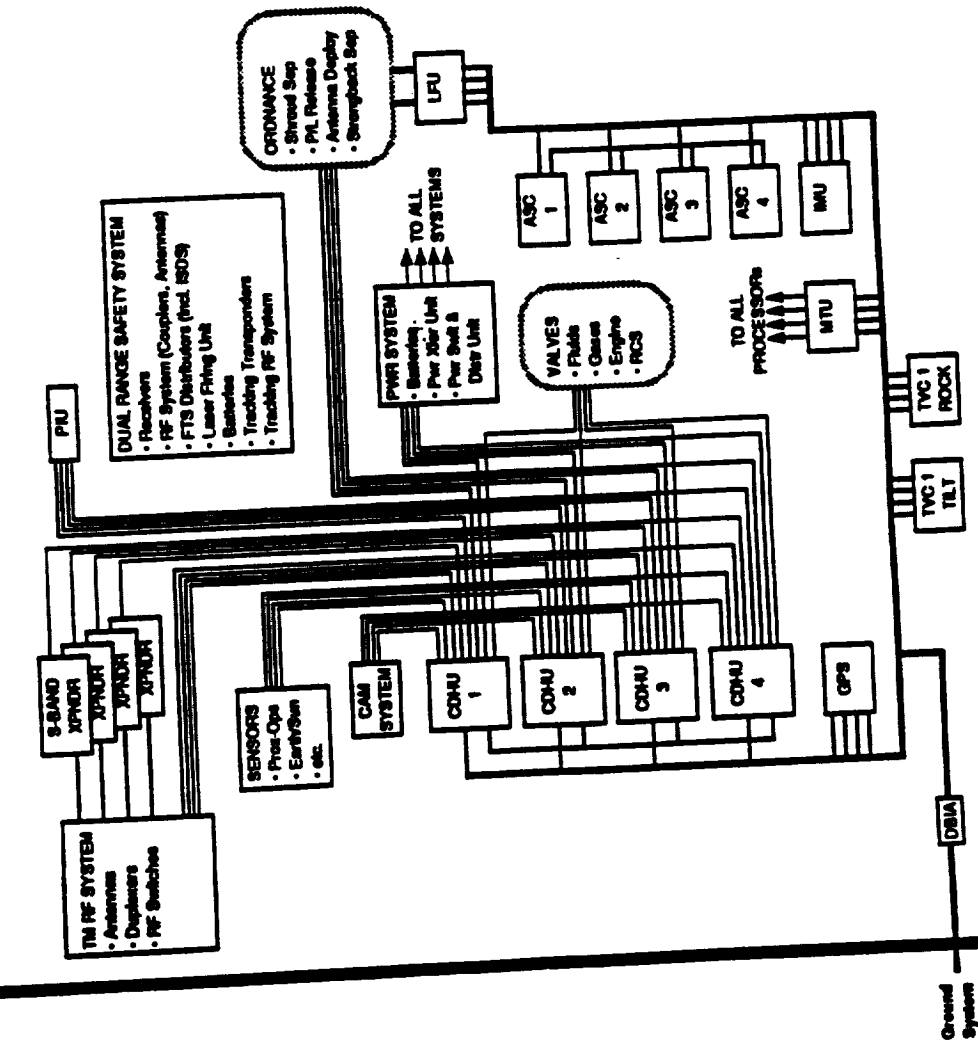
CORE STAGE

NLS AVIONICS FUNCTION ALLOCATION



NLS Avionics Block Diagram - Cargo Transfer Vehicle (CTV)

CARGO TRANSFER VEHICLE (CTV)

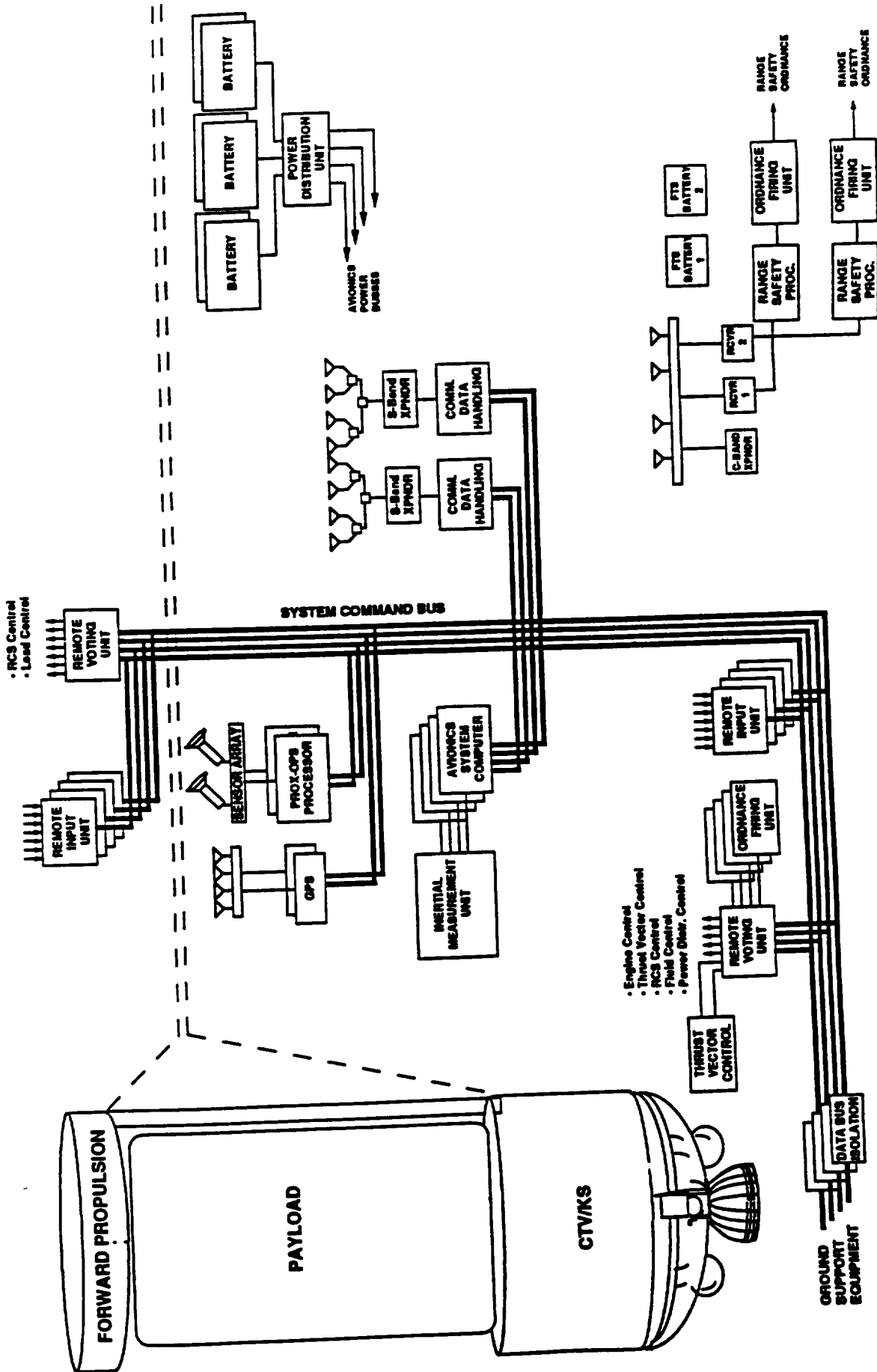


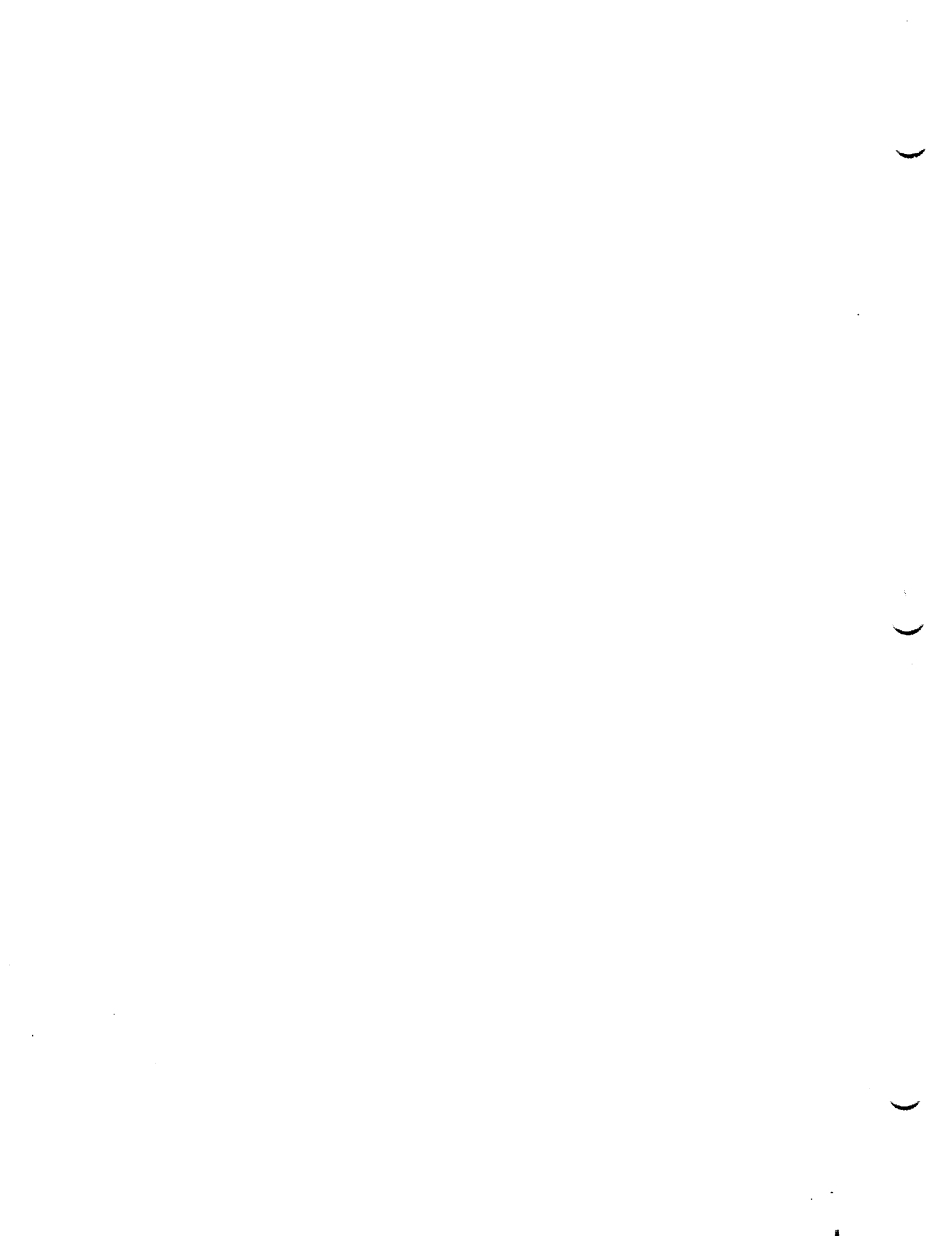
ASC = Avionics System Computer
 CAM = Collision Avoidance Manoeuvr
 COHU = Command & Data Handling Unit
 GPS = Global Positioning System
 IMU = Inertial Measurement Unit
 LFU = Laser Firing Unit
 MTU = Master Timing Unit
 PIA = Payload Interface Unit
 RSP = Range Safety Processor
 TI = Telemetry
 TVC = Thrust Vector Controller
 XPDR = Transponder

- VEHICLE & DATA MANAGEMENT**
- Mode Control (ASC)
 - Command Process & Distr (ASC)
 - Vehicle Timekeeping (MTU)
 - Vehicle Health Monitor (ASC)
 - Operating System Services (All Proc)
 - Bus Management (ASC/COHU)
- TELEMETRY & COMMAND**
- Formatting Telemetry (COHU)
 - Storage (COHU)
 - Receive
 - Transmit
 - Decode (COHU)
 - RF Link Control (COHU)
 - Instrumentation (COHU)
 - T&C Health Management (COHU)
- PROPULSION CONTROL**
- Engine Controller Cmds (ASC)
 - Manage Fluids (ASC)
 - Manage Gases (ASC)
 - Secondary Propulsion Control (ASC)
 - Propulsion Health Management (ASC)
- MECHANISMS & ORDNANCE CTRL**
- Mechanisms
 - Separators
 - M&O Health Management (ASC)
- ELECTRICAL PWR & DISTRIBUTION**
- Distribution (ASC)
 - Source Control (ASC)
 - Power Changeover Control (ASC)
 - Source
 - EPS Health Management (ASC)
- ENVIRONMENTAL CONTROL**
- Thermal Control (ASC)
 - Environ Control Health Mgmt (ASC)
- PAYLOAD ACCOMMODATIONS**
- Electrical Power Control (ASC)
 - Telemetry Data Collecting (COHU)
 - Thermal Management (ASC)
 - Mode Control (ASC)
 - Payload Accom Health Mgmt (ASC)
- COLLISION AVOID MANEUVR - CTV**
- CAM Process & Control (ASC)
 - Vehicle Sailing (ASC)
- RANGE SAFETY**
- Tracking Beacon
 - Receive Destruct Commands (RSP)
 - Range Safety Sailing (RSP)
 - Range Safety Health Mgmt (RSP)
- NAVIGATION**
- Inertial Measurement
 - Sensor Compensation (IMU)
 - State Vector Update Comp (ASC)
 - GPS Processing (GPS)
 - On-Pad Align & Sensor Bias Est (ASC)
 - Other Raw Sensor Processing (ASC)
 - State Vector Update Data Acq (ASC)
 - New Health Mgmt (ASC/IMU/GPS)
- GUIDANCE**
- Guidance Predict & Anal (ASC)
 - Engine Cut-Off Timing (ASC)
 - Transitional Thruster Firing (ASC)
 - Steer/Missalign Correction (ASC)
 - Guidance Health Management (ASC)
- FLIGHT CONTROL**
- Gain Computation (ASC)
 - Sensor Acquisition Filtering (ASC)
 - Compensation Filtering (ASC)
 - Compute Gimbal Angle Cmds
 - Autopilot (ASC)
 - Wind Load Attenuation (ASC)
 - Engine Actuator Mixer - TVC Cmds (ASC)
 - Compute RCS Cmds - Autopilot (ASC)
 - Flight Control Health Mgmt (ASC)

CTV AVIONICS CONFIGURATION

GENERAL DYNAMICS
Space Systems Division





3-FM-003

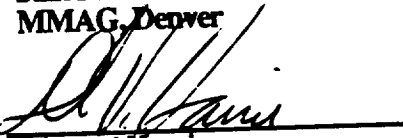
**NLS Cycle 1
Acoustics Analysis**

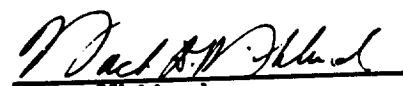
January, 1992

Distribution:
NLS / Shuttle-C Contracts (1)
NLS Technical Library (1)

Author:


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Richard Harris
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Systems Engineering Director
NLS / Shuttle-C

FOREWORD

This report was prepared by Martin Marietta Manned Space Systems in New Orleans and Martin Marietta Aerospace Group in Denver. The effort was conducted under Contract NAS8-37143 Shuttle-C for the period September 1991 through December 1991.

1.0 Summary

An acoustics environments analysis was conducted for the NLS Reference Configurations to estimate the sound pressure levels for the external and internal locations. The NLS 1 (HLLV) and the NLS 2 (1.5 Stage Vehicle) were each evaluated for both the liftoff and ascent conditions. Titan, STS, and Saturn flight and test data were used to estimate the external levels for various longitudinal locations from the payload fairing nose to the aft engine compartment. The HLLV was determined to exhibit a 5 dB exceedence in the low frequency end of the spectrum due to the liftoff conditions over the STS ICD payload bay requirement. The 1.5 Stage Vehicle internal levels were somewhat lower than the HLLV, but a payload bay requirement has not been imposed for this condition. A subscale test to determine the impact of the NLS water suppression system has been recommended to further define the degree of acoustic level accuracy to understand verify the acoustic levels.

2.0 Problem

The reference NLS vehicle configurations have been established to develop preliminary design data to determine potential concept risks and "show stoppers". The acoustics environment levels on past launch vehicles have been in the past technical concerns due to exceedences in payload design levels and due to the complex nature of the acoustic propagation on the vehicle for both liftoff and ascent conditions. This study has been conducted to understand the degree of noise suppression required to meet STS payload bay requirements.

3.0 Objective

The objective of this study is to determine the external and internal acoustics levels of the reference NLS 1 and 2 configurations. Particular interest is in the NLS 1 configuration payload bay where STS ICD 2-19001 Sound Pressure Levels (SPL) are specified permitting the vehicle to fly with STS compatible payloads. Additionally, internal levels are required to evaluate the impact to STS/ET hardware that is anticipated on the NLS core stage.

4.0 Approach

The approach for this study is to use existing flight and test data from Titan, STS, and Saturn programs where applicable. Scaling of the data is performed to account for power, source location, and frequency content differences between the measured data and the NLS configurations. A 3 dB uncertainty factor is applied to account for the statistical uncertainty in the estimation process. Both external and internal levels are developed based on the attenuation properties of the payload fairing and vehicle skin wall structure.

5.0 Results

The results of this study indicate that the NLS 1 configuration has as much as a 5 dB exceedence in the low frequency spectrum in the payload bay compared to the STS payload design levels. The NLS 2 has some slight exceedences also but are slightly lower. There currently is not a payload level requirement for the NLS 2, so the exceedence is of no concern to date. External and internal levels have been established for Cycle 1 analysis. These acoustic levels are based on nominal trajectory cases provided in the fall of 1991. These results do not reflect increased levels due to dispersed conditions. A revision update is currently in process to consider dispersed conditions. The critical condition for the payload bay levels is due to liftoff.

6.0 Conclusions & Recommendations

The following conclusions were derived from this study:

- 1) The noise attenuation properties of the Titan IV Fairing are considerably less than the STS.
- 2) A 5 dB payload bay exceedence has been determined for the NLS 1 configuration due to the liftoff condition.
- 3) This analysis assumed STS / MLP Acoustic characteristics. It is recommended that a subscale water suppression be performed with the flame trench to determine the impacts of configuration change for the NLS.
- 4) Finally, the 3 inches of blankets used in the analysis can be optimized to reduce the high frequency levels. Additional analysis is recommended to develop additional attenuation in the fairing.

7.0 Supporting Data

The following attachments listed in Section 8.0 are included to provide detailed information relative to the Acoustics Analysis study.

8.0 Attachments

Interoffice Memo 5486/CB-91-526, 20 December 1991, Final Report on the NLS Acoustic Study, Stan Barrett.
Acoustics Analysis Executive Summary Presentation, January, 1992

3-FM-003 Acoustics Analysis

Attachment 1

Executive Summary, January 1992

**NLS Cycle 1
3-FM-003
Acoustics Analysis**

Executive Summary

January 1992

3-FM-003 NLS Acoustics

Objective: Determine the External and Internal Acoustics Levels for the Reference Configuration

Key Issues:

- Liftoff Condition (Pad Configuration & H2O Suppression)
- Ascent Conditions (Nominal & Dispersed)
- STS Payload ICD 2-19001 Requirement
- Baseline Titan IV Fairing Attenuation Properties
- Uncertainties in Prediction of Acoustic Levels

Approach:

- Use Applicable Titan, STS, & Saturn Flight & Test Data
- Analytically Correct for Power, Source Location, & Frequency Differences
- Add a 3dB Uncertainty Factor for Statistical Uncertainty

3-FM-003 NLS Acoustics

Key Requirements:

Source: SRD Ver 4.0 18 Sept 1991

**3.1.3.1 NLS 1 - "accommodate a STS Dual Class Payload"
(ref 5.1.20 "complies with NSTS 07700 Vol 14 rqmts)**

3.1.3.2 NLS 2 - "Titan IV-derived shroud capable of accommodating a payload or payload/NLSUS"

3.2.7 Payload Shroud Environment - ref to Payload Planning Handbook (Appendix VI)

- HLLV meets STS Payload Levels in Fairing
- 1.5 Stage Meets TBD Levels (Maybe Titan IV Levels)
- Meet ET/STS Vibroacoustic Requirements

3-FM-003 NLS Acoustics

Groundrules & Assumptions

- **Used Nominal No Engine Out Ref Trajectories**
- **Reference Vehicle Configuration Weights Oct 1991**
- **580 Klbs STME's**
- **Baselined STS Water Suppression System**
- **Titan IV Payload Fairing with 3 in Blankets**
- **Made Use of STS, Titan, Saturn Flight and Test Data**
- **MLP / Flame Trench Acoustics Characteristics Similar to STS**
- **Internal Payload Bay Levels for Empty Bay Volume**
- **Vent Acoustic Environment Effects Not Included**

3-FM-003 NLS Acoustics

Configuration Comparison		Titan IV	STS	NLS 1	NLS 2
Liftoff Thrust	2.84 Mlbs	4.68 Mlbs	5.03 Mlbs	2.97 Mlbs	
Ascent Max Q	926 psf	743 psf	791 psf	632 psf	

3-FM-003 NLS Acoustics

Acoustics Primer:

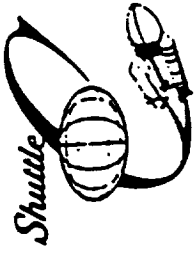
SPL = Sound Pressure Level Measured in dB's

$$\Delta \text{ dB 's} = 10 \log \frac{\text{Ve * Thrust}_2}{\text{Ve * Thrust}_1}$$

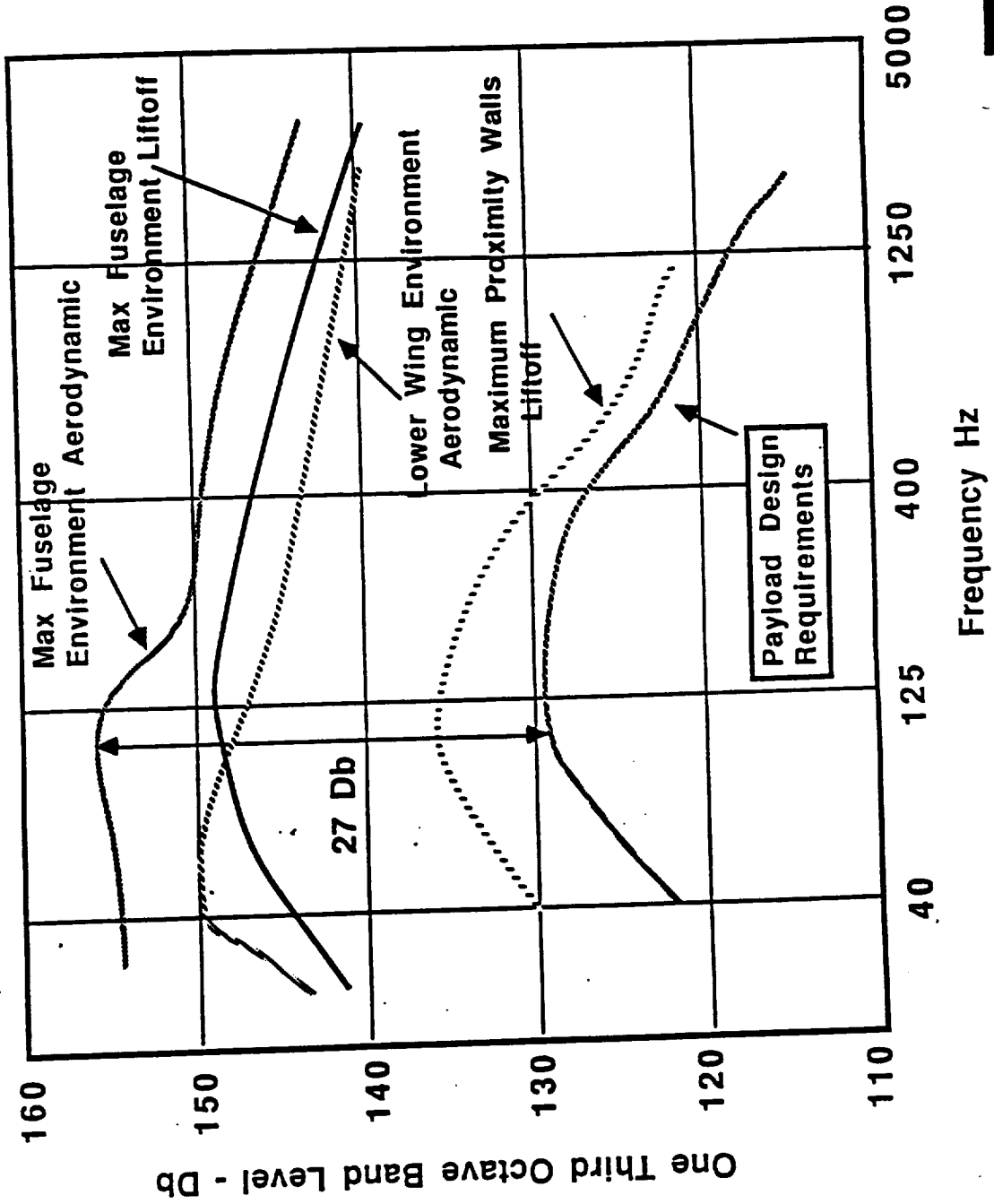
2 Times Increase
in Power = 3 dB

$$\Delta \text{ dB 's} = 20 \log \frac{Q_2}{Q_1}$$

2 Times Increase
in Pressure = 6 dB



Orbiter Acoustic Levels Measured



MARTIN MARIETTA
MANNED SPACE SYSTEMS

Titan IV Bare and Empty Noise Reductions
 One Third Octave Band Spectral Predictions

T34D PLF Acoustic Test Scaled Bare & Empty

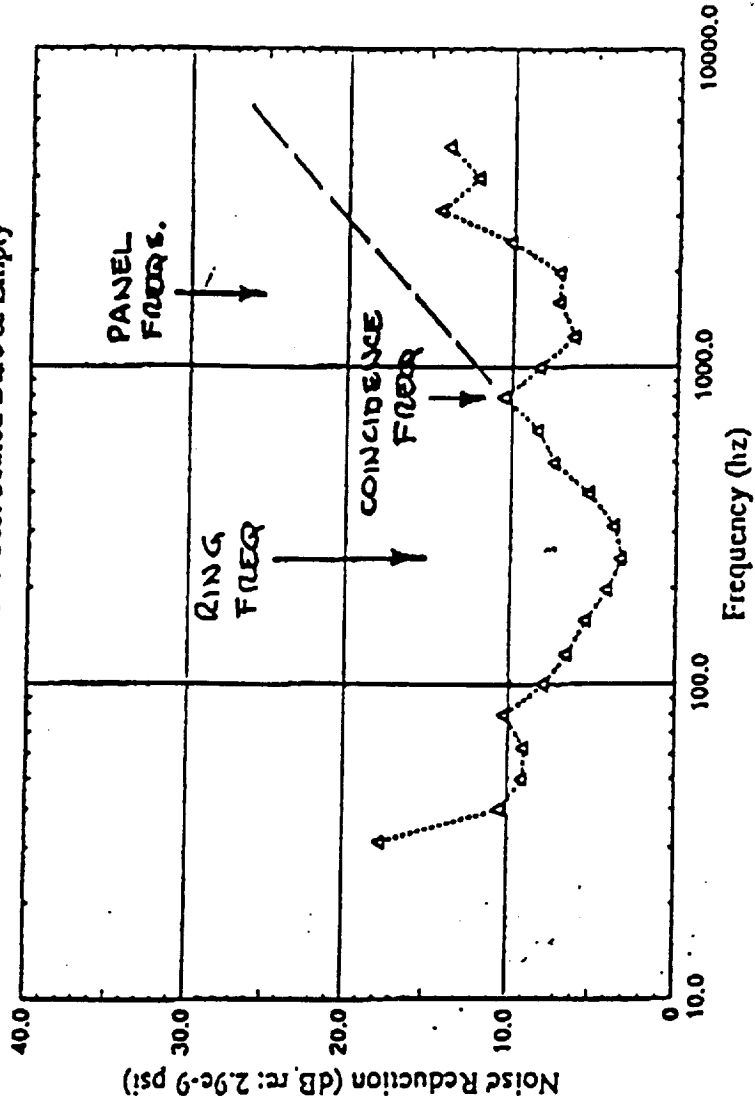
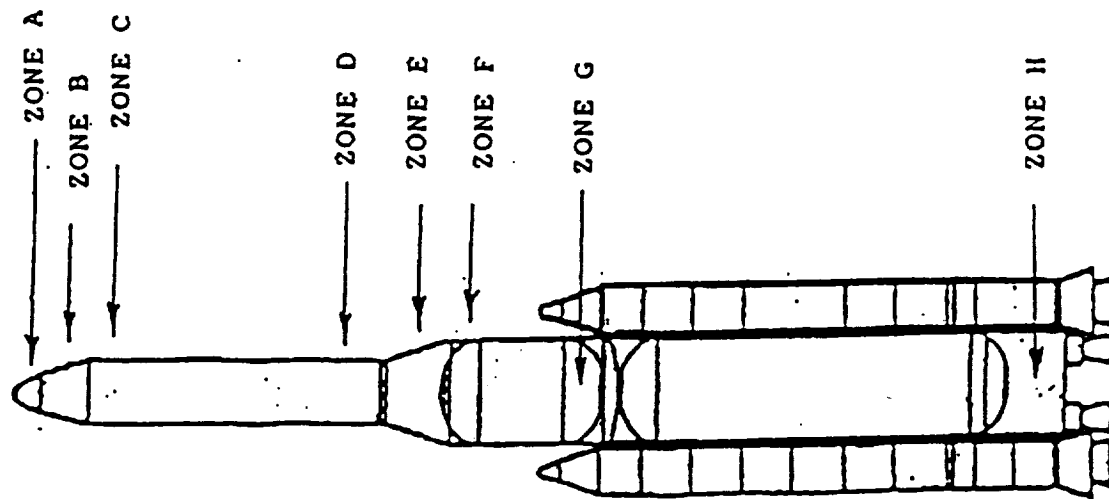


Fig. 22. TIV Predicted Bare and Empty PLF Noise Reductions.

ACOUSTIC ANALYSIS FOR NLS

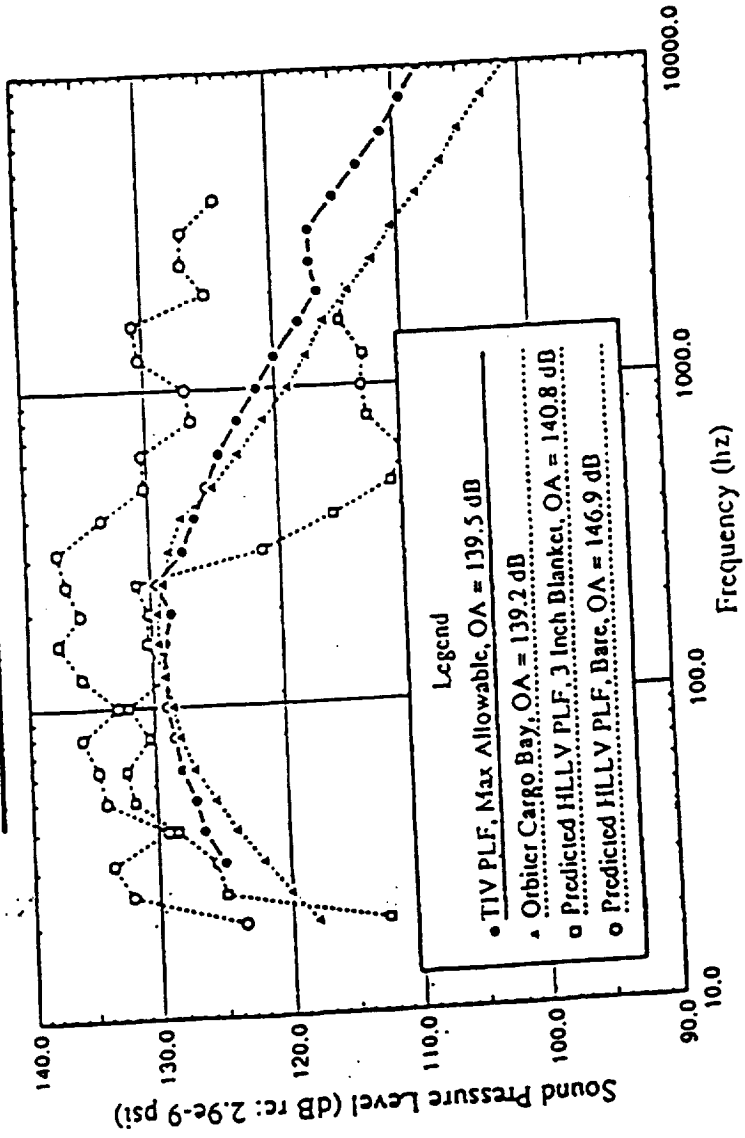
DEFINITION OF HLLV ZONES



VG No. 8

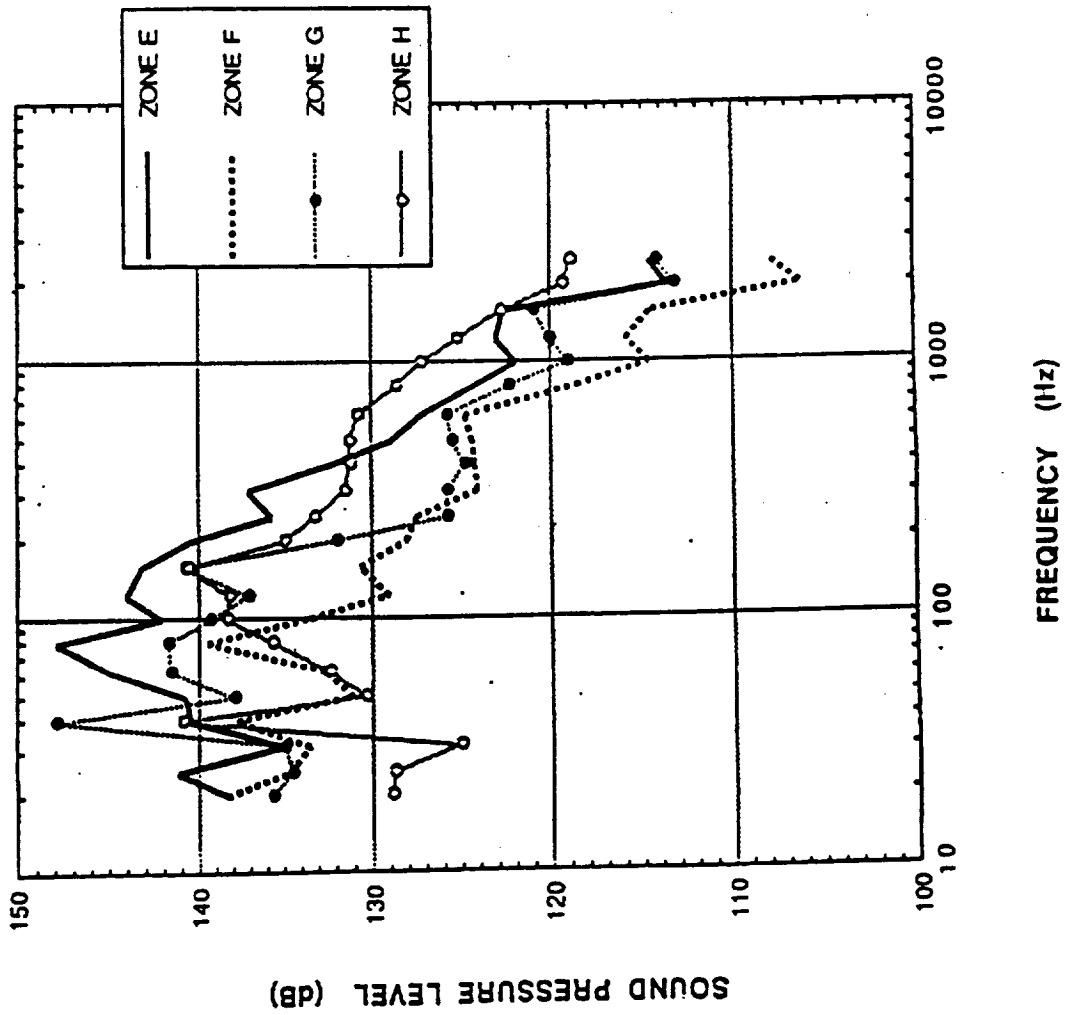
ACOUSTIC ANALYSIS FOR NLS

Comparison of Internal Acoustic Levels for Zone D
With Titan IV and Orbiter Payload Requirements
(ENVELOPE OF L/O & MAX AERO)



ACOUSTIC ANALYSIS FOR NLS

SUMMARY OF INTERNAL LEVELS FOR HLLV
(MAX OF L/O AND AERO), DOWNSTAGE ZONES

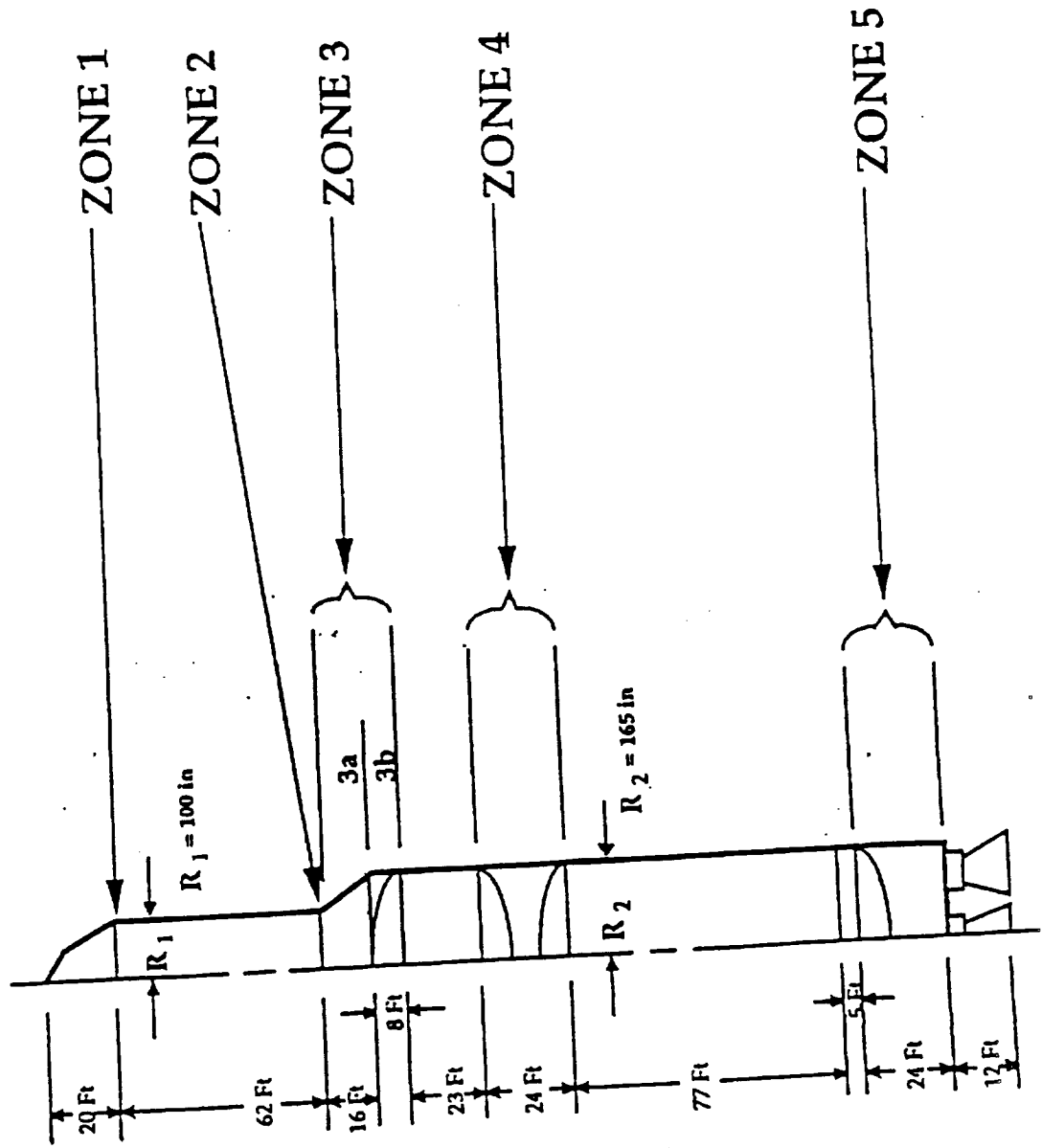


YG No. 15

11
12

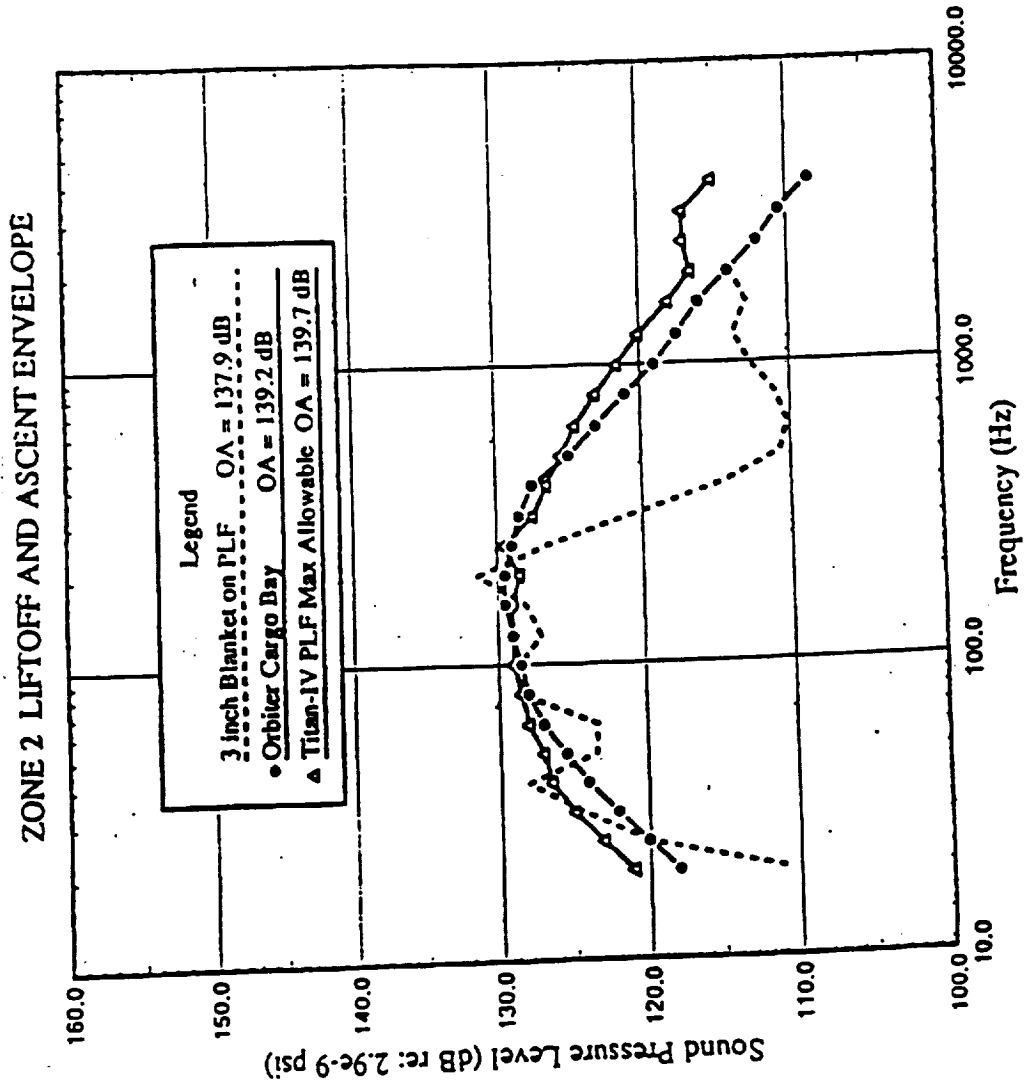
ACOUSTIC ANALYSIS FOR NLS

NLS 1.5-Stage Acoustic Prediction Zones



ACOUSTIC ANALYSIS FOR 1-5

REQUIREMENT COMPARISON FOR ZONE 2



3-FM-003 NLS Acoustics

Summary/ Conclusions

NLS 1 - HLLV

- **Liftoff Data Base Used Mostly Resembles HLLV Configuration**
- **STS Noise Reduction Significantly Greater than Titan IV Fairing**
- **3 in Blankets in PLF Adequate for Ascent Conditions**
- **Liftoff Condition Indicates STS ICD Exceedence 5 dB**

NLS 2 - 1.5 Stage

- **Levels Reduced from HLLV**
- **No Defined Payload Requirement for Configuration**

3-FM-003 NLS Acoustics

Recommendations

- **Assess Dispersed Trajectory Conditions and Impact of Engine Thrust Level Increase**
- **Evaluate the Component Levels on NLS and Compare to STS/ET Hardware**
- **Perform PLF (Blanket) Trade Study to Optimize Noise Attenuation Capability to Meet STS Levels**
- **Reassess Analytically the Predictions Based on Recent Titan IV Flight Data (More Microphone Data)**
- **Perform Subscale Acoustic Test to Improve Confidence in External Levels and Define Pad Requirements**

3-FM-003 Acoustics Analysis

Attachment 2

**Interoffice Memo 5486/CB-91-526
Final Report on NLS Acoustic Study**

Interoffice Memo

MARTIN MARIETTA


5486/CB-91-526
20 December 1991

To: R. Harris
cc: D. Rich, R. Hruda, B. Lowe, R. Foss
From: S. Barrett Ext: 7-9045 MS: L-5505 Fax: 1-2599
Subject: FINAL REPORT ON NLS ACOUSTIC STUDY

The attached report describes the acoustic study that was conducted by the Environmental & Subsystem Dynamics Group over the period 1 September to 20 December 1991 in support of the NLS contract which Martin Marietta Manned Space Systems is performing for NASA/MSFC.

Two launch vehicle configurations were addressed during the study -- the Heavy Lift Launch Vehicle (HLLV) and the 1.5 Stage Launch Vehicle (1.5 LV). External and internal acoustic environments were predicted during liftoff and ascent at appropriate locations on both vehicles. The results were compared with allowable acoustic environments which have been specified for Titan IV and the Space Shuttle. Methods of mitigating the environments were discussed and several areas for further study were suggested.

Please address any questions or comments to the undersigned.



S. Barrett, Unit Head
Environmental & Subsystem Dynamics
Space Launch Systems.

FINAL REPORT

PREDICTED ACOUSTIC ENVIRONMENTS FOR THE NLS
HEAVY LIFT LAUNCH VEHICLE AND 1.5 STAGE LAUNCH VEHICLE

PREPARED BY:

 FOR
R. B. LOWE, STAFF ENGINEER


R. L. FOSS, SENIOR ENGINEER


S. BARRETT, UNIT HEAD

ENVIRONMENTAL & SUBSYSTEM DYNAMICS
SPACE LAUNCH SYSTEMS

20 DECEMBER 1991

MARTIN MARIETTA ASTRONAUTICS GROUP
P.O. BOX 179
DENVER, COLORADO 80201

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SUMMARY

An acoustic study was performed for two candidate NLS launch vehicle configurations, referred to as the Heavy Lift Launch Vehicle (HLLV) and the 1.5 Stage Launch Vehicle (1.5 LV). External and internal acoustic environments were predicted at selected stations for both configurations and presented in the form of one-third octave band Sound Pressure Level spectra. The predictions were made by extrapolating data obtained from previous launch vehicles -- primarily those associated with the Titan, Space Shuttle and Apollo programs. Adjustments were made for differences in engine power, physical size, structural configuration and launch trajectories.

Two flight phases were addressed; the first occurrence of severe acoustics immediately following liftoff, then the later aeroacoustic phase in which high levels of fluctuating pressure are generated during the transonic and maximum dynamic pressure periods of flight. In the absence of any definition of payload sizes, the internal predictions for the payload fairings (PLF) were calculated only for the empty configuration.

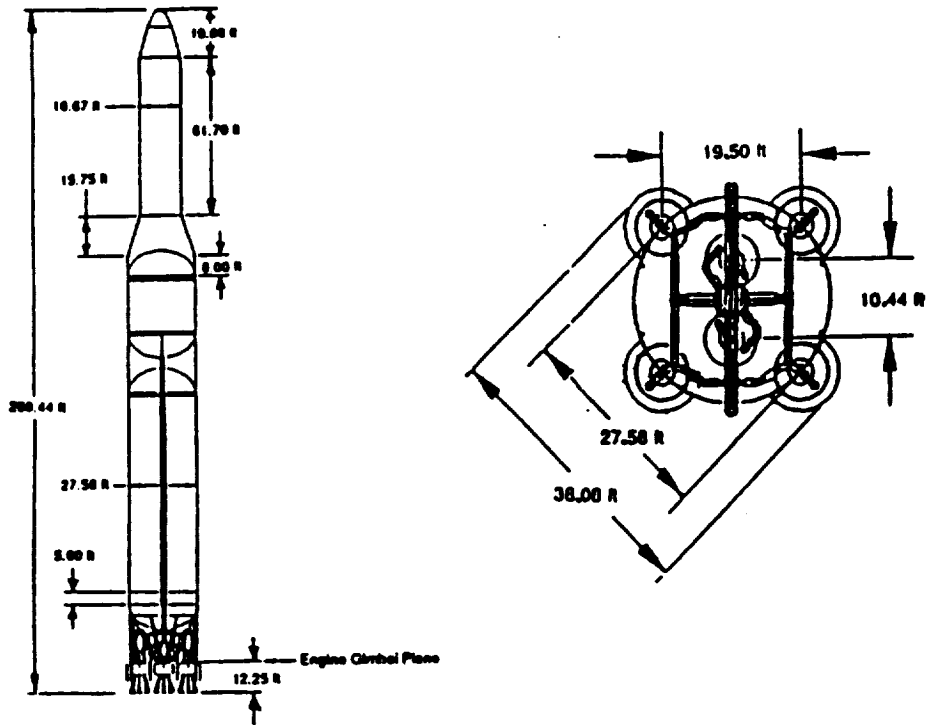
When the calculated PLF internal acoustic levels were compared with the specified allowable empty fairing levels for the Titan IV and the Space Shuttle, severe exceedances were found across wide frequency ranges, showing that steps would have to be taken to reduce the noise levels. As an example of a partial solution, the effects of applying standard Titan acoustic blankets (three inches thick) inside the PLF were investigated. This treatment significantly reduced the high frequency part of the problem but did little to help the lower frequencies. It was concluded that the low frequency problem could best be reduced by adding a dense acoustic barrier inside the fairing. This would require some further detailed analysis before the optimum barrier could be selected.

1.0 INTRODUCTION

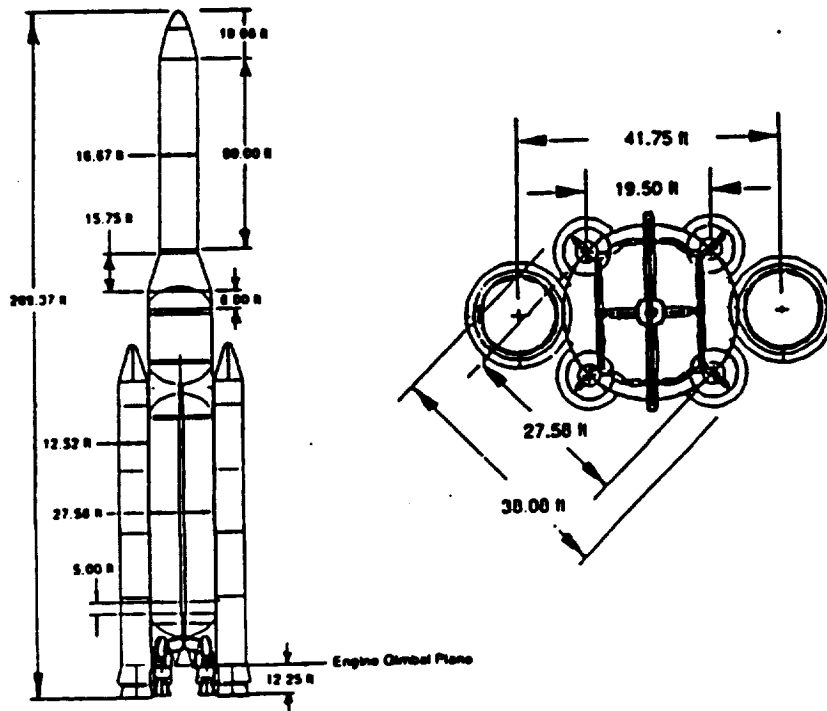
This study was performed by the Environmental & Subsystem Dynamics Group, which is part of the SLS Loads and Dynamics Department, in response to a request for technical support from Martin Marietta Manned Space Systems in New Orleans, Louisiana. The objectives of the study were to perform acoustic analyses in support of various National Launch System (NLS) trade studies being conducted by MMSS under contract to the NASA/Marshal Space Flight Center.

Specifically, we were to establish the distribution of Sound Pressure Level (SPL) along the external surface of two candidate NLS vehicles, during liftoff and then during ascent through the atmosphere. The two launch vehicles are referred to as the Heavy Lift Launch Vehicle (HLLV) and the 1.5 Stage Launch Vehicle (1.5 LV); see Figure 1.1. After calculating the noise reduction properties associated with the launch vehicles, we were then required to predict the SPL which would occur inside the payload fairings and inside various core stage locations such as intertank compartments, forward and aft skirts and propulsion modules. An overview of the sequential steps followed in the prediction process for liftoff and ascent is provided in Figures 1.2 and 1.3

The purpose of this report is to describe the analytical methods used, in appropriate detail, to document and discuss the results of the study, and to provide convenient access to the data base that was used in the development of the estimates.



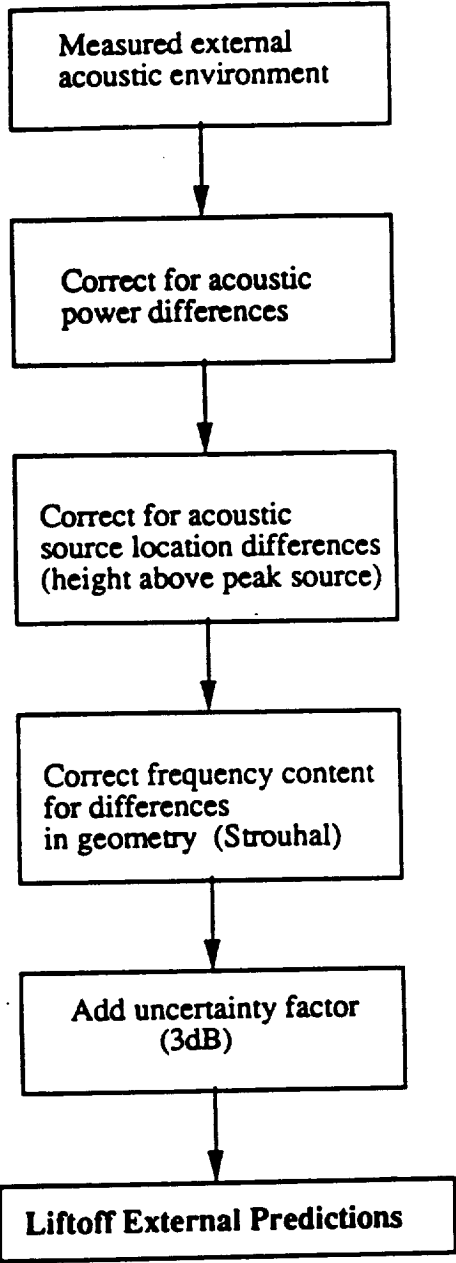
a) 1.5 Stage Launch Vehicle



b) Heavy-Lift Launch Vehicle

Figure 1.1 NLS Launch Vehicle Configurations

Liftoff External Predictions



Liftoff Internal Predictions

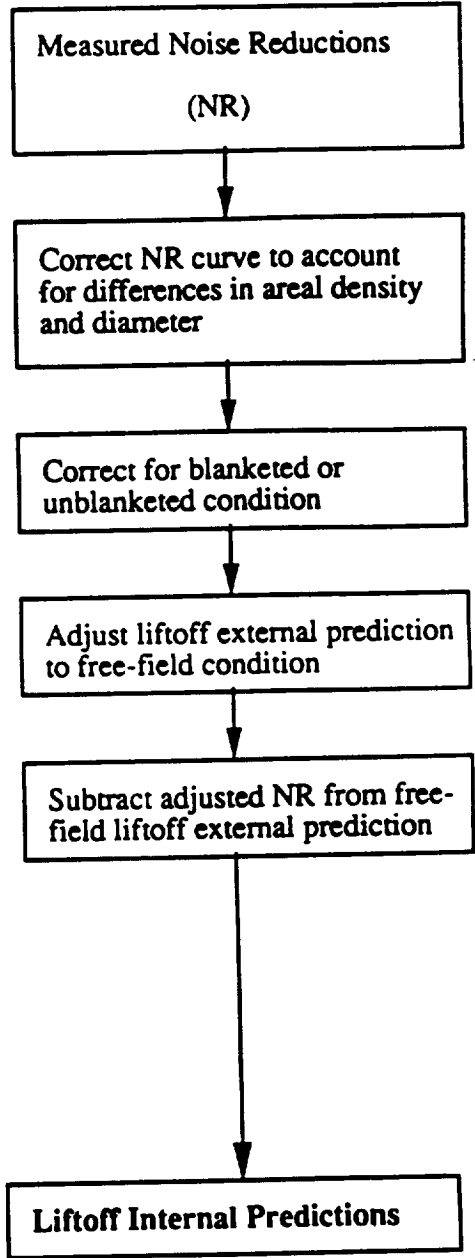


Figure 1.2
Liftoff Prediction Sequence

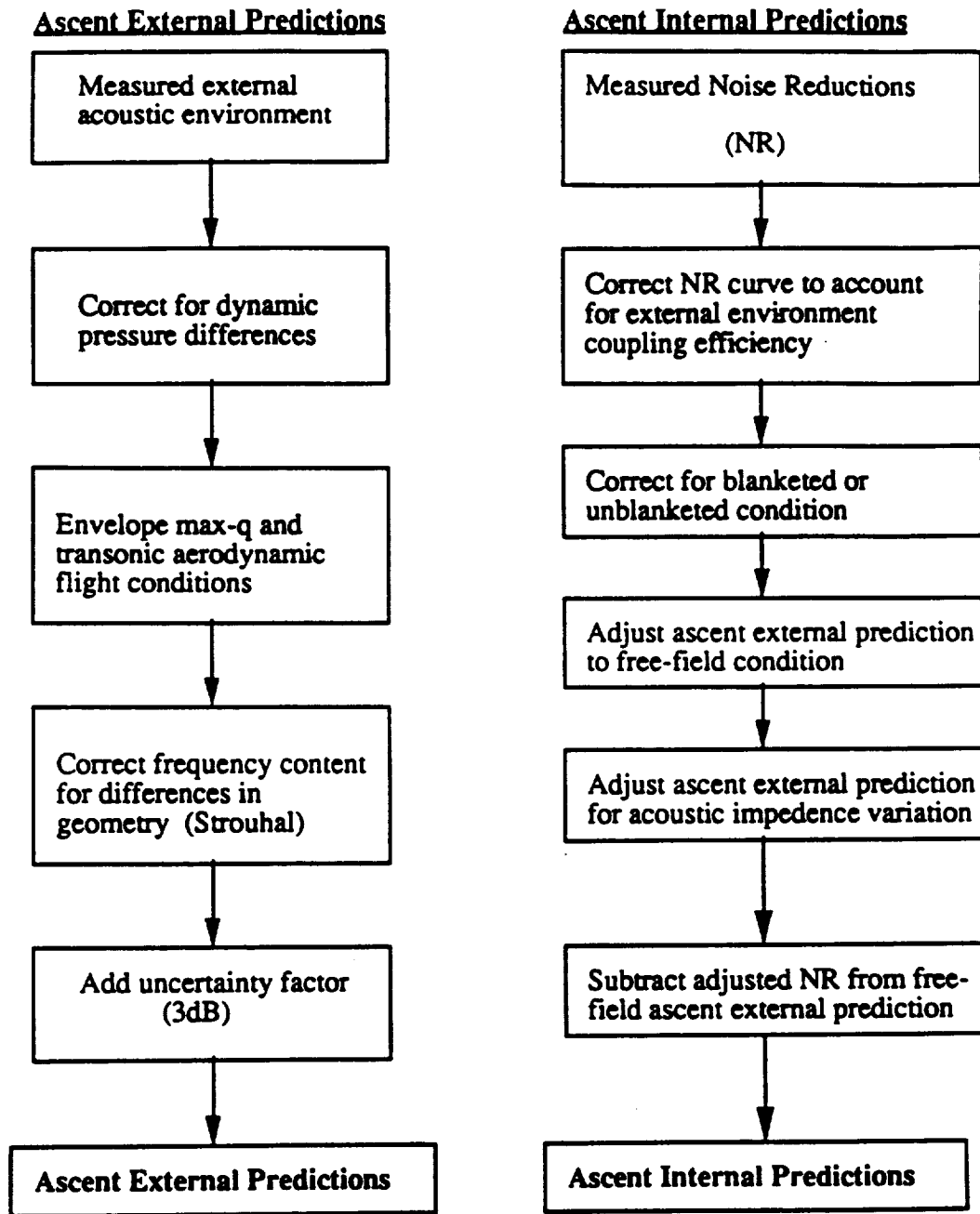


Figure 1.3
Ascent Prediction Sequence

2.0 HLLV PREDICTIONS

The acoustic predictions for HLLV were made for a number of zones along the vehicle, selected at the areas of primary interest. The zones are defined in Figure 2.1.

2.1 External Environment During Liftoff

2.1.1 Method of Analysis

The predictions of the external environment for the liftoff phase were derived by extrapolating data obtained from ground and flight tests on earlier programs. Much of the basic information for this phase was taken from STS ground and flight data, because of the similarity in engine configuration between the STS vehicle and the HLLV; see Reference 1, 2 and 3. In addition, data from the Titan programs was used where applicable. After the basic predictions were established, an uncertainty factor of 3 dB was added to the results.

Three scaling parameters were used, as follows:

(i) acoustic power, which is proportional to the mechanical power produced by the liftoff engines and therefore to the product of engine thrust and exhaust velocity. This was used to scale the overall sound pressure level (OASPL).

(ii) acoustic source location, which was derived from subscale STS model engine firings. This was used to calculate the variation in OASPL as a function of vehicle zone.

(iii) Strouhal number. This parameter allowed the frequency content of the calculated spectrum to be adjusted to account for differences in nozzle diameter and exhaust velocity.

The application of the parametric scaling will now be discussed in more detail.

(i) The acoustic power correction factor (APCF) was calculated from the ratio of the engine properties of the baseline vehicle (the SSME's and SRB's on STS--Reference 2) to the HLLV:

$$\text{APCF (dB)} = 10 \text{ Log}_{10} \frac{2 \times T_{\text{ASRB}} \times V_{\text{ASRB}}^4 \times T_{\text{STME}} \times V_{\text{STME}}}{2 \times T_{\text{SRB}} \times V_{\text{SRB}} + 3 \times T_{\text{SSME}} \times V_{\text{SSME}}}$$

where T = thrust = 14,680,000 N for the ASRB; 11,800,000 N for the SRB; 2,593,000 N for the STME and 1,780,000 N for the SSME, and V = exhaust velocity = 2673 m/s for ASRB; 2500 m/s for the SRB; 4247 m/s for the STME and 3250 m/s for the SSME.

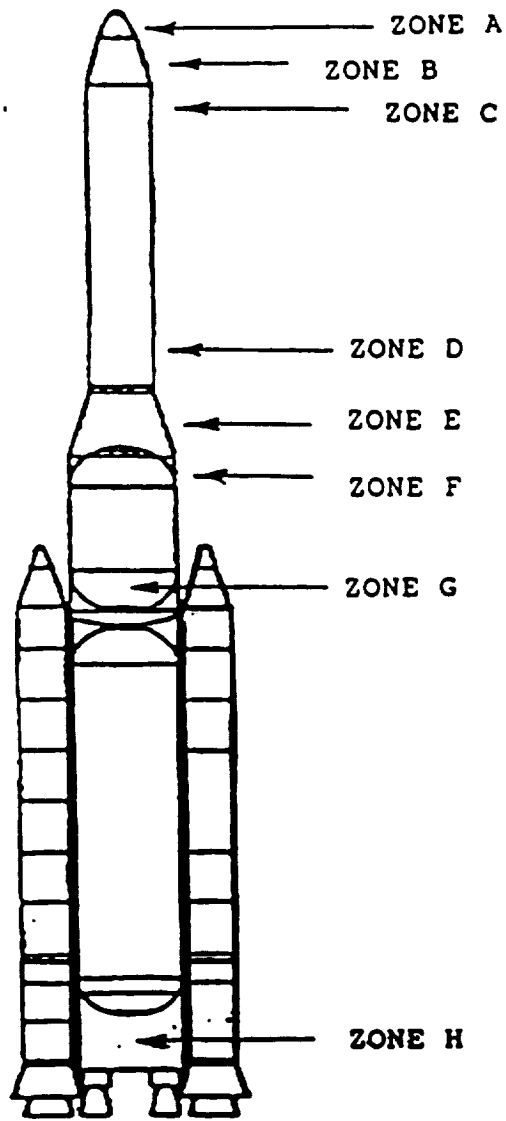


Figure 2.1 Definition of Acoustic Zones for HLLV

(ii) In the calculation of the source location correction, results obtained from a launch simulation test performed on a 6.4% scale model of the STS (References 1 and 3) were used. SPL spectra were measured at a fixed location on the Orbiter as the vehicle was moved up away from the pad. The scaled height above the pad which gave the highest spectral value, regardless of frequency, was defined to represent the worst case source location for the STS; this was called R(STS).

The effective source location for the HLLV was estimated by considering the mixing pattern of exhaust plumes from the four STME's and the two ASRB's. Two equations from the literature (Reference 3) were used to bound the estimate of the supersonic core length, as follows:

$$L_0 = D_e [1.2 + 3.65M_e]$$

and
$$L_0 = 3.45D_e [1 + 0.38M_e]^2$$

--where L_0 is laminar flow core length, D_e is exit diameter and M_e is Mach number at the exit plane.

An assumed 12 degree plume growth was used to determine the downstream distance at which the plumes might intersect, relative to the above calculated core lengths and the elevation where maximum acoustics was measured, assuming no cant angle. Indications were that the STME plumes will intersect but the ASRB plumes probably will not intersect within the elevation at which maximum acoustics is experienced on the vehicle.

The distance from the source to the zone of interest was called R(NLS).

The source location correction factor is given by

$$SLCF \text{ (dB)} = 20 \log_{10}(R(NLS)/R(STS))$$

This correction was added to the baseline OASPL scaled from the STS data. The process was repeated for each NLS zone.

(iii) The frequency correction was calculated on the basis of maintaining a constant Strouhal number, $SN = f \times D/V$:

$$\text{ie., } (f \times D/V)_{HLLV} = (f \times D/V)_{STS}$$

--where f = frequency in Hz
 D = Effective nozzle diameter
 and V = Effective exhaust velocity

The concept of "effective" values must be used because each vehicle has two different sets of nozzles, operating simultaneously. Effective nozzle diameter and exhaust velocity were calculated for the two cases on the basis of geometry and power. Since the STME's are all equal in power, the correction applied increased the Strouhal diameter by the square root of the number (4) of STME engines. These were then combined, based on their contribution to the overall sound power level (OAPWL) and compared with the STS combined SSME and SRB power.

2.1.2 Numerical Correction Factors

The following numerical correction factors were calculated by the processes described in the previous section.

(i) Calculation of Acoustic Power Correction Factor:

$$\text{APCF} = 10 \log_{10} \frac{2 \times 14.68\text{E}06 \times 2763 + 4 \times 2.593\text{E}06 \times 4247}{2 \times 11.8\text{E}06 \times 2500 + 3 \times 1.78\text{E}06 \times 3250}$$

$$= 2.1 \text{ dB.}$$

(ii) Calculation of Strouhal parameter:

$$\begin{aligned} \text{SN}(\text{STME})/f &= D_e(\text{STME})/V(\text{STME}) = [4]^{1/2} D(\text{STME})/V(\text{STME}) \\ &= 2 \times 2.21/4247 \\ &= 0.00104 \end{aligned}$$

$$\begin{aligned} \text{SN}(\text{ASRB})/f &= D(\text{ASRB})/V(\text{ASRB}) \\ &= 3.78/2673 \\ &= 0.00141 \end{aligned}$$

$$\begin{aligned} \text{SN}(\text{SSME})/f &= D_e(\text{SSME})/V(\text{SSME}) = [3]^{1/2} D(\text{SSME})/V(\text{SSME}) \\ &= 1.73 \times 2.39/3250 \\ &= 0.001274 \end{aligned}$$

$$\begin{aligned} \text{SN}(\text{SRB})/f &= D(\text{SRB})/V(\text{SRB}) \\ &= 3.77/2500 \\ &= 0.00151 \end{aligned}$$

(iii) Calculation of mechanical power ratio:

$$P(\text{ASRB})/P(\text{TOT}) = 3.9\text{E}10/6.1\text{E}10 = 0.64$$

$$P(\text{SRB})/P(\text{TOT}) = 2.95\text{E}10/3.8\text{E}10 = 0.78$$

(iv) Calculation of equivalent nozzle exit diameter:

$$D_e(\text{STS}) = [0.78 \times 3.77^2 + 0.22 \times 4.14^2]^{1/2} = 3.85 \text{ m}$$

$$D_e(\text{HLLV}) = [[0.64 \times 3.78^2 + 0.36 \times 4.42^2]^{1/2} = 4.02$$

$$V_e(\text{STS}) = 0.78 \times 2500 + 0.22 \times 3250 = 2665 \text{ m/s}$$

$$V_e(\text{HLLV}) = 0.64 \times 2673 + 0.36 \times 4247 = 3248 \text{ m/s}$$

(v) Calculation of Strouhal parameter:

$$\text{SN}(\text{STS})/f = 3.85/2665 = 0.00145$$

$$\text{SN}(\text{HLLV})/f = 4.02/3240 = 0.00124$$

(vi) Calculation of frequency shifts

Under the assumption that Strouhal number is constant,

$$\text{SN}(\text{HLLV}) = \text{SN}(\text{STS})$$

$$\begin{aligned} \text{--therefore} \quad \frac{f(\text{HLLV}) \times D(\text{HLLV})}{V(\text{HLLV})} &= \frac{f(\text{STS}) \times D(\text{STS})}{V(\text{STS})} \\ \frac{f(\text{HLLV})}{f(\text{STS})} &= \frac{D(\text{STS}) \times V(\text{HLLV})}{D(\text{HLLV}) \times V(\text{STS})} \\ &= 0.00145/0.00124 \\ &= 1.17 \end{aligned}$$

This is greater than 1/6 octave band but less than 1/3 octave band. A similar calculation which assumed that SSME's and STME's do not combine led to a frequency shift of approximately 1/6 octave band; therefore it was concluded that a shift of 1/3 octave band was appropriate and this was applied to the data.

2.1.3 Results

Using the method and corrections described above, external spectra for various zones on the HLLV were calculated and plotted. The spectra are shown in Figures 2.2 through 2.7, for Zones C, D, E, F, G and H; refer to Figure 2.1 for a definition of the zones. It was assumed that the spectrum shape will be constant along the exterior of the payload fairing. The variation in overall SPL is given in Figure 2.8.

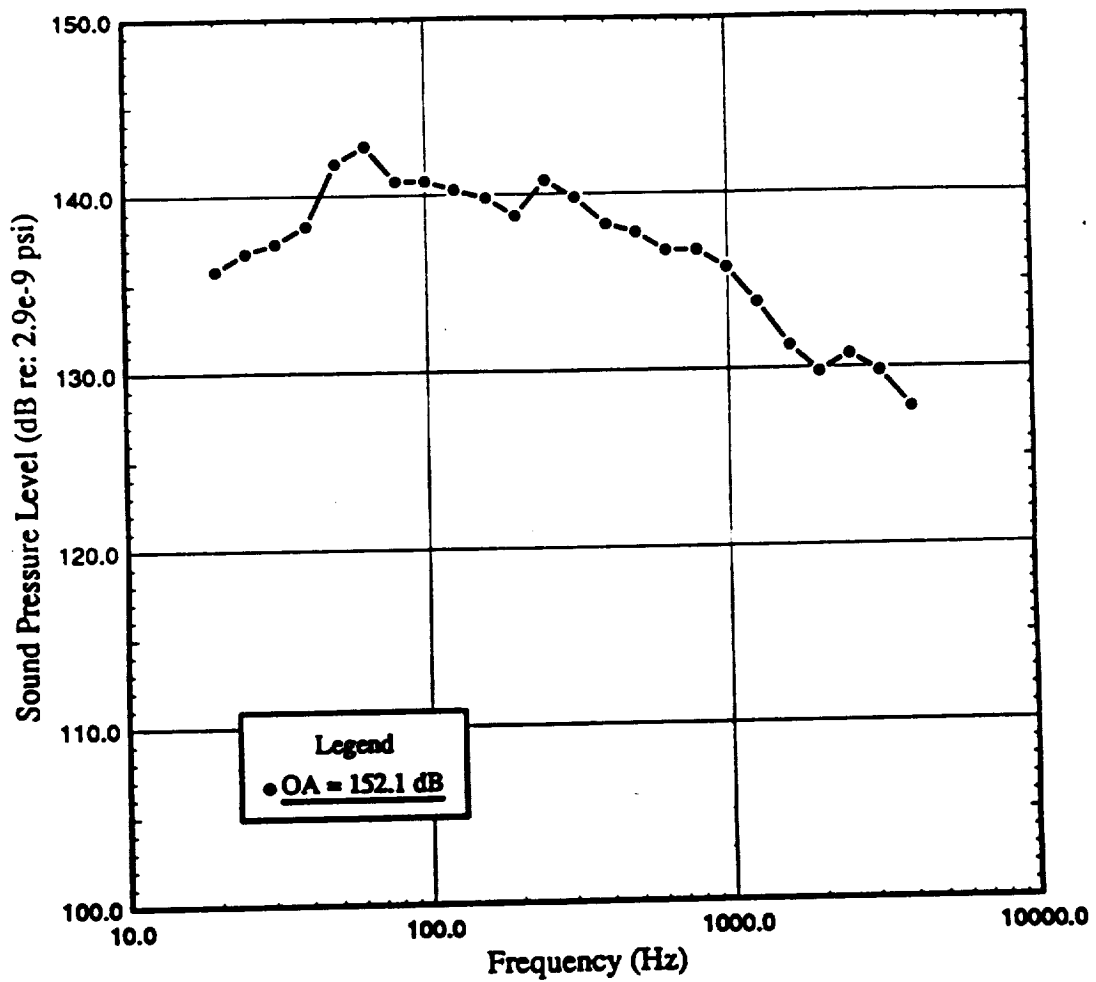


Figure 2.2

HLLV Liftoff Zone C External Acoustic Levels

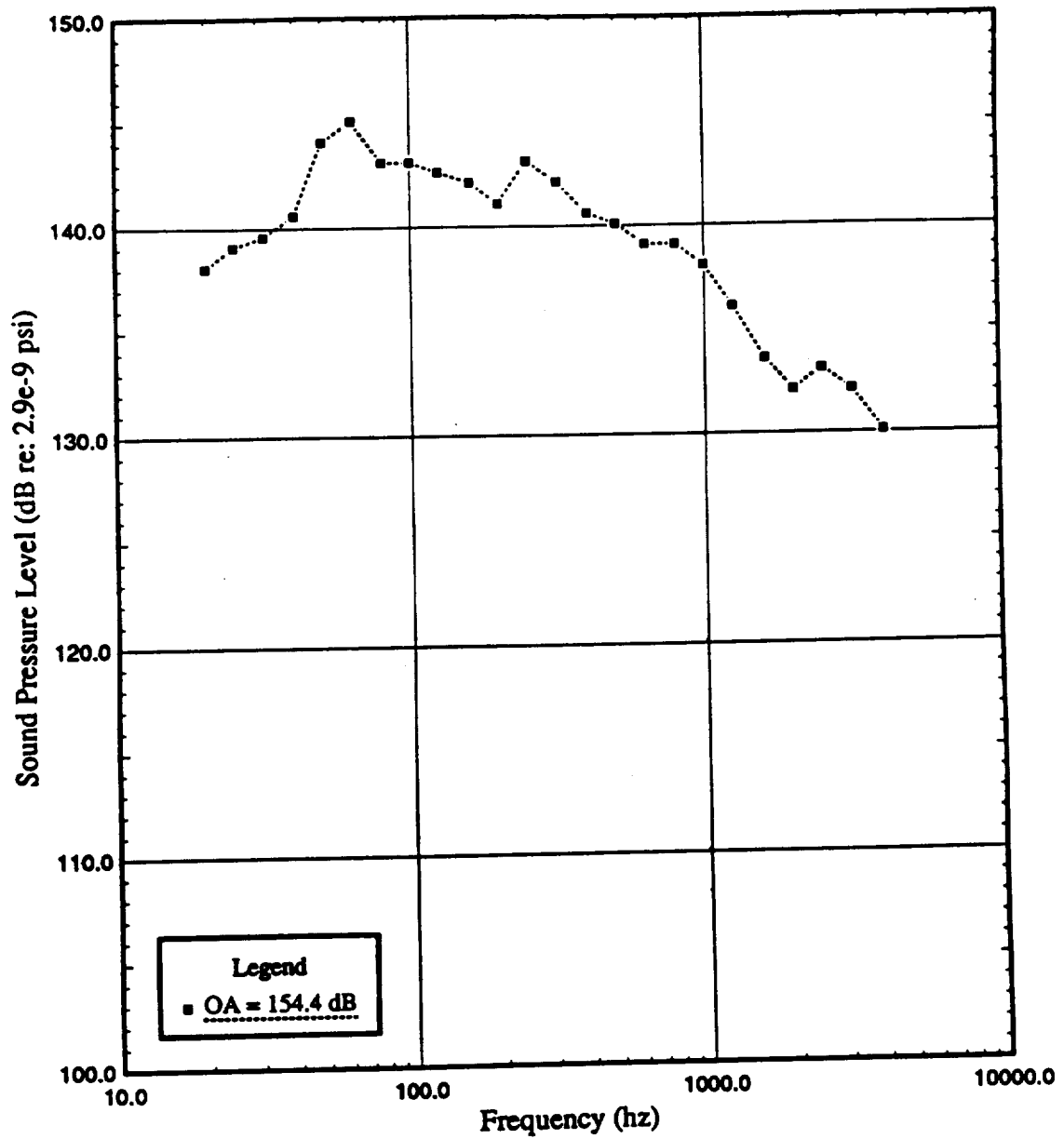


Figure 2.3

HLLV Liftoff Zone D External Surface Acoustic Levels

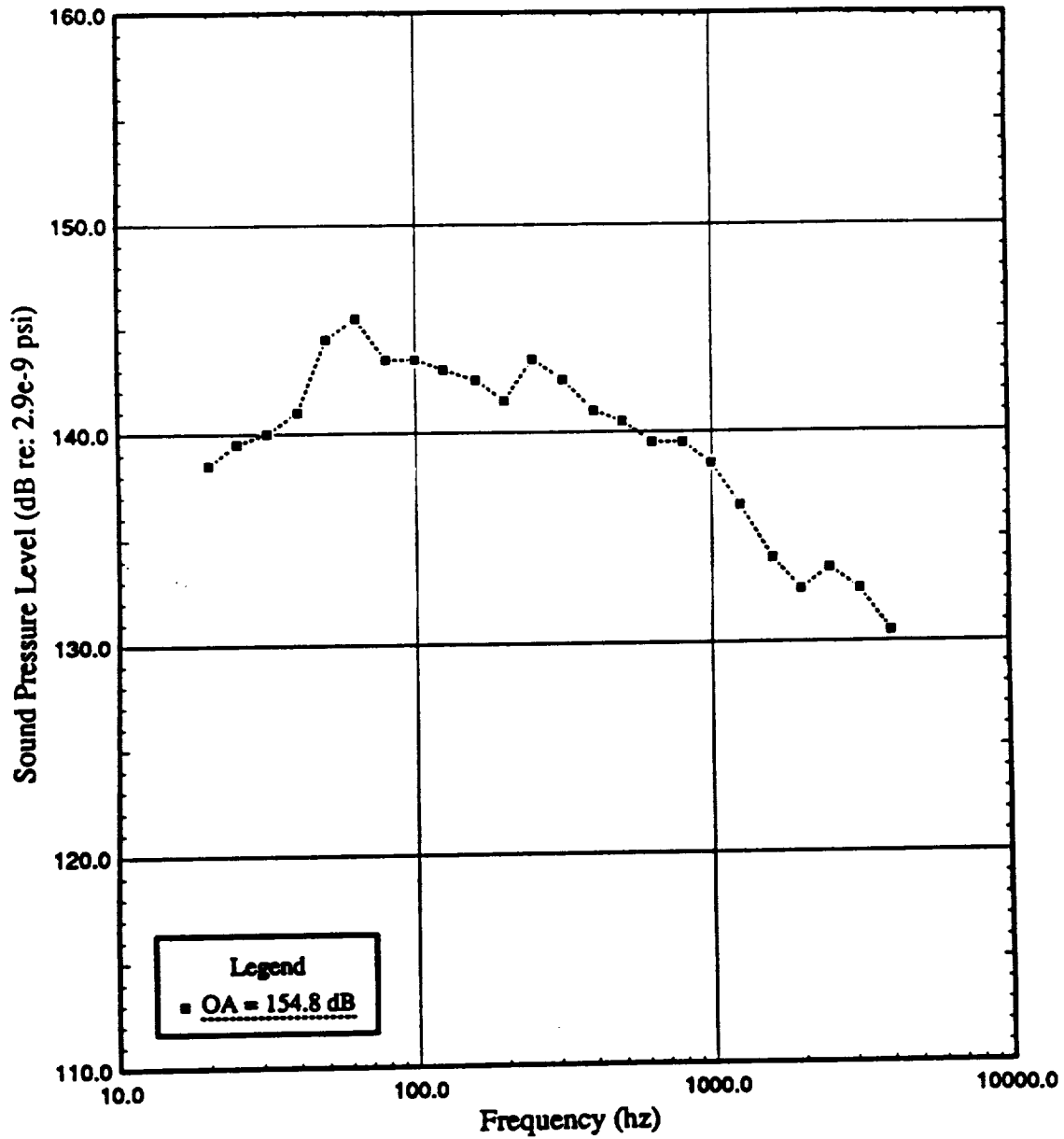


Figure 2.4

HLLV Liftoff Zone E External Surface Acoustic Levels

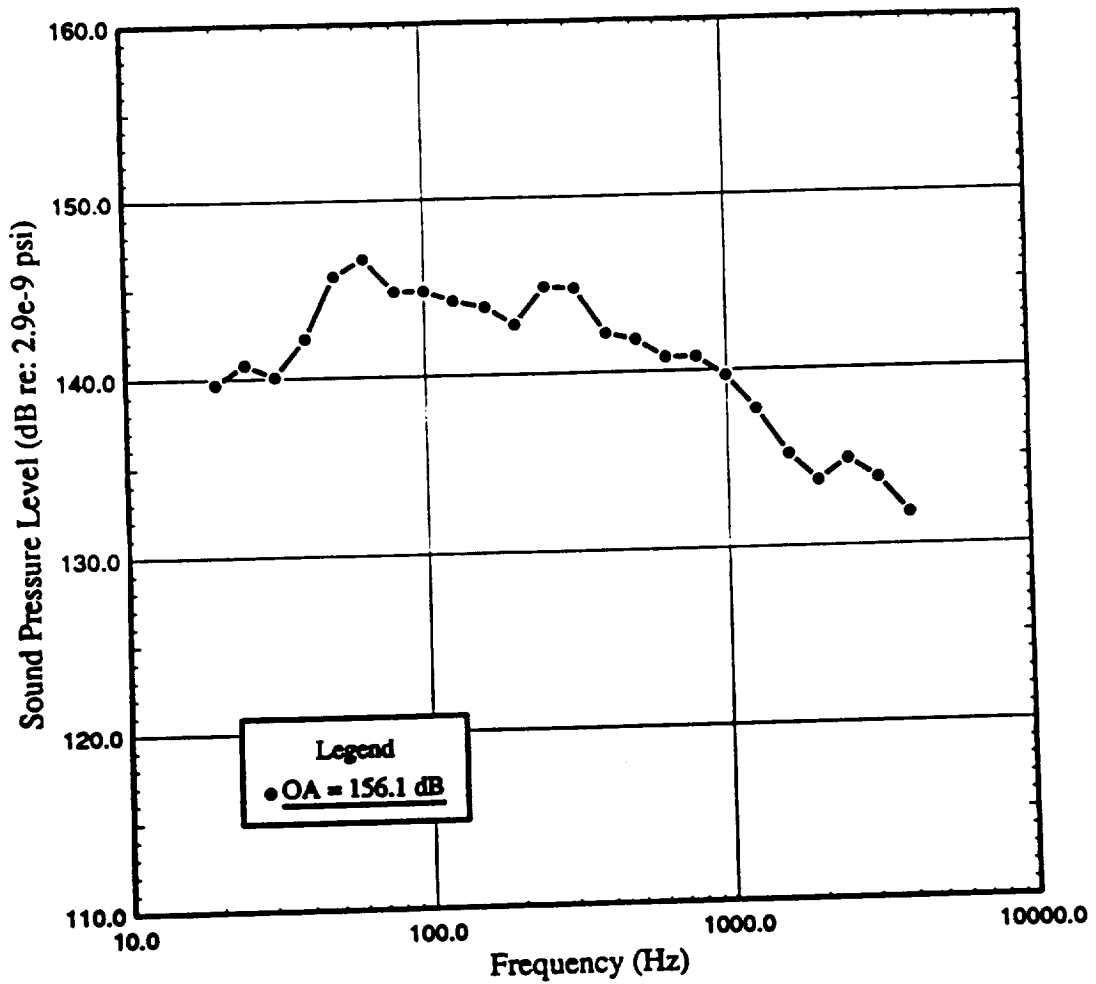


Figure 2.5

HLLV Liftoff Zone F External Acoustic Levels

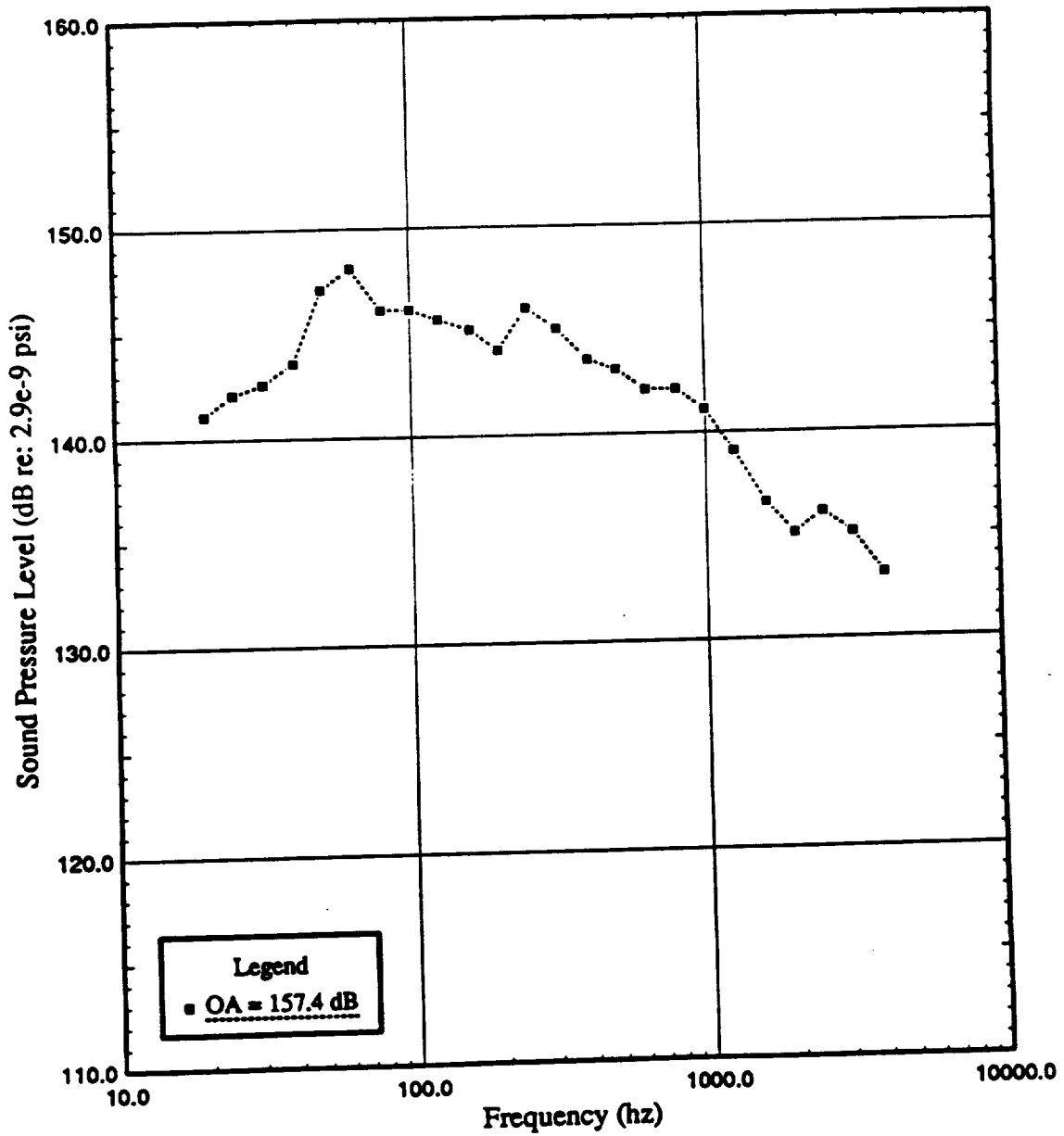


Figure 2.6

HLLV Liftoff Zone G External Surface Acoustic Levels

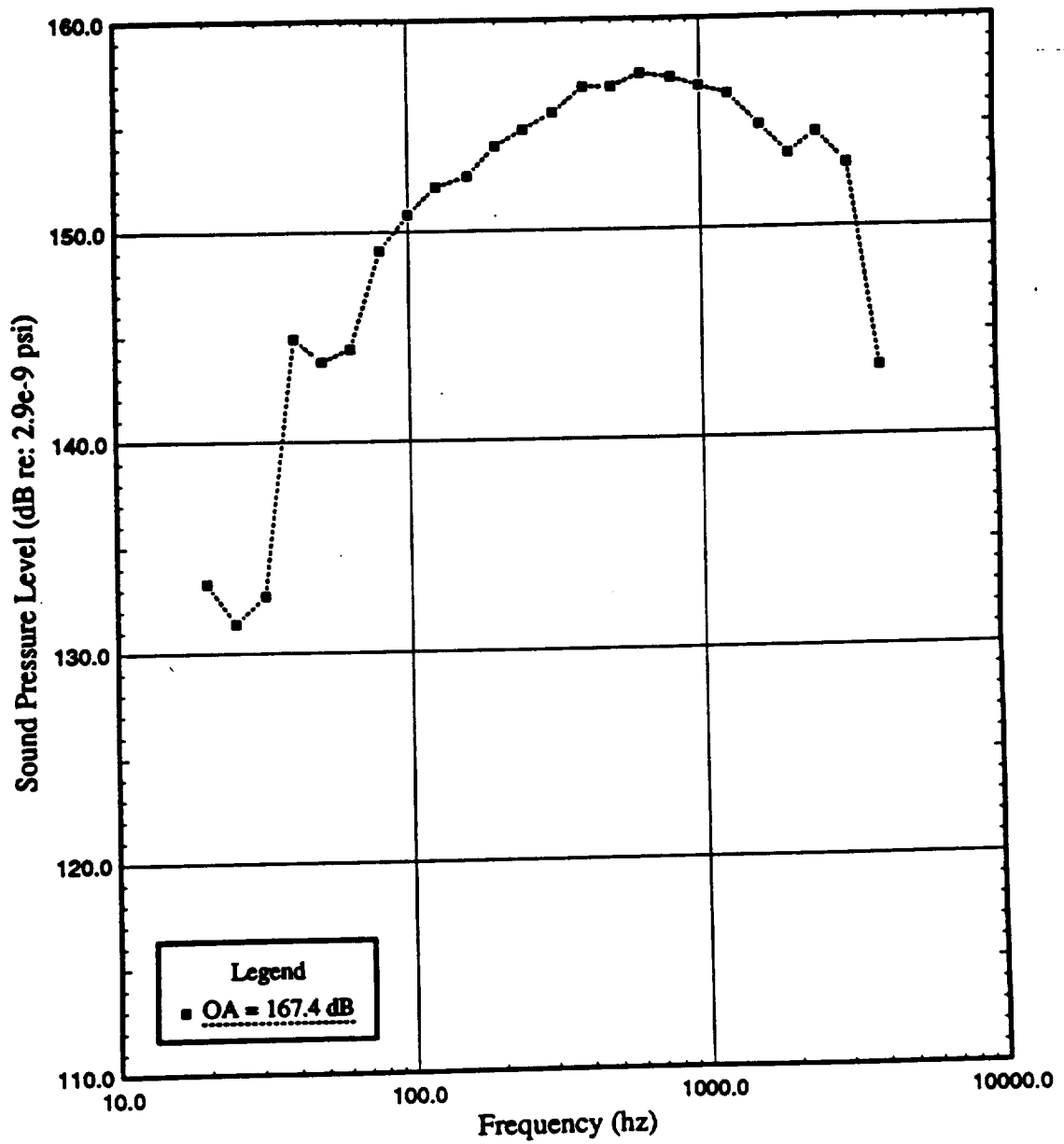
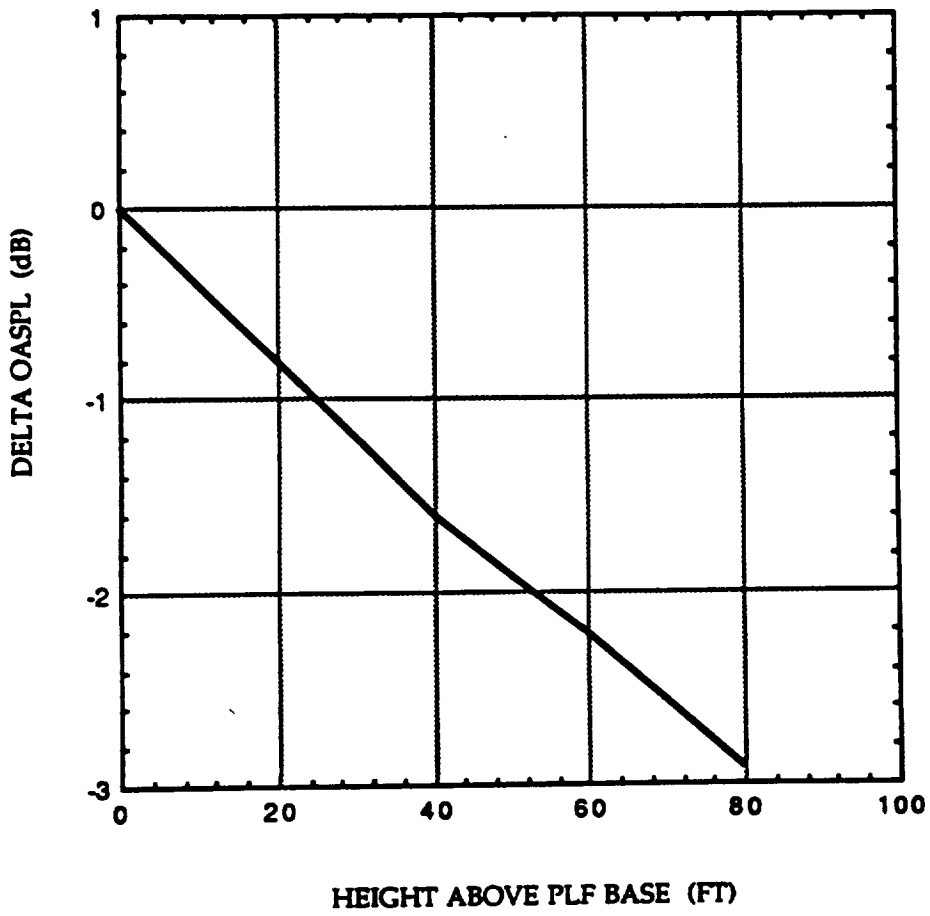


Figure 2.7

HLLV Liftoff Zone H External Surface Acoustic Levels

Figure 2.8

Variation of External Ltoff Level Along
the HLLV Payload Fairing.



2.2 Internal Environment During Liftoff

2.2.1 Method of Analysis

The first step in predicting the internal environment was to correct the external data from surface values, as measured, to free-field conditions, using the set of frequency-related corrections in Table 1. The internal spectrum was then calculated by subtracting the Noise Reduction (NR) curve for the protective structure. The NR curves for the payload fairing were developed by scaling acoustic data measured on the Titan 34D program (Reference 5), for the bare (no blanket) condition and on Titan IV (Reference 6) for the blanketed configuration. NR curves for the downstage structures were derived from Commercial Titan development testing that was performed at MMC in 1988 on a cylindrical skirt (Reference 7). The results were scaled on the basis of weight per unit area, which inversely affects the amplitude of the curve, and the diameter, which causes a shift in the ring frequency:

Ring frequency $f_R = [E/\rho]^{1/2}/\pi d_{cyl}$, so that

$$\frac{f_R(\text{HLLV})}{f_R(\text{CT})} = \frac{d_{cyl}(\text{CT})}{d_{cyl}(\text{HLLV})}$$

2.2.2 Numerical Correction Factors

Correction factors were calculated having the following values:

Density scaling factor (DSF) for the PLF adapter:

$$\begin{aligned} \text{DSF (dB)} &= 20 \text{ Log } (0.013773/0.013003) \\ &= +0.5 \text{ dB} \end{aligned}$$

Density scaling factor (DSF) for forward skirt:

$$\begin{aligned} \text{DSF (dB)} &= 20 \text{ Log}_{10} ([W/A]_{\text{NLS}} / [W/A]_{\text{TEST}}) \\ &= 20 \text{ Log } (0.013624/0.013003) \\ &= +0.4 \text{ dB} \end{aligned}$$

Density scaling factor for intertank:

$$\begin{aligned} \text{DSF (dB)} &= 20 \text{ Log } (0.023282/0.013003) \\ &= +5.0 \text{ dB} \end{aligned}$$

Density scaling factor for propulsion module aft skirt:

$$\begin{aligned} \text{DSF (dB)} &= 20 \text{ Log } (0.02648/0.013003) \\ &= +6.2 \text{ dB} \end{aligned}$$

Ring frequency shift for PLF adapter:

$$r_{\text{TEST}}/r_{\text{NLS}} = 69"/143" = 0.42$$

Frequency shift (in oct) = $\text{Log } 0.42 / \text{Log } 2 = -1.25$

To the nearest 1/3 octave this represents a downward shift of four 1/3 octave bands.

Ring frequency shift for forward skirt, intertank and aft skirt:

$$r_{\text{TEST}}/r_{\text{NLS}} = 60"/165" = 0.36$$

To the nearest 1/3 octave this represents a downward shift of five 1/3 octave bands.

2.2.3 Results

Using the corrections developed above, internal spectra at the HLLV zones of interest were calculated. The results were combined with the internal spectra calculated in the next two sections for the ascent phase of the mission, and plotted as worst-case envelopes. The spectra are presented in Section 2.4.3. as Figures 2.17 through 2.22.

2.3 External Environments During Ascent

2.3.1 Method of Analysis

For the ascent phase, the predictions were based on a combination of data sources. The basic approach was the same as that used for liftoff; appropriate flight and ground test data were collected and modified to allow for differences in the governing parameters.

Wherever possible, the Titan IV database was used, since it contains up-to-date information and it continues to be refined as more flights are accomplished. Also, the data acquisition and analysis techniques which are inherent in the Titan IV database are much superior to those used a few years ago. For the zones on the payload fairing, advantage was taken of a large body of wind-tunnel test data performed to support the Titan IIIC, IIIE and IV programs in 1988. These tests typically collected data from 24 acoustic transducers and covered Mach numbers ranging from 0.70 to 1.60, for various combinations of angle of attack and sideslip angle. The results were reported in detail in Reference 8.

The measured data was corrected for differences in maximum dynamic pressure (q_{max}), which directly scales the magnitude of the acoustic spectra, and for the frequency shift introduced by differences in external diameter, following the constant Strouhal number law.

2.3.2 Numerical Correction Factors

Scaling for dynamic pressure:

q_{\max} for T-IV = 936 psf (typical)

q_{\max} for HLLV = 806 psf,

--therefore, dynamic pressure correction factor is

$$\begin{aligned} \text{DPCF (dB)} &= 20 \text{ Log}_{10} (q_{\max}(\text{HLLV}) / q_{\max}(\text{T-IV})) \\ &= 20 \text{ Log } 806/936 = -1.3 \text{ dB.} \end{aligned}$$

Frequency correction:

The calculated correction shifted the frequency scale upward by two 1/3 octave bands.

2.3.3 Results.

Figures 2.9 through 2.16 give the predicted external environments during ascent. These were next used to calculate the internal environments.

2.4 Internal Environments During Ascent

2.4.1 Method of Analysis

After correcting the external estimates to correspond to free-field levels the internal environments were calculated by subtracting the appropriate noise reduction curves from the external spectra. The NR curves, which had been computed for liftoff conditions, were first adjusted for the differences in performance at high altitude. It is known that better noise reduction is realized from a payload fairing during aeroacoustics than during liftoff, especially in the lower frequencies (below 1000 Hz or so). The phenomenon is not fully understood, but it is related to the reduction in acoustic impedance (the product of air density and speed of sound) and the difference in the nature of the noise field, caused during aeroacoustics by fluctuating aerodynamic pressures which progress past the surface rather than the fairly stationary reverberant acoustic field characteristic of liftoff. In this study, an empirical correction was derived from a comparison of the effective NR (defined as External SPL minus Internal SPL) measured on Titan IV during liftoff versus the same quantity measured during the transonic/max q phase.

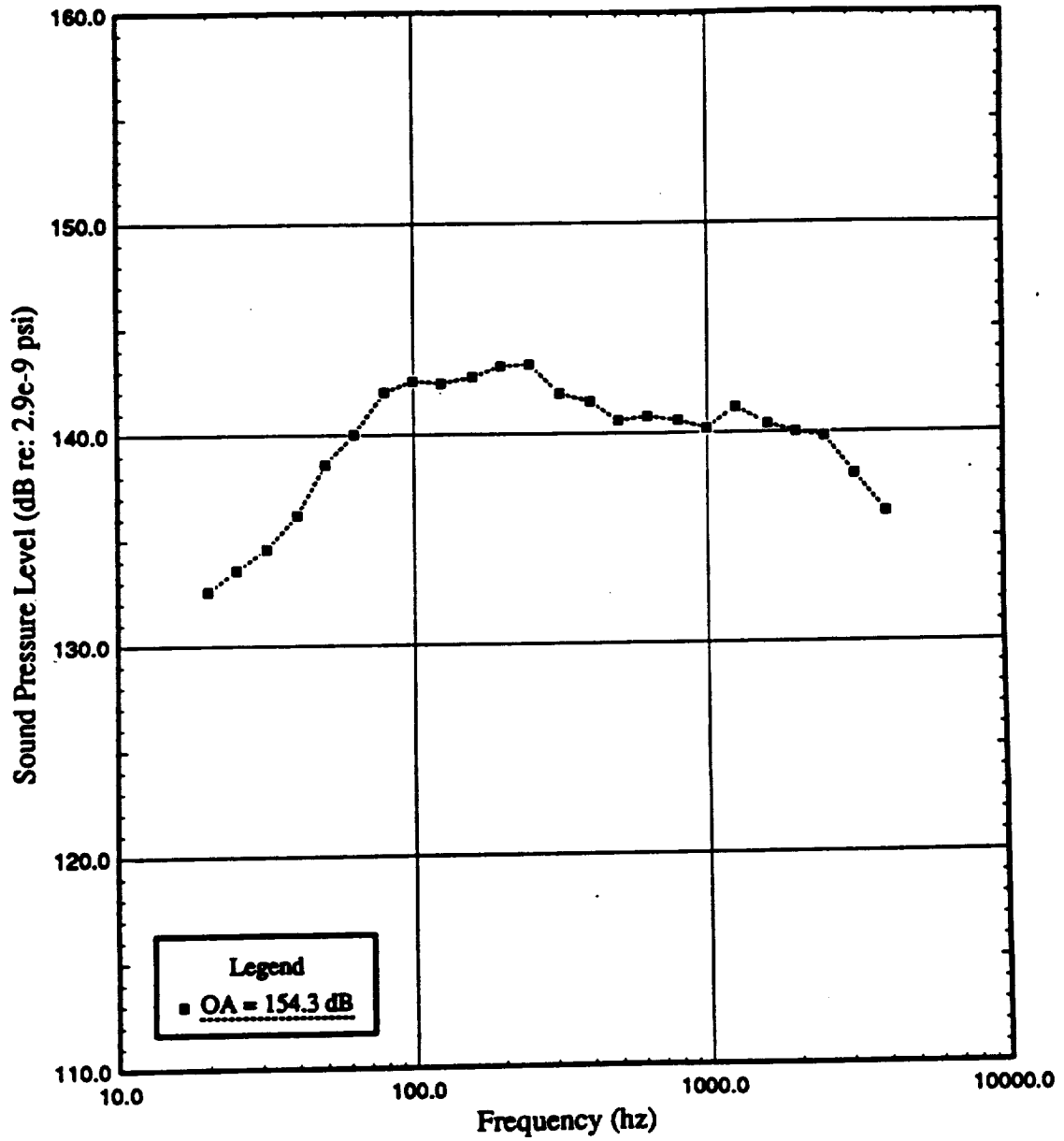


Figure 2.9

HLLV Zone A Max Aero Predicted External Surface Acoustic Levels

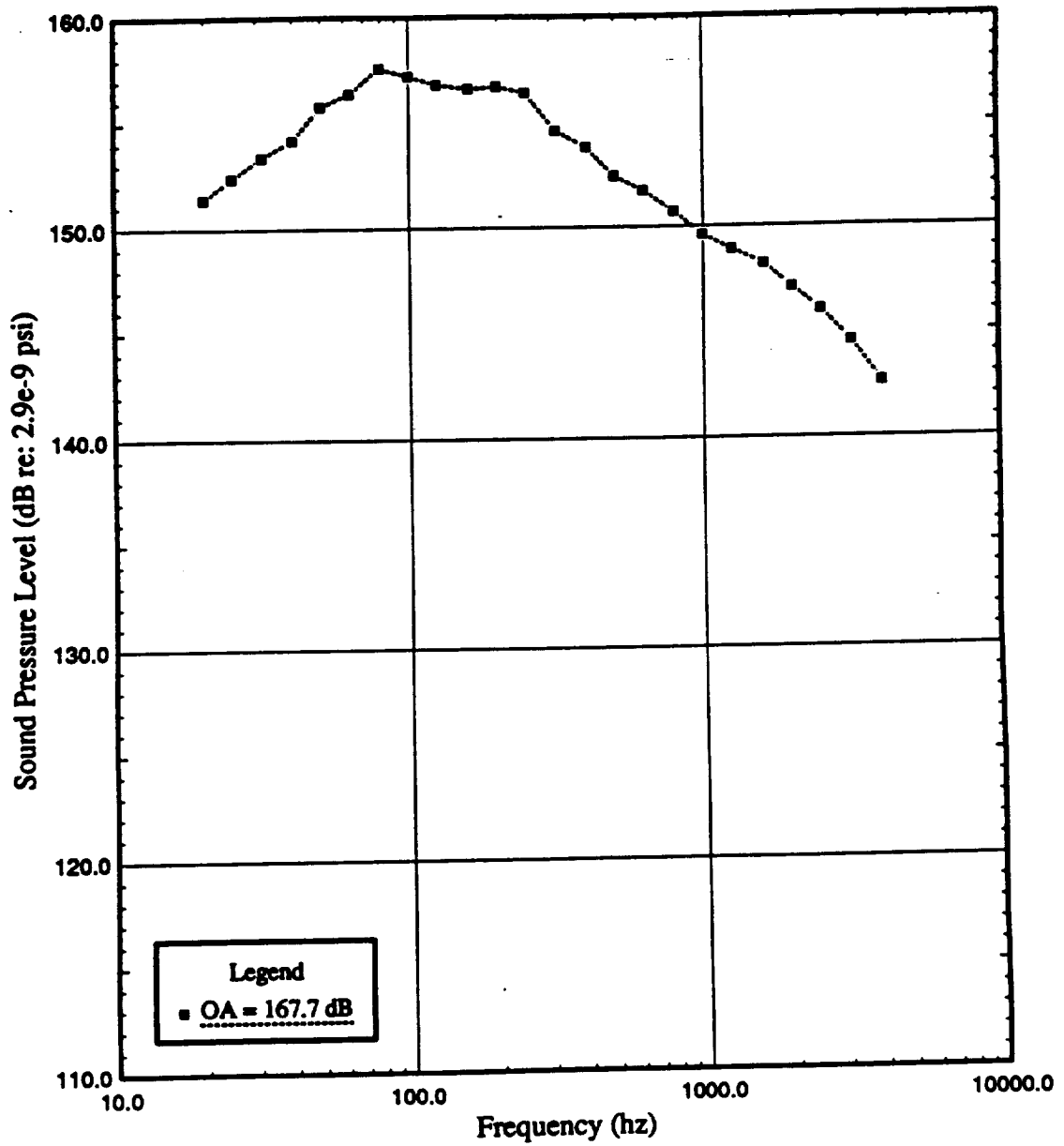


Figure 2.10

HLLV Zone B Max Aero Predicted External Surface Acoustic Levels

2000 5/ 10, 2000

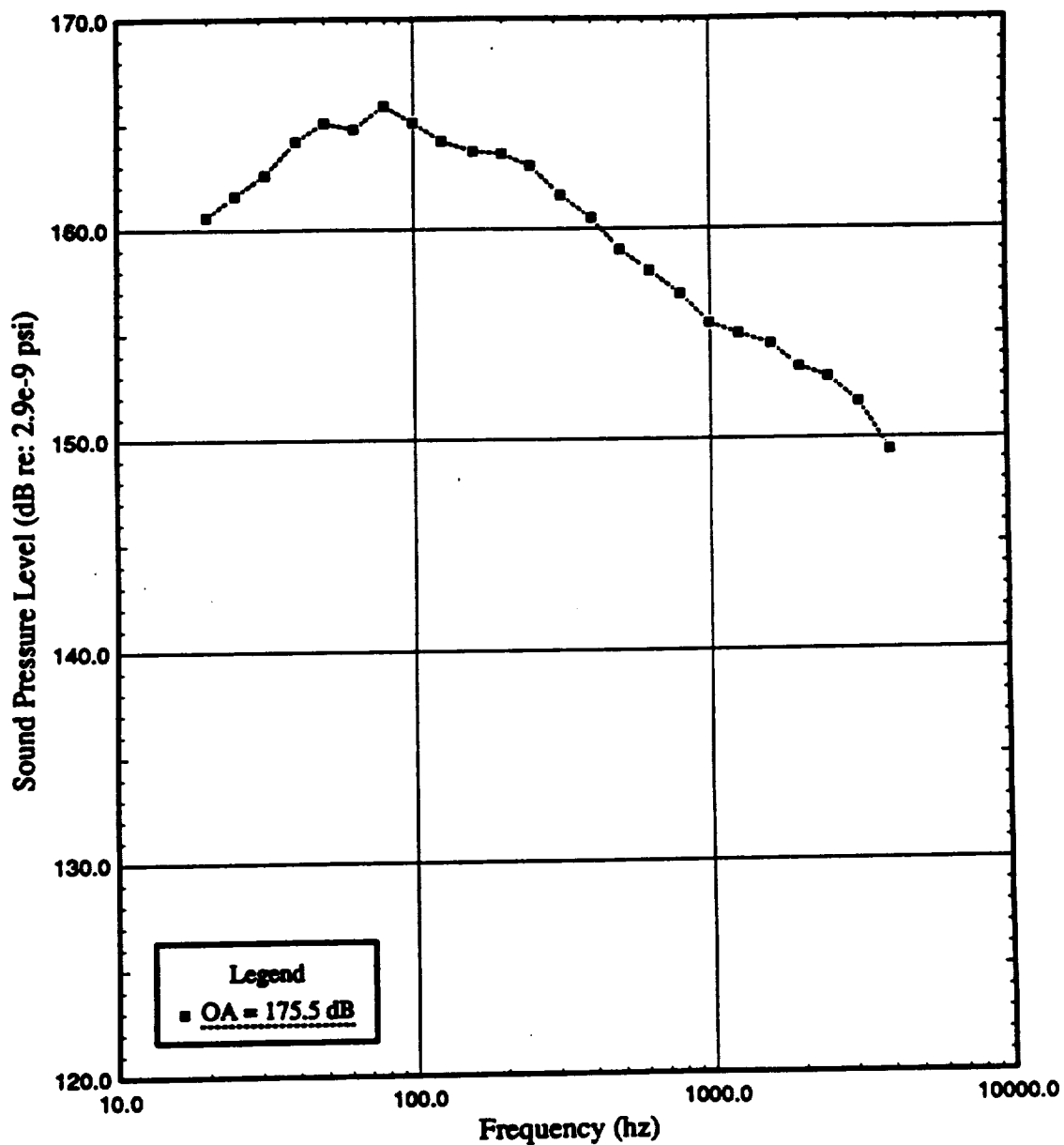


Figure 2.11

HLLV Zone C Max Aero Predicted External Surface Acoustic Levels

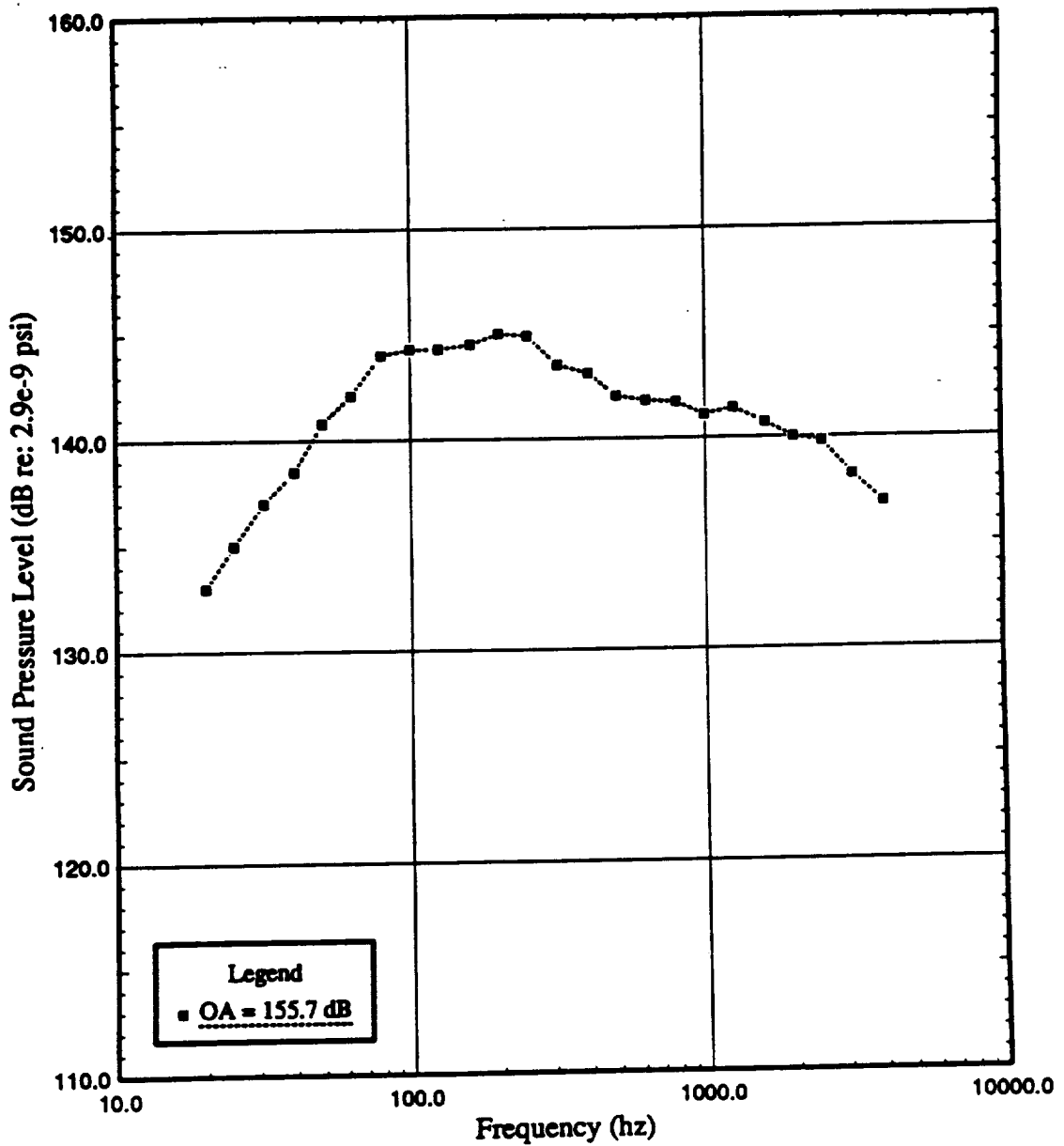


Figure 2.12

HLLV Zone D Max Aero Predicted External Surface Acoustic Levels

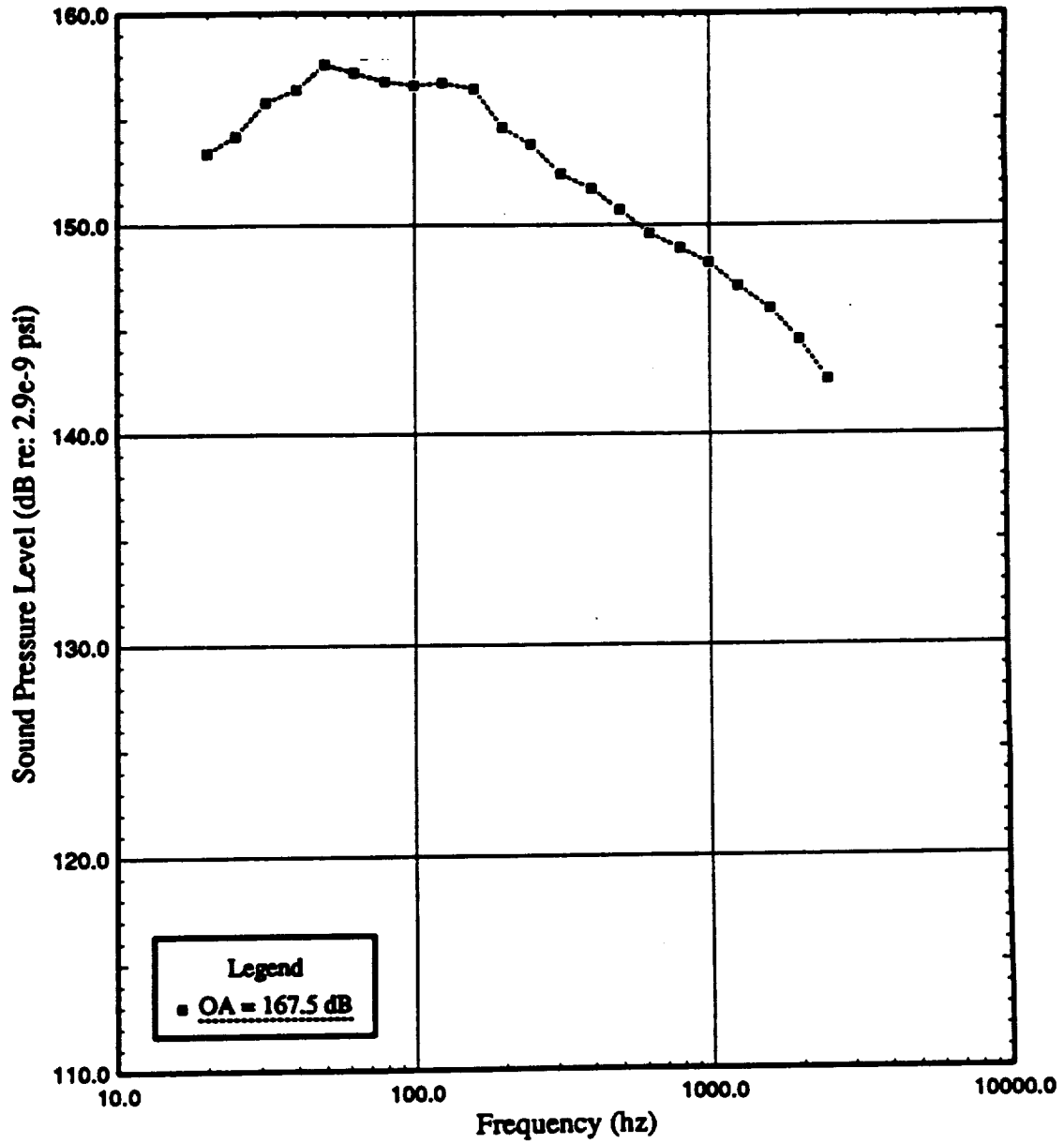


Figure 2.13

HLLV Zone E Max Aero Predicted External Surface Acoustic Levels

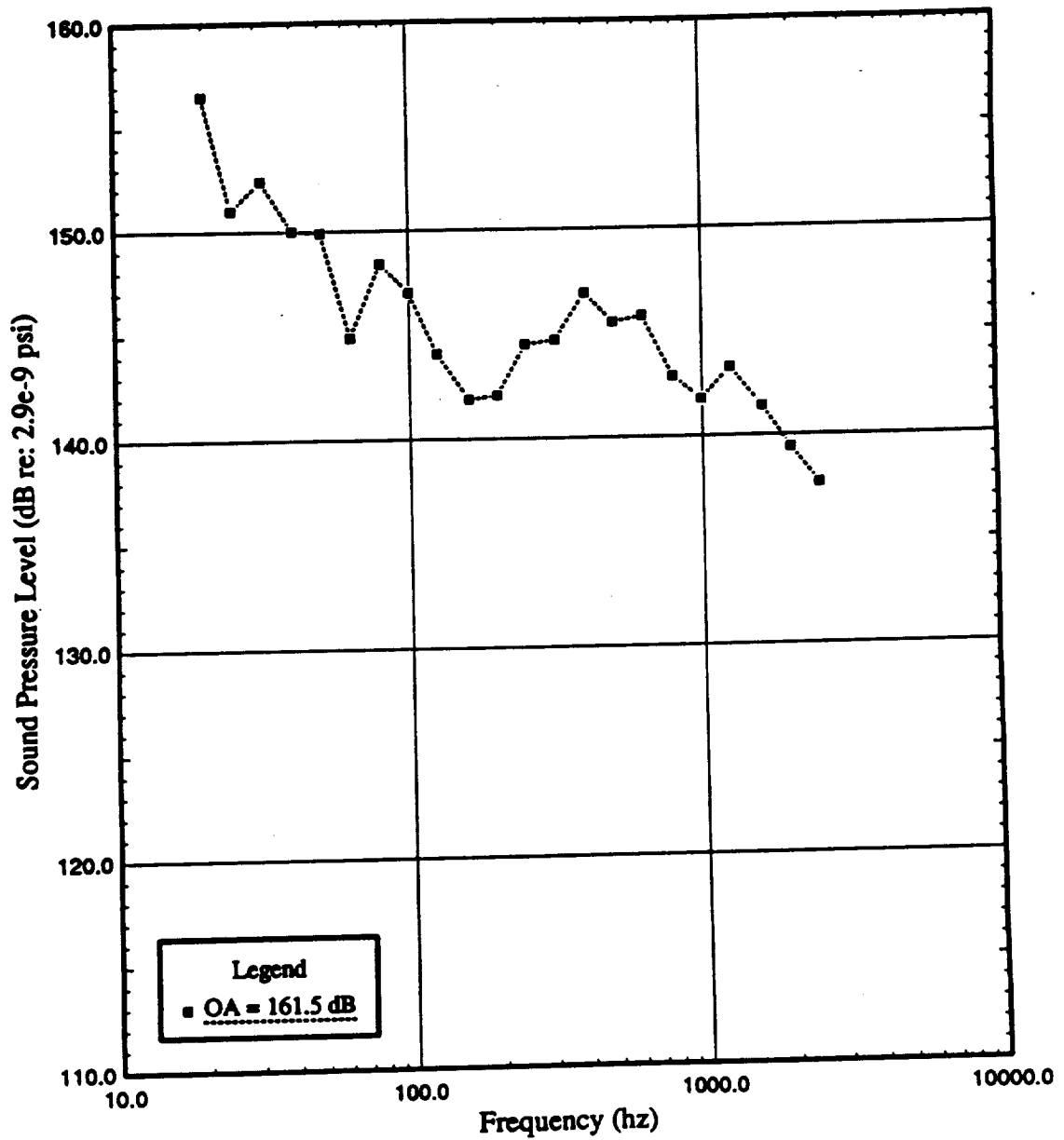


Figure 2.14

HLLV Zone F Max Aero Predicted External Surface Acoustic Levels

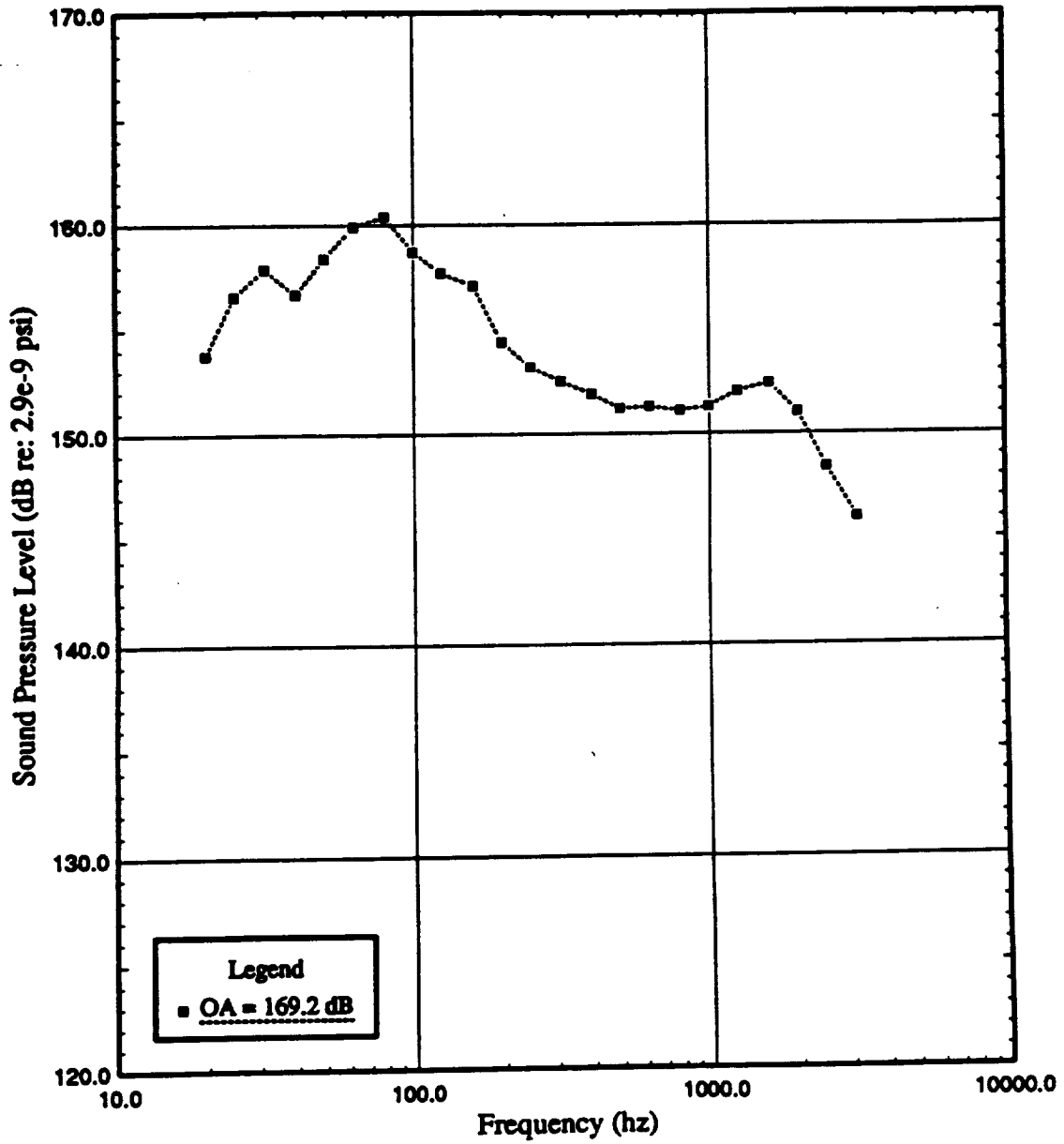


Figure 2.15

HLLV Zone G Max Aero Predicted External Surface Acoustic Levels

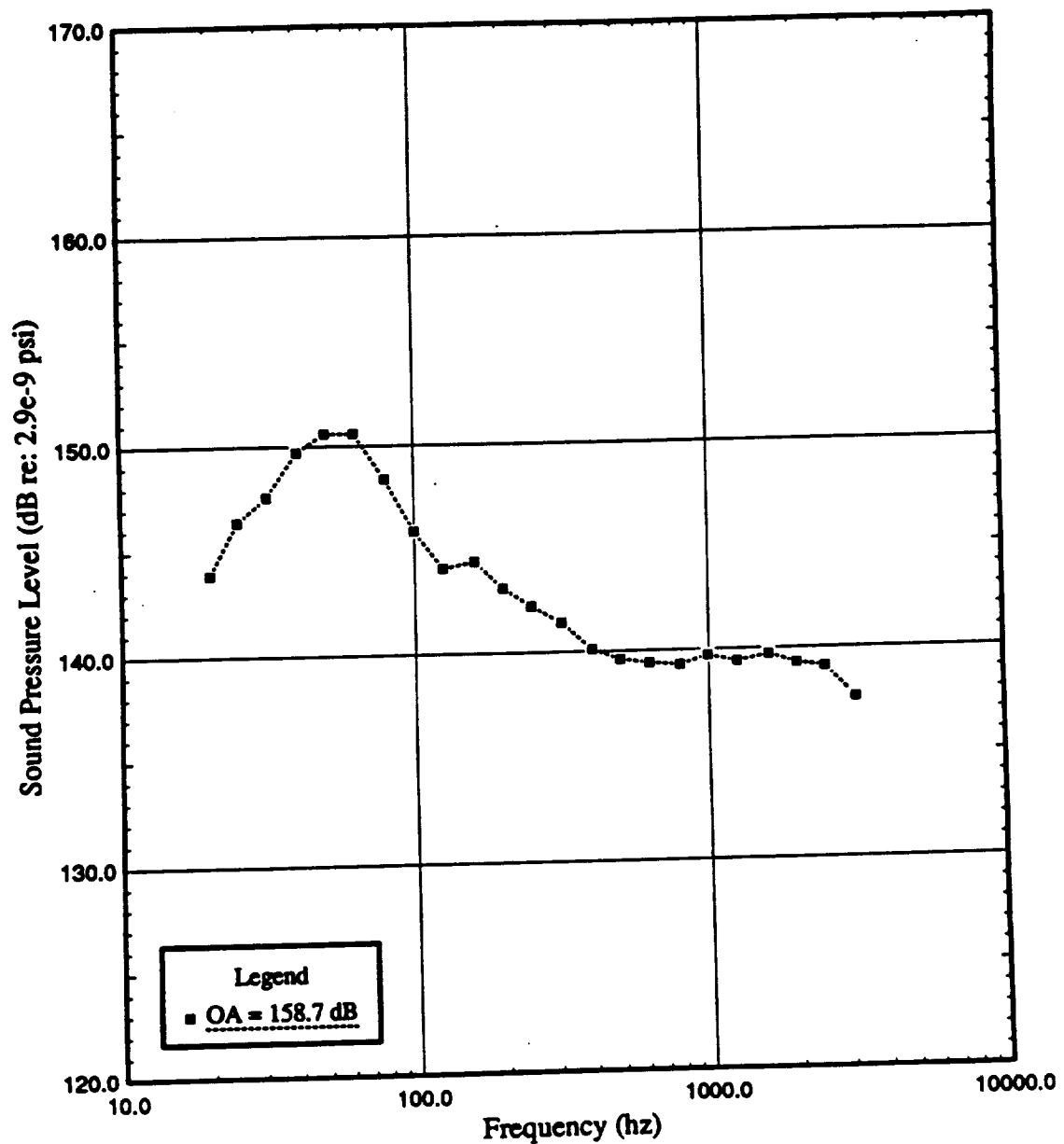


Figure 2.16
HLLV Zone H Max Aero Predicted External Surface Acoustic Levels

The NR curves for both bare and blanketed conditions were applied, using the data sources cited in Section 2.2.1.

2.4.2 Numerical Correction Factors

A correction was applied across the spectrum to account for the difference in the acoustic impedance at altitude; this was a factor of +0.5 dB.

The correction factors which we used to modify the liftoff NR curve before applying it to the aeroacoustic external predictions are listed in Table 2.1 which follows.

Table 2.1. Noise Reduction Correction Factors

1/3 OB Center Frequency (Hz)	Delta NR Applied at Transonics (dB)	Delta NR Applied at Max q (dB)
20	-3.2	3.5
25	-3.4	12.1
32	4.0	9.9
40	0.5	-2.8
50	2.4	8.9
63	-1.1	6.6
80	-4.5	7.0
100	1.1	8.7
125	-0.3	8.5
160	-0.8	6.2
200	2.2	8.4
250	4.7	9.8
315	-0.6	5.6
400	1.1	4.5
500	1.8	3.0
630	2.4	1.9
800	3.8	3.6
1000	3.9	5.6
1250	0.1	3.8
1600	-2.0	1.8
2000	3.9	6.6
2500	-0.5	1.6
3150	-2.9	-4.1
4000	-2.1	-0.6

2.4.3 Results

The predicted internal environments for the HLLV payload fairing and downstage compartments are plotted in figures 2.17 through 2.22. The curves represent worst-case conditions, since they plot envelopes of the liftoff, transonic and max q spectra.

The PLF curves in Figures 2.17 and 2.18 address the two interior conditions, bare and blanketed. For comparison, the two plots also contain the maximum allowable acoustic environments for the STS Orbiter cargo bay and the Titan IV payload fairing; these are considered to be "baseline requirements" in the sense that many potential NLS payloads will have been designed and tested to fly on one of those two vehicles. The results are discussed from this point of view in Section 4.0.

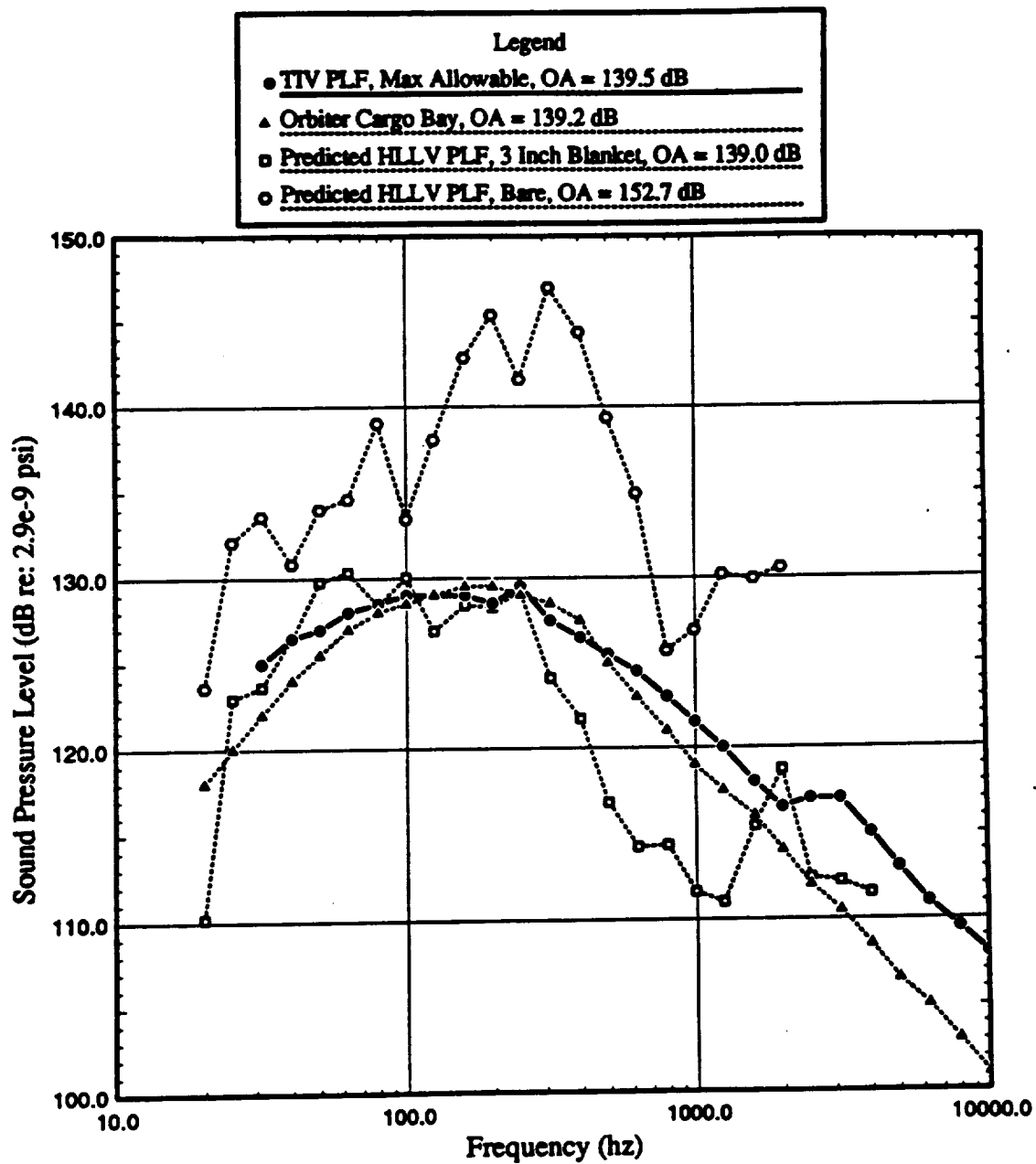


Figure 2.17

Comparison of Internal Acoustic Levels for Zone C With Titan IV and Orbiter Payload Requirements

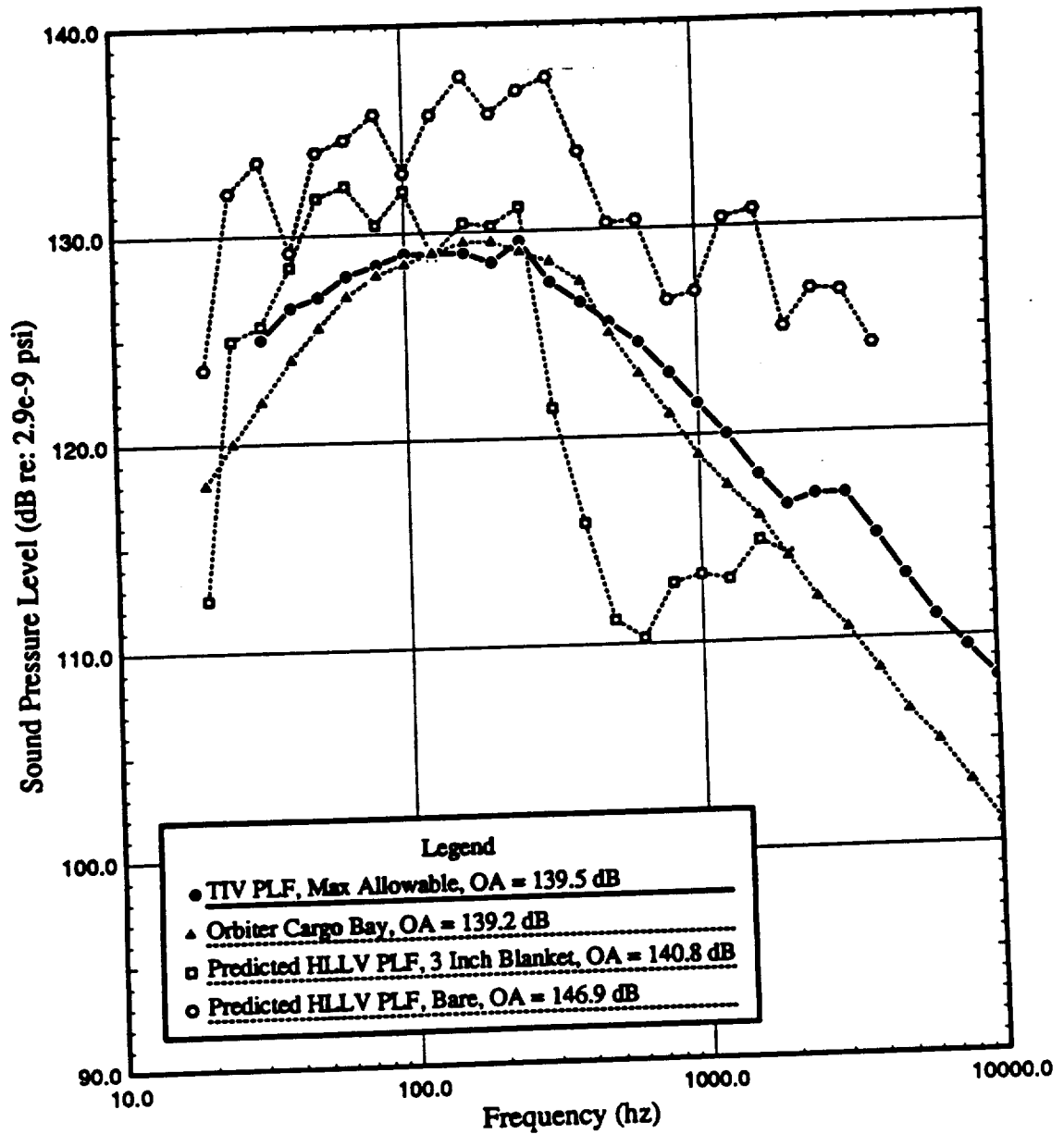


Figure 2.18
 Comparison of Internal Acoustic Levels for Zone D
 With Titan IV and Orbiter Payload Requirements

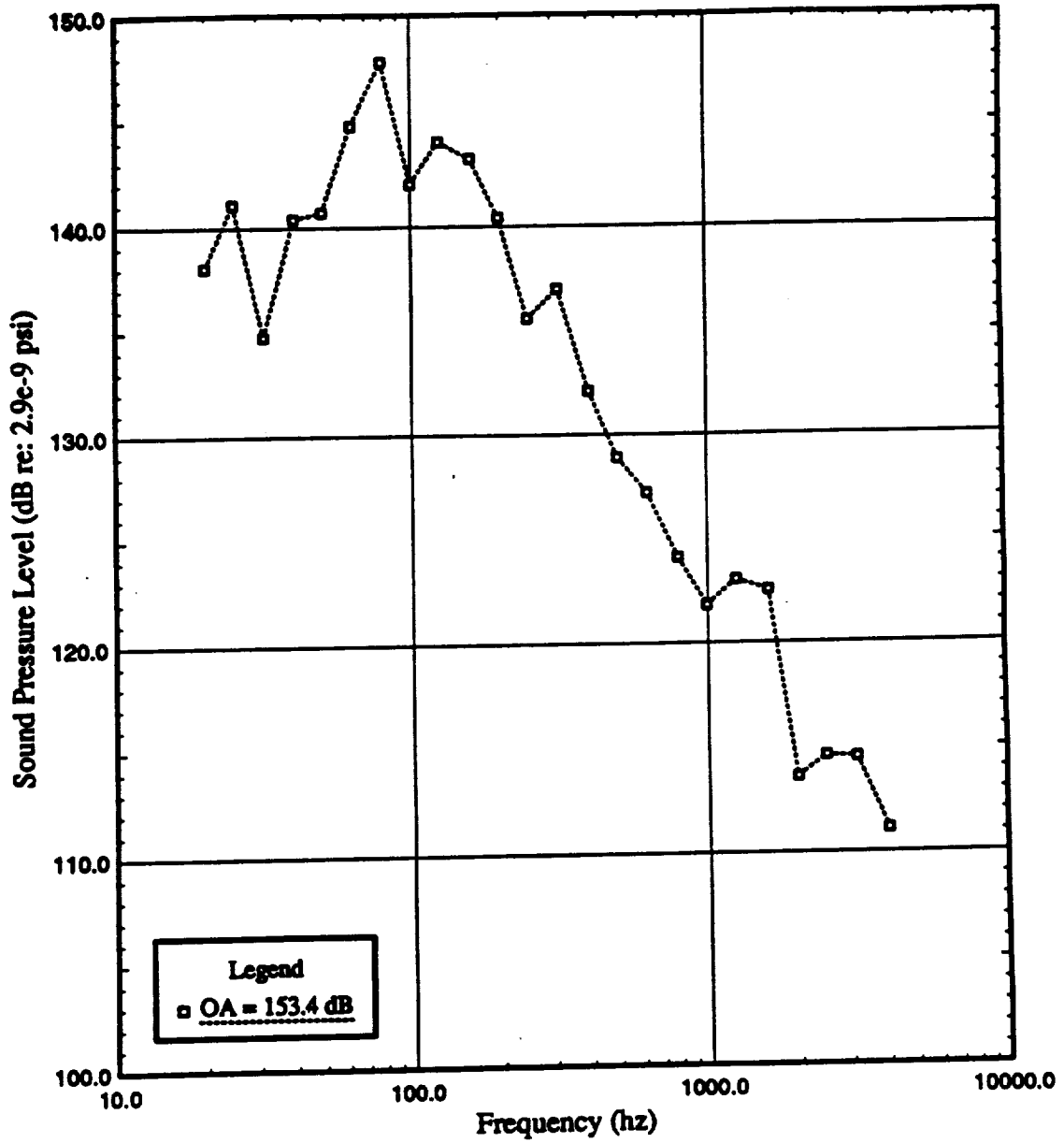


Figure 2.19
 HLLV Zone E Internal Predicted Acoustic Levels

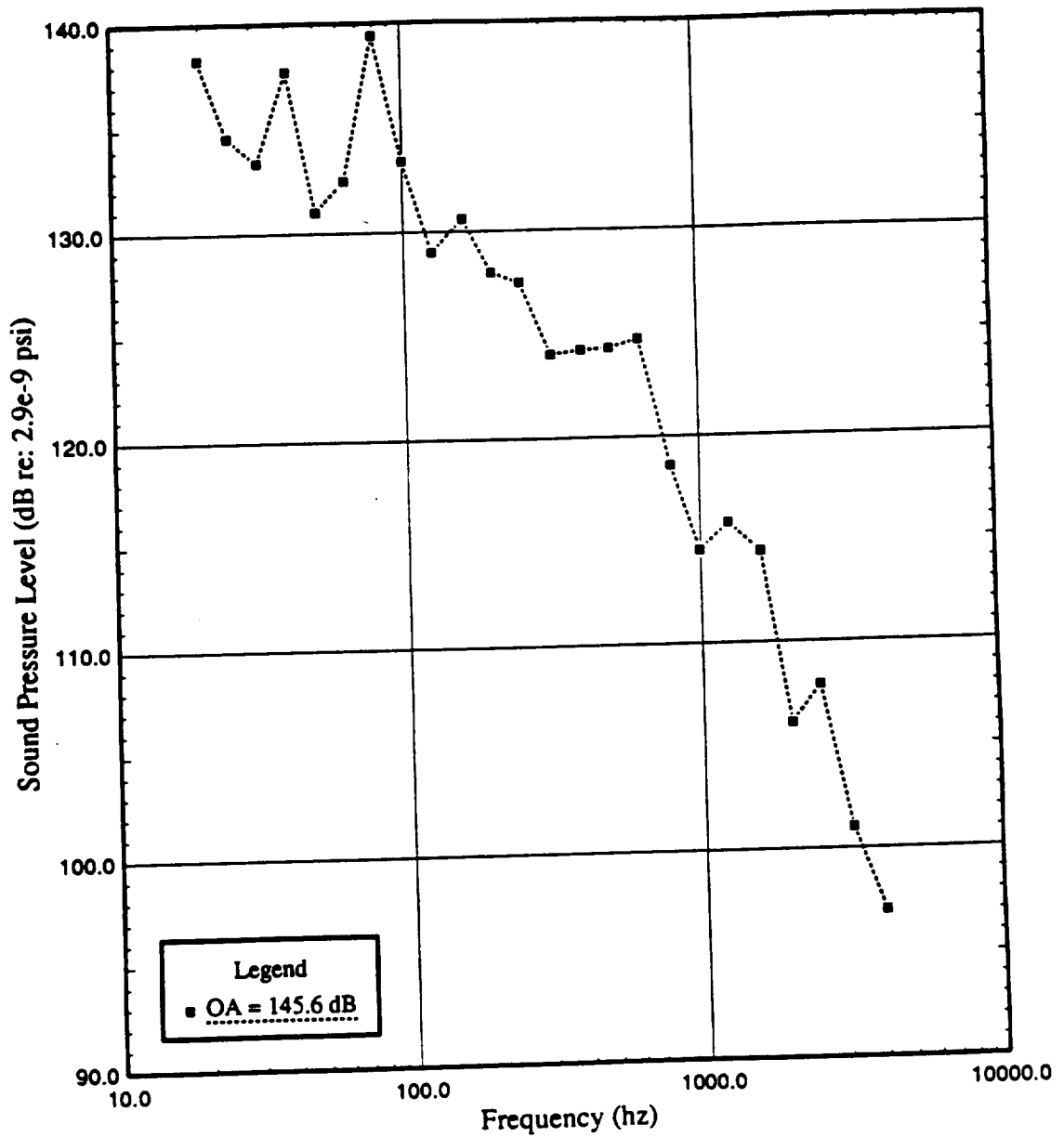


Figure 2.20
HLLV Zone F Internal Predicted Acoustic Levels

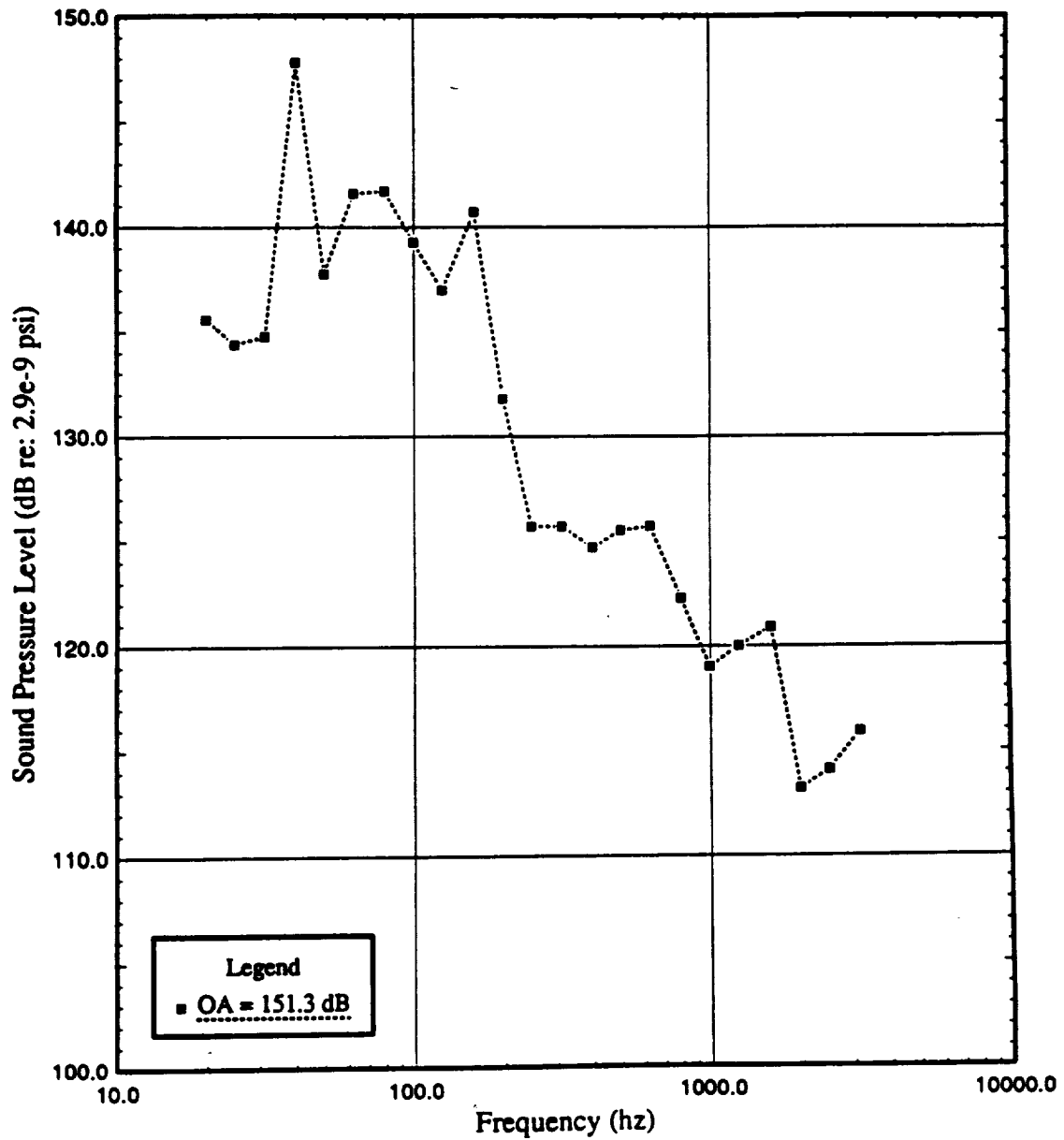


Figure 2.21
HLLV Zone G Internal Predicted Acoustic Levels

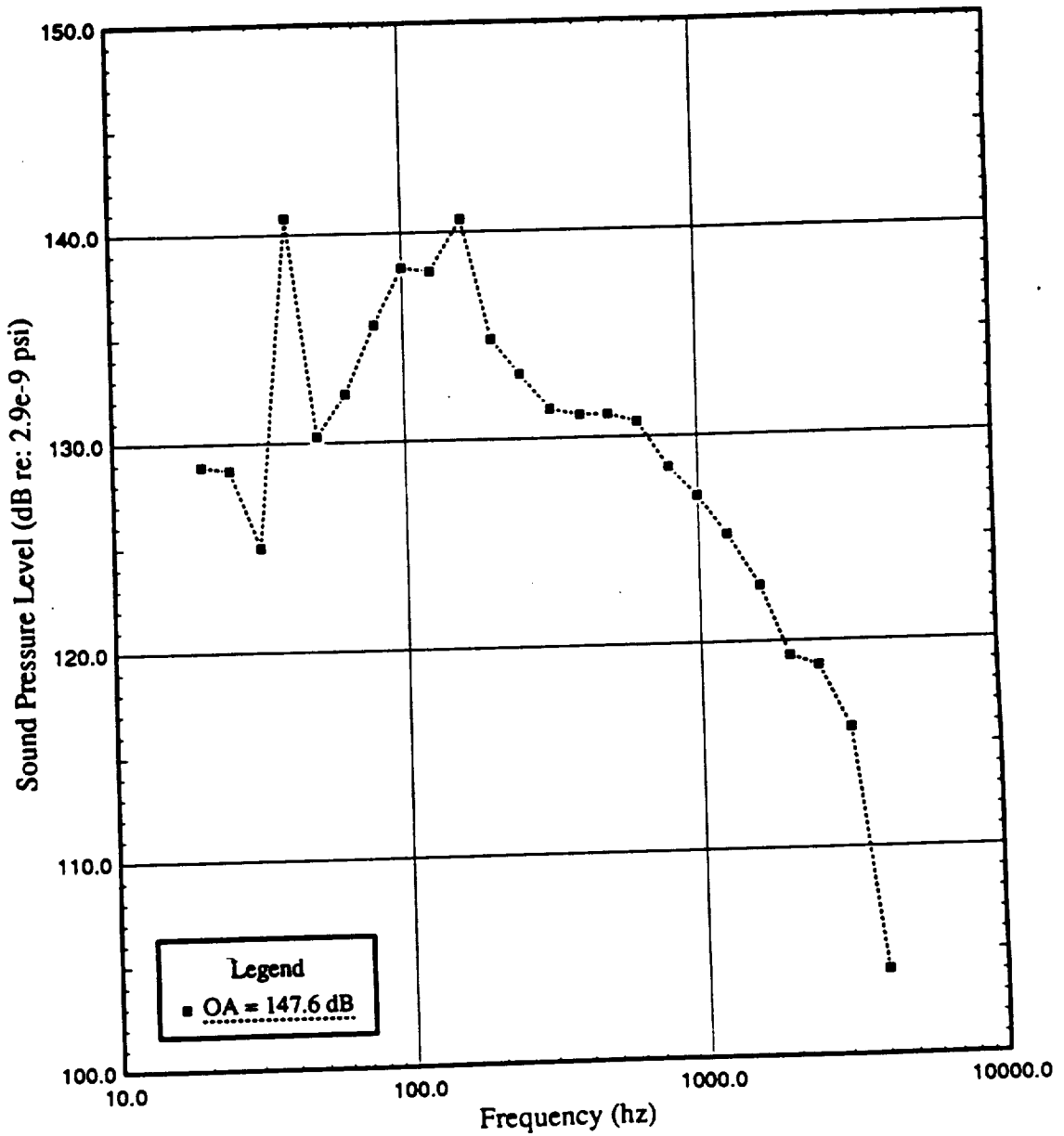


Figure 2.22
HLLV Zone H Internal Predicted Acoustic Levels

3.0 1.5 LV PREDICTIONS

The acoustic predictions for the 1.5 Stage Launch Vehicle were made for the zones defined in Figure 3.1.

3.1 External Environment During Liftoff

3.1.1 Method of analysis

The predictions of the external environments used the same method of analysis as was used for the HLLV. The method was described in detail in Section 2.1.1. The same general parametric scaling approach was adopted, incorporating numerical values appropriate to the 1.5 LV to obtain the correction factors listed below:

3.1.2 Numerical Correction Factors

(i) Acoustic power correction factor:

$$\text{APCF (dB)} = 10 \text{ Log}_{10} \frac{6 \times T(\text{STME}) \times V(\text{STME})}{2 \times T(\text{SRB}) \times V(\text{SRB}) + 3 \times T(\text{SSME}) \times V(\text{SSME})}$$

where T = thrust = 2,650,000 lb for the SRB; 390,000 lb for the SSME and 583,000 lb for the STME,
and V = exhaust velocity = 8200 fps for the SRB; 10,660 fps for the SSME and 13,934 fps for the STME, leading to

$$\begin{aligned} \text{APCF (dB)} &= 10 \text{ Log}_{10} \frac{6 \times 583,000 \times 13,934}{2 \times 2,650,000 \times 8,200 + 3 \times 390,000 \times 10,660} \\ &= -0.6 \text{ dB} \end{aligned}$$

(ii) Strouhal parameter:

$$\begin{aligned} \text{SN}(\text{STME})/f &= D_e(\text{STME})/v(\text{STME}) = [6]^{1/2} D(\text{STME})/V(\text{STME}) \\ &= 2.45 \times 7.25/13934 \\ &= 0.00128 \end{aligned}$$

$$\text{SN}(\text{SSME})/f = 0.001274 \qquad D_e(\text{SSME}) = [3]^{1/2} \times 7.8 = 13.51 \text{ ft}$$

$$\text{SN}(\text{SRB})/f = 0.00151 \qquad D_e(\text{SRB}) = D(\text{SRB}) = 12.4 \text{ ft}$$

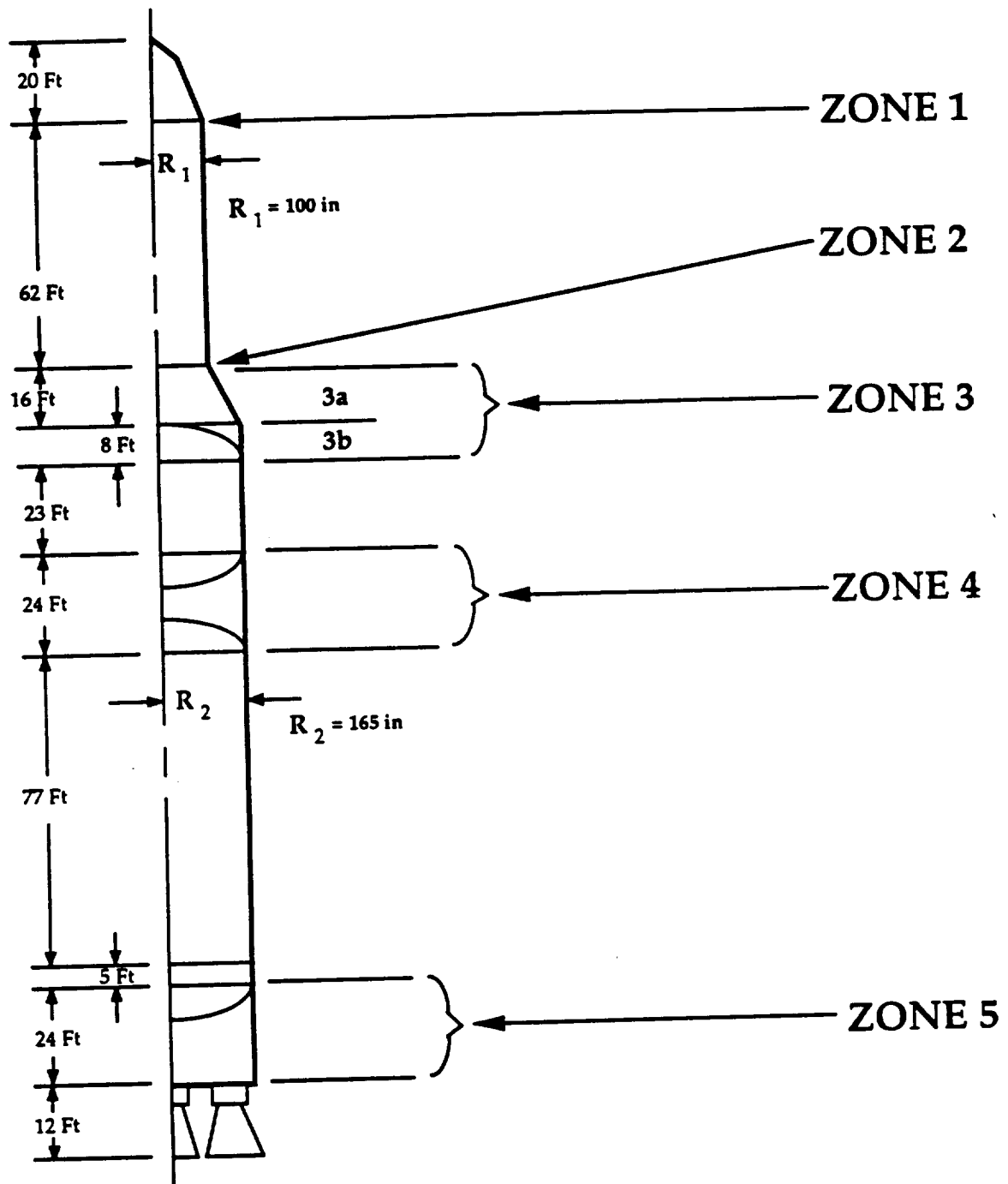


Figure 3.1 Definition of Acoustic Zones for 1.5 Stage LV

(iii) Mechanical power ratio:

$$\begin{aligned} P(\text{SRB})/P(\text{STS}) &= \frac{2 \times T(\text{SRB}) \times V(\text{SRB})}{2 \times T(\text{SRB}) \times V(\text{SRB}) + 3 \times T(\text{SSME}) \times V(\text{SSME})} \\ &= 4.35\text{E}10/5.59\text{E}10 \\ &= 0.78 \end{aligned}$$

$$\begin{aligned} P(\text{SSME})/P(\text{STS}) &= \frac{3 \times T(\text{SSME}) \times V(\text{SSME})}{2 \times T(\text{SRB}) \times V(\text{SRB}) + 3 \times T(\text{SSME}) \times V(\text{SSME})} \\ &= 1.23\text{E}10/5.59\text{E}10 \\ &= 0.22 \end{aligned}$$

(iv) Equivalent nozzle diameter and equivalent velocity:

$$D_e(\text{STS}) = [0.78 \times 12.4^2 + 0.22 \times 13.51^2]^{1/2} = 12.65 \text{ ft}$$

$$D_e(1.5\text{LV}) = [6]^{1/2} \times D(\text{STME}) = 17.76 \text{ ft}$$

$$V_e(\text{STS}) = 0.78 \times 8200 + 0.22 \times 10,660 = 8741 \text{ fps}$$

$$V_e(1.5\text{LV}) = 13,934 \text{ fps}$$

(v) Strouhal parameter:

$$\text{SN}(\text{STS})/f = 12.65/8741 = 0.00145$$

$$\text{SN}(1.5\text{LV})/f = 17.76/13,934 = 0.00128$$

(vi) Frequency shift:

$$f(\text{STS})/f(1.5 \text{ LV}) = 0.00145/0.00128 = 1.13$$

This is equivalent to about a 1/6 octave band, so no frequency shift will be applied.

3.1.3 Results

The predicted external acoustic spectra for the 1.5 LV during liftoff were calculated for zones 1 through 5, using the above numerical corrections. The results are plotted in Figures 3.2 through 3.6. The variation in OASPL along the PLF is shown in Figure 3.7.

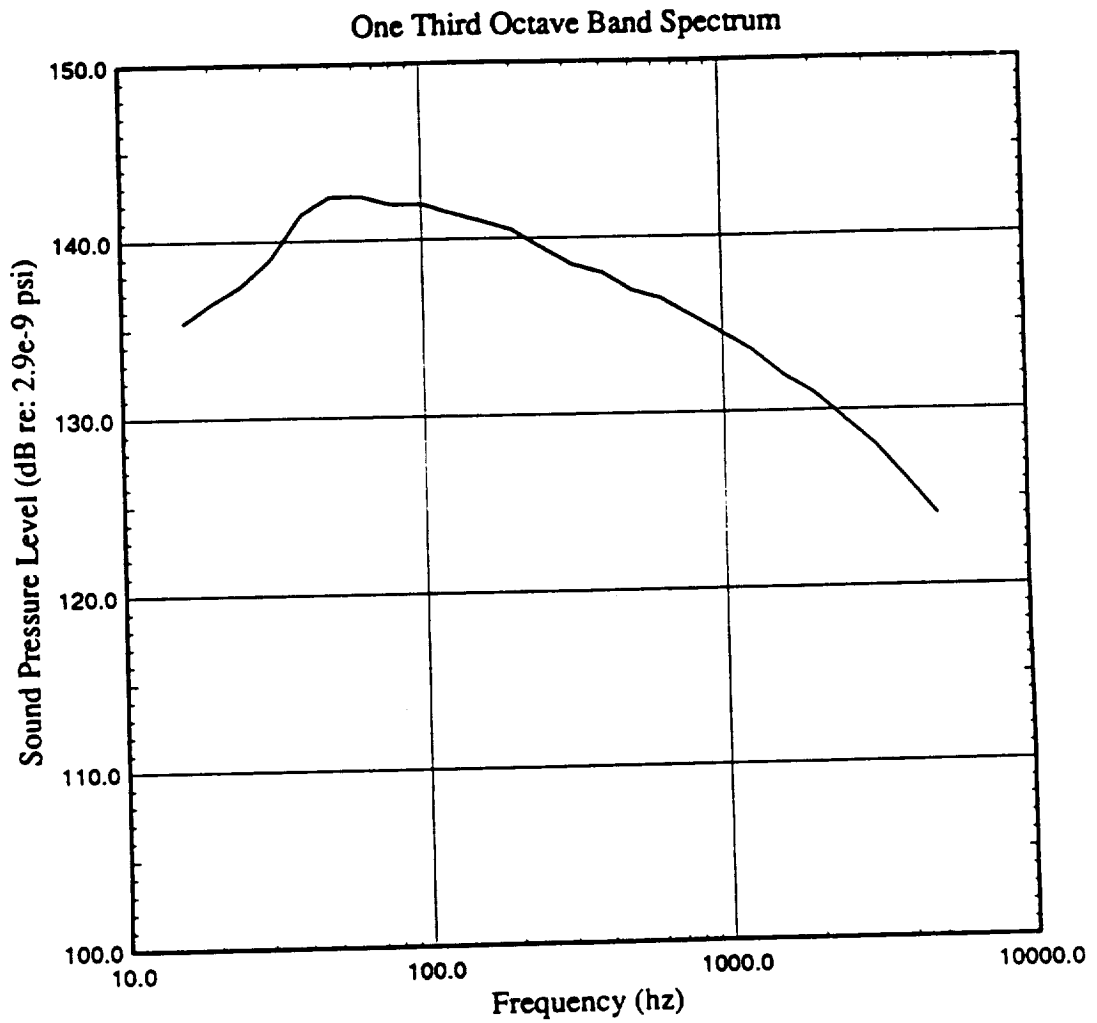


Figure 3.2

Smoothed NLS 1.5-Stage, Liftoff External Surface Prediction
 ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 152.7 dB

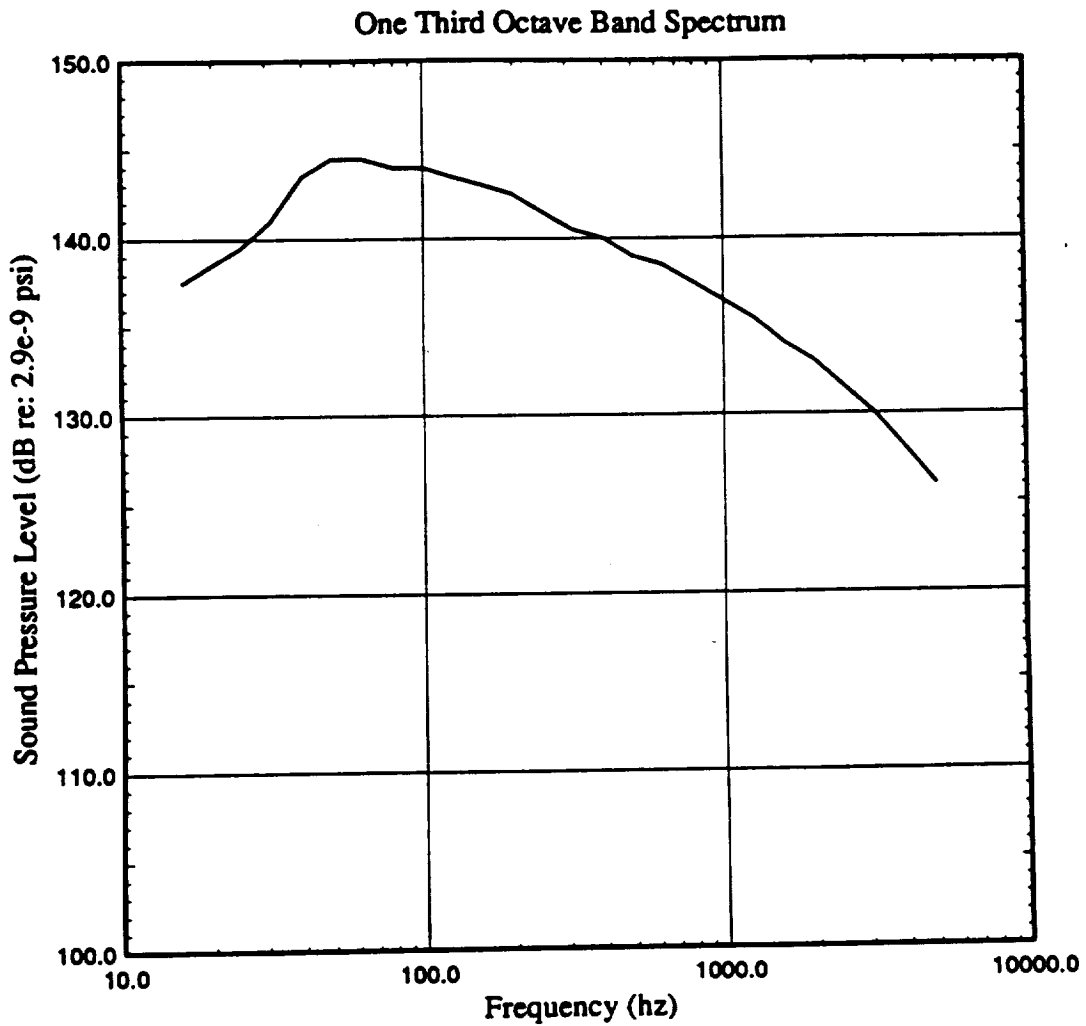


Figure 3.3

Smoothed NLS 1.5-Stage, Liftoff External Surface Prediction
 ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 154.7 dB

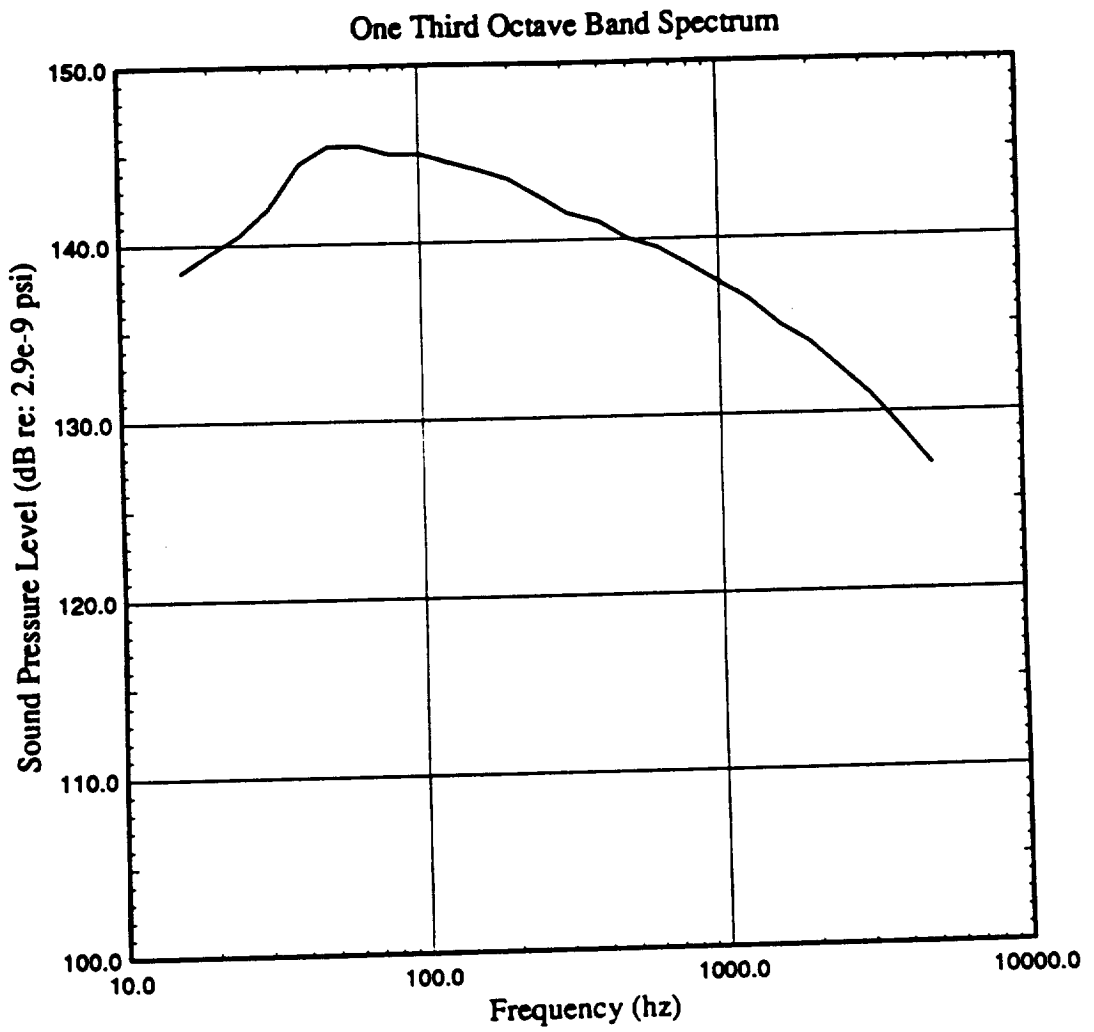


Figure 3.4
Smoothed NLS 1.5-Stage, Liftoff External Surface Prediction
ZONE 3: PLF-Adapter Region OASPL = 155.7 dB

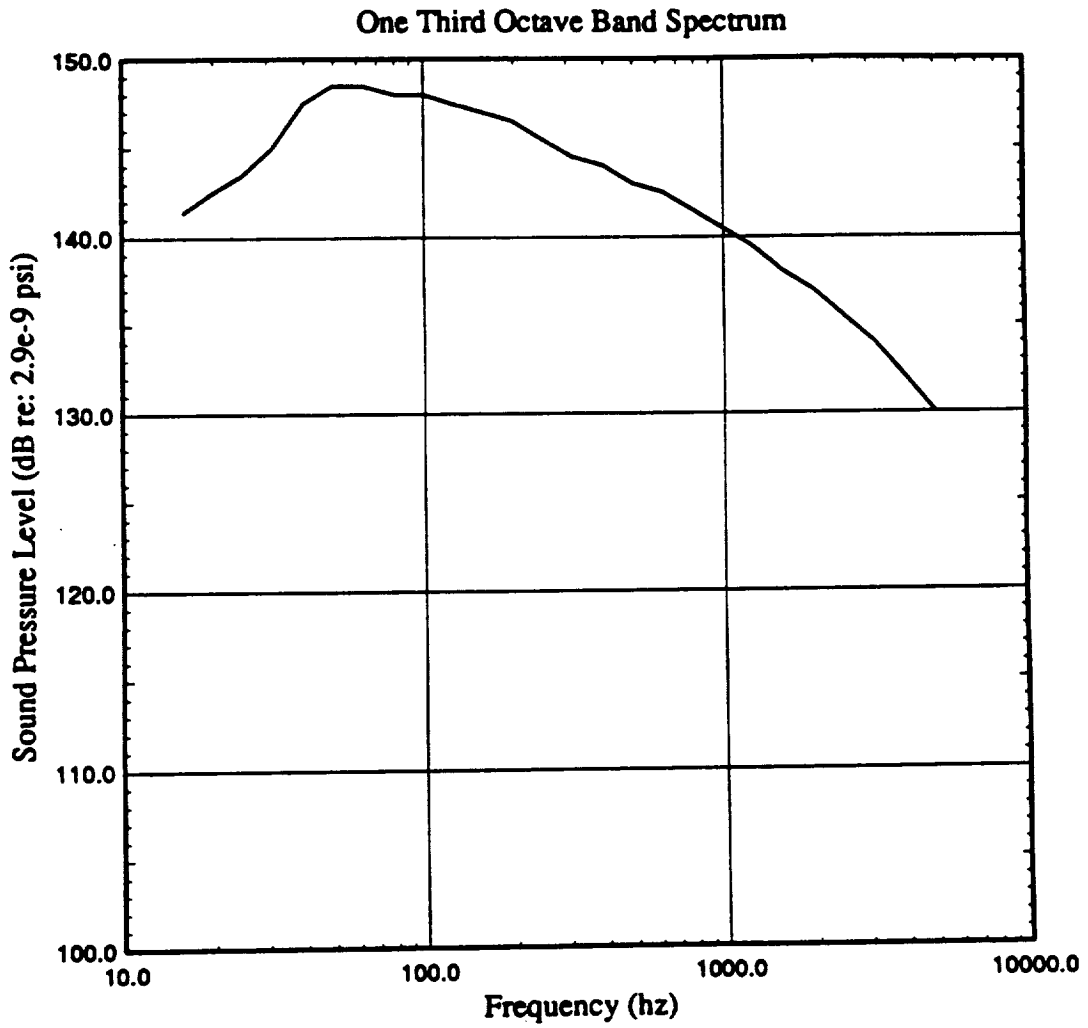


Figure 3.5
Smoothed NLS 1.5-Stage, Liftoff External Surface Prediction
ZONE 4: Core Intertank Skirt OASPL = 158.7 dB

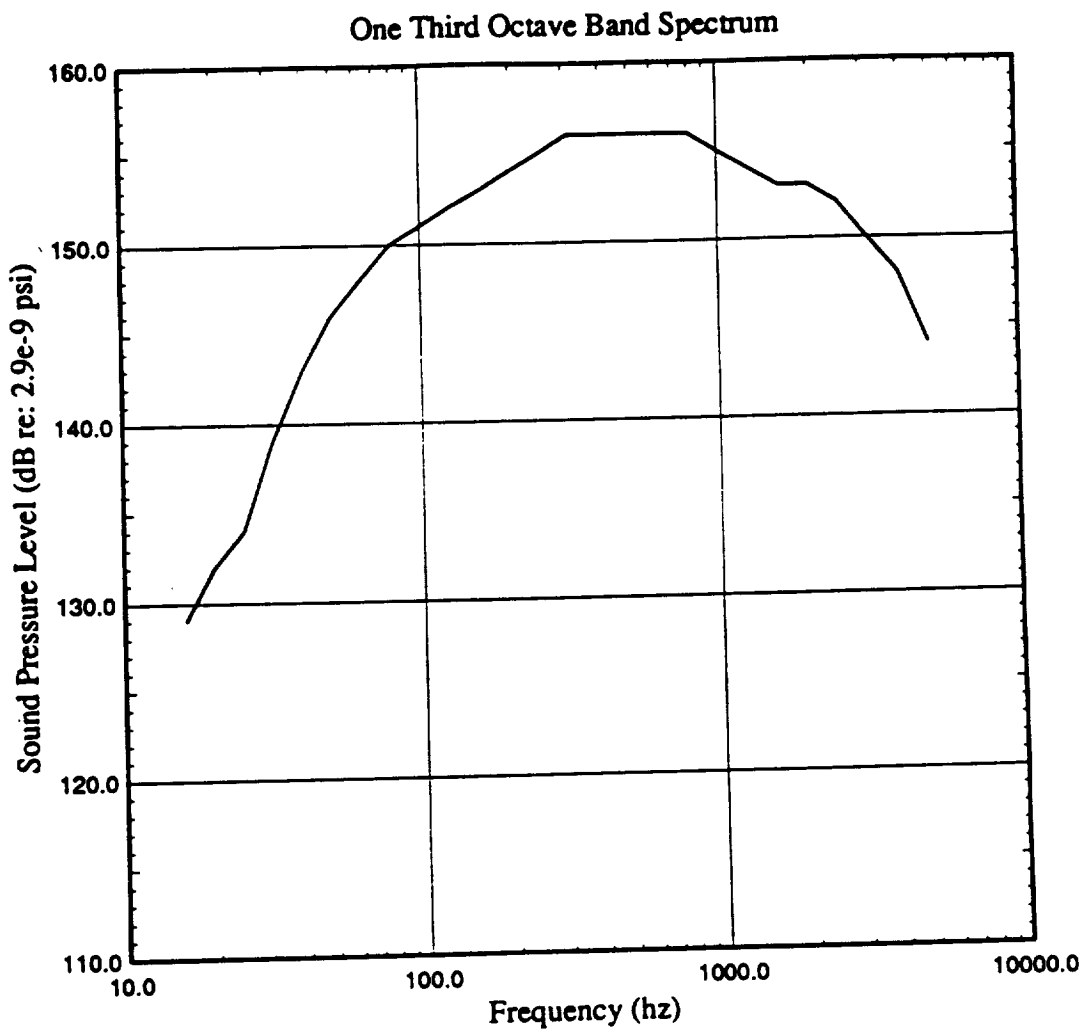


Figure 3.6
 Smoothed NLS 1.5-Stage, Liftoff External Surface Prediction
 ZONE 5: Aft Skirt and Prop. Module OASPL = 166.6 dB

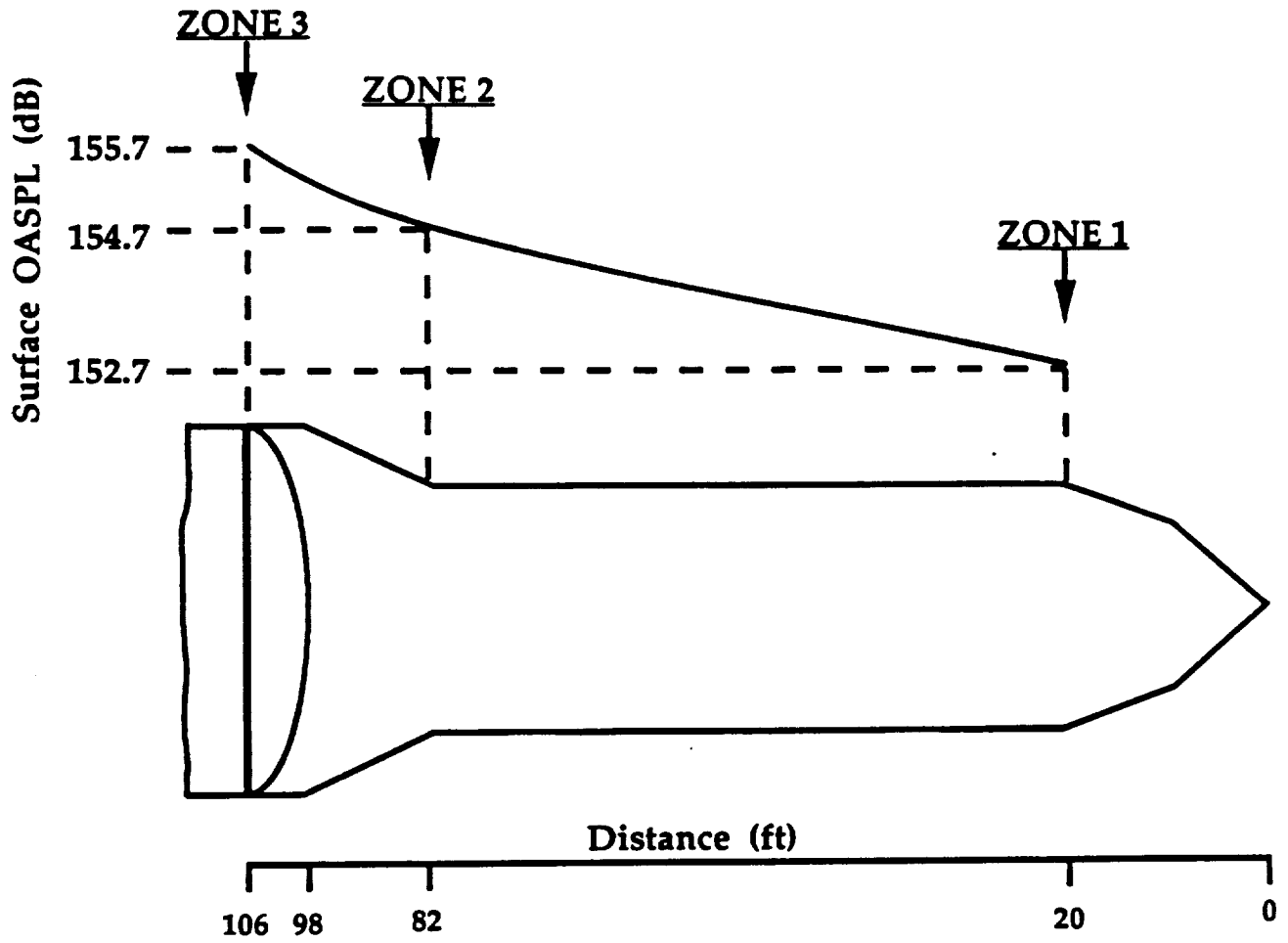


Figure 3.7
 Variation of Liftoff External Surface Pressure with Distance for 1.5 LV.

3.2 Internal Environments During Liftoff

3.2.1 Method of Analysis

The same methodology was employed for this section as was used in the HLLV analysis. Since the core vehicle is common to both configurations and the PLF's are essentially identical, the same noise reduction curves apply to both cases.

3.2.2 Numerical Correction Factors

Because of the similarities discussed above it was not necessary to calculate any numerical corrections that were different to the HLLV factors.

3.2.3 Results

The internal acoustic environments during liftoff for zones 1 through 5 were calculated, incorporating the correction factors identified above. The results are plotted in Figures 3.8 through 3.13. These results were also modified, for Zones 1 and 2, to show the predicted effects of adding a standard 3 inch blanket inside the PLF, then presented in Figures 3.14 and 3.15.

3.3 External Environments During Ascent

3.3.1 Method of Analysis

The same basic analytical approach was used for the 1.5 LV as for the HLLV for the ascent phase, but different reference data was required on the core because of the absence of the ASRB's. Saturn flight data (Reference 9) was used for the baseline intertank and aft skirt after concluding that the max q environment was critical, not transonics.

3.3.2 Numerical Correction Factors

The HLLV levels calculated for the ascent external phase were modified for a difference in q at a Mach number of 0.76. This applies to 1.5 LV zones 1, 2, 3a and 3b.

$$\begin{aligned}\text{Correction Factor} &= 20 \text{ Log } (q_{1.5LV}/q_{HLLV}) \\ &= 20 \text{ Log } (514/575) = -1.0 \text{ dB}\end{aligned}$$

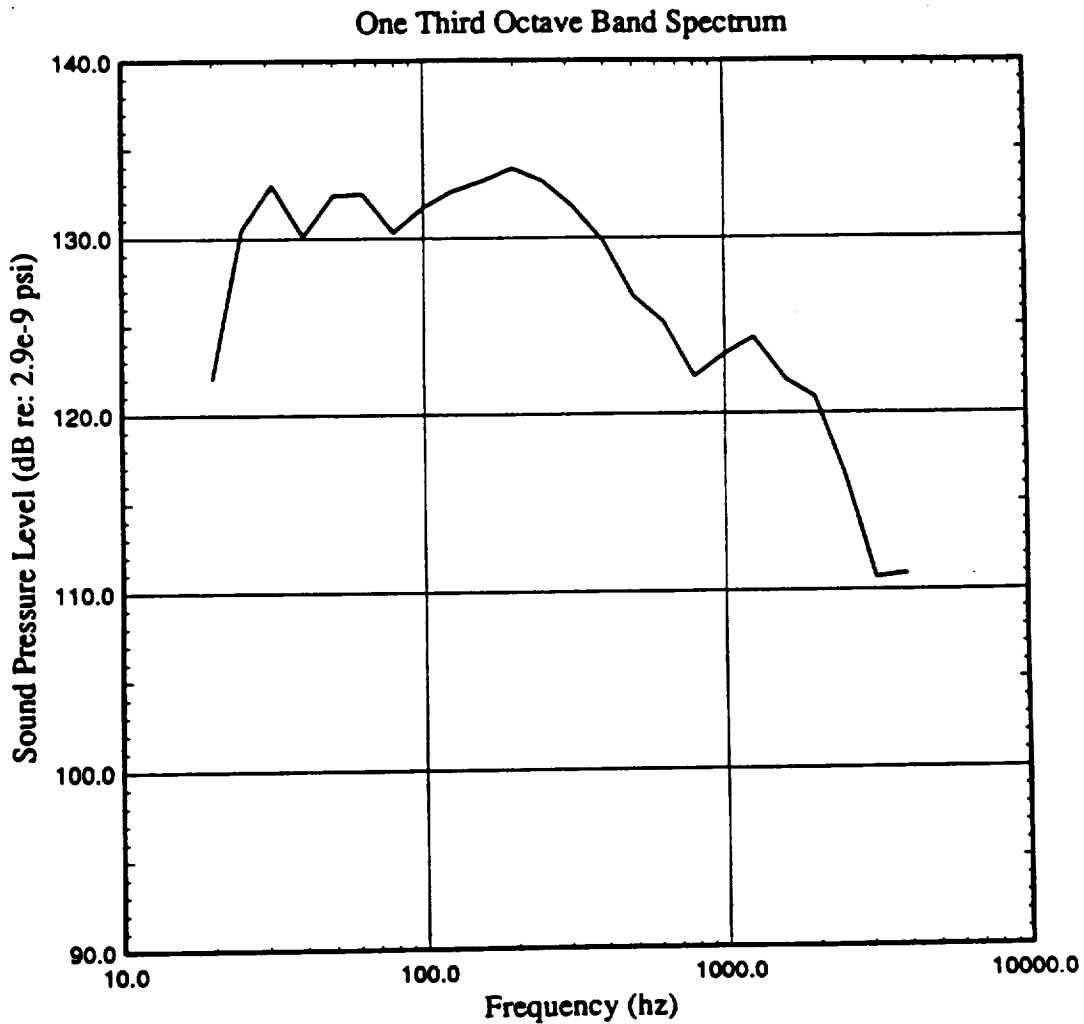


Figure 3.8

NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 143.6 dB

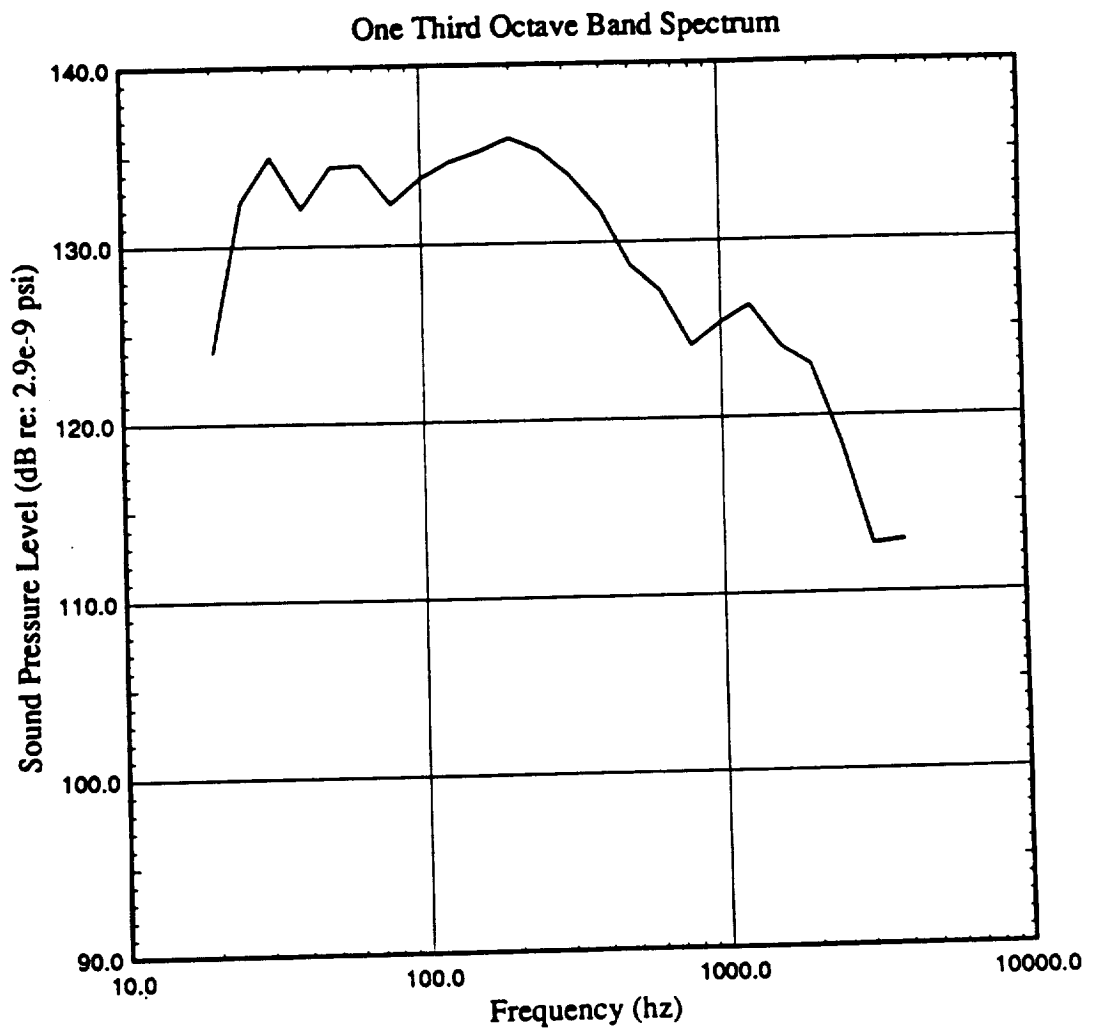


Figure 3.9
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 145.6 dB

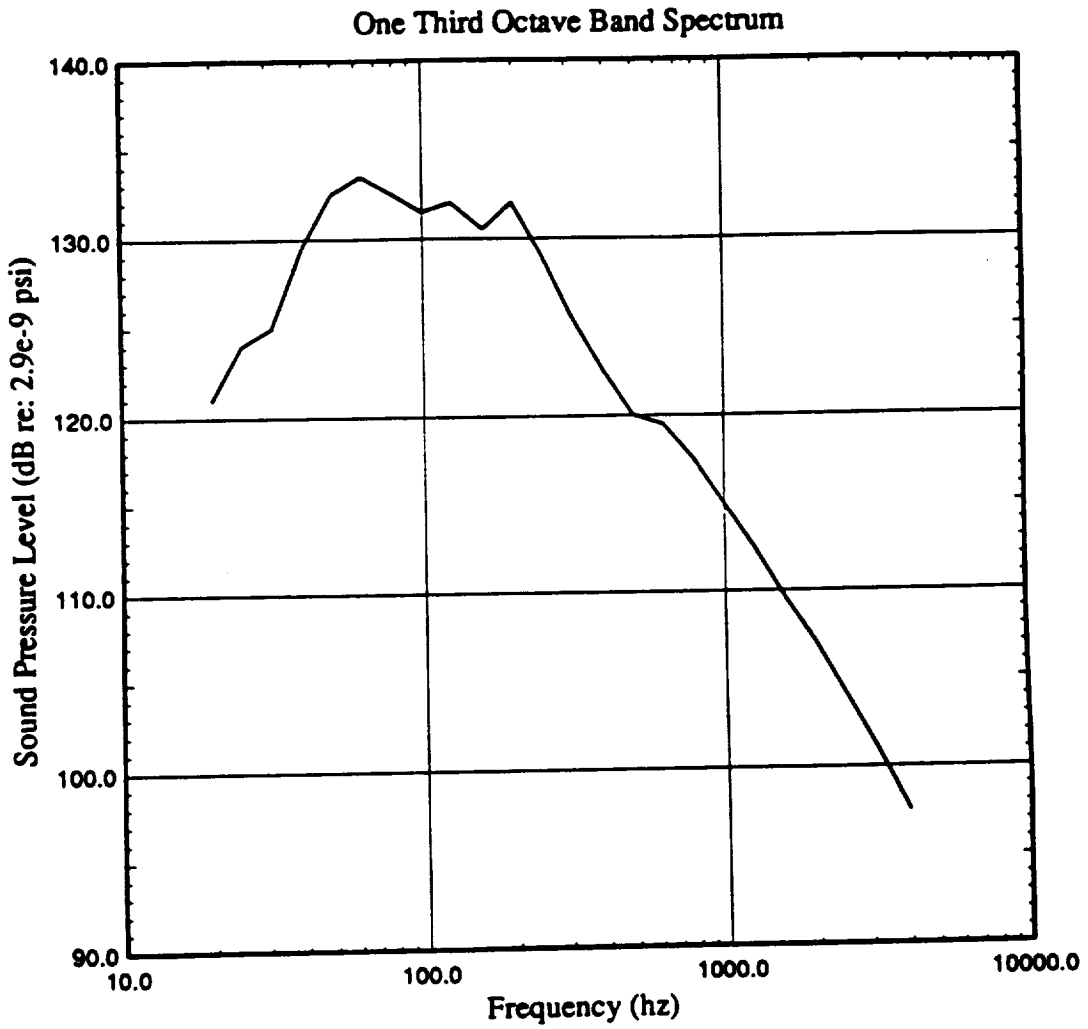


Figure 3.10
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
ZONE 3a: PLF/Core Adapter, Conic Frustrum OASPL = 141.7 dB

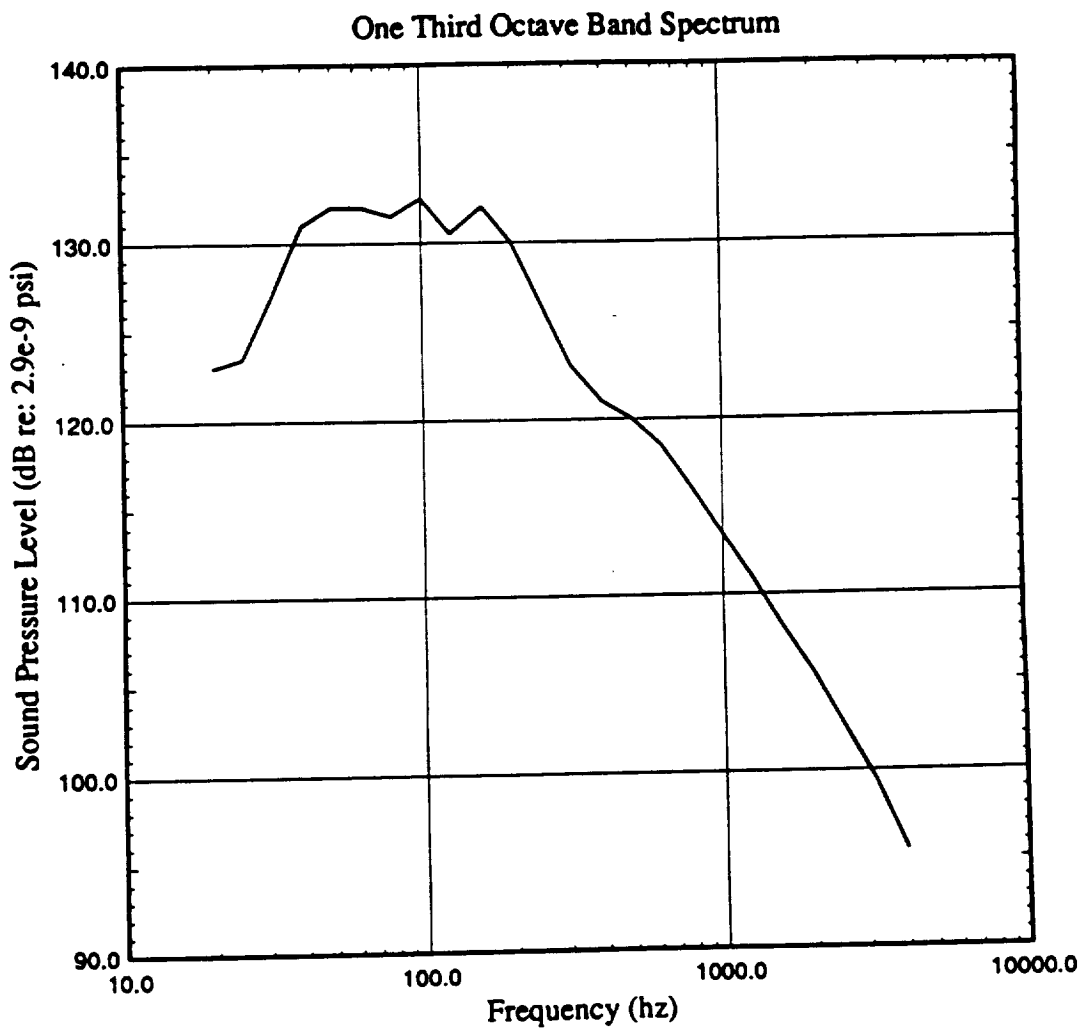


Figure 3.11

NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
 ZONE 3b: Core Forward Skirt, Aft of Adapter OASPL = 141.2 dB

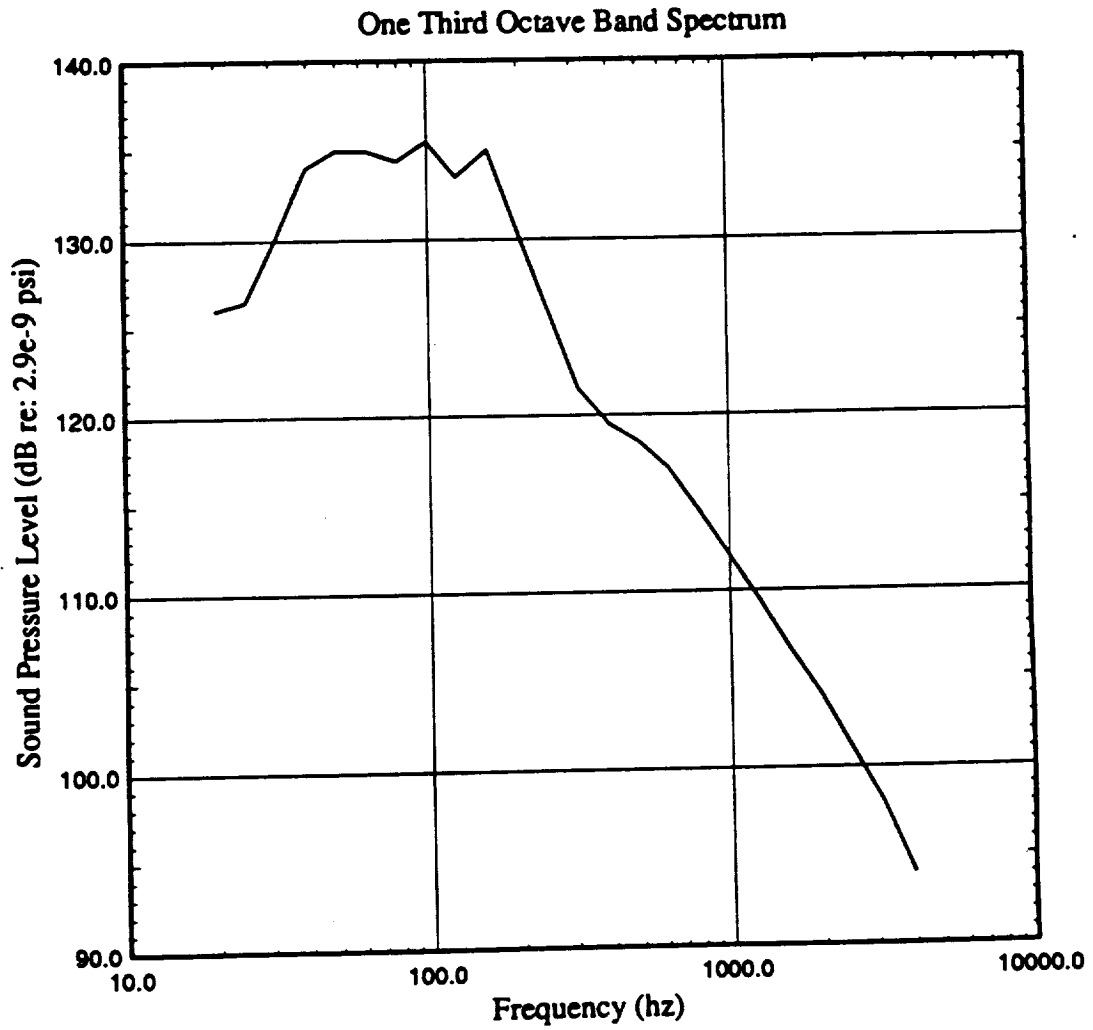


Figure 3.12
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
ZONE 4: Core Intertank Skirt OASPL = 143.9 dB

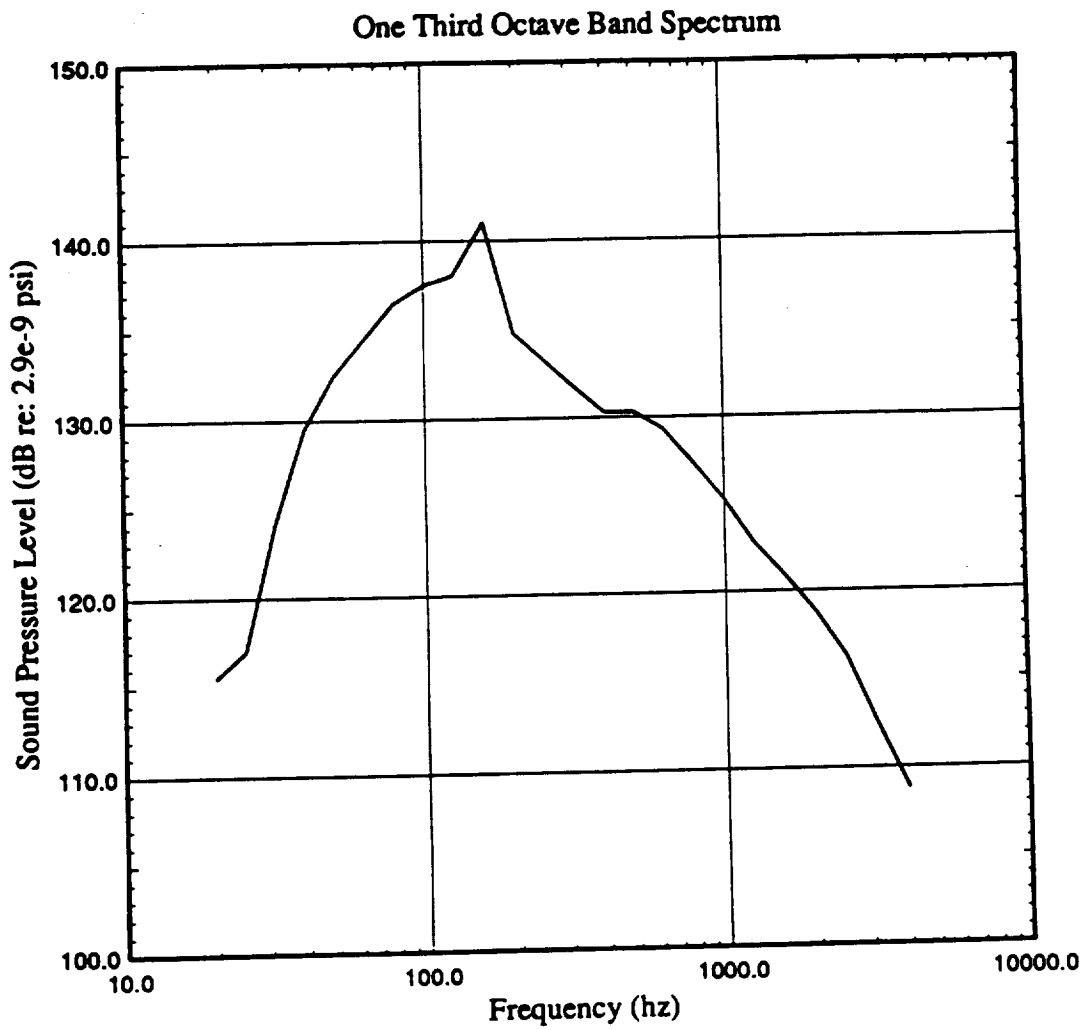


Figure 3.13
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
ZONE 5: Aft Skirt and Prop. Module OASPL = 146.6 dB

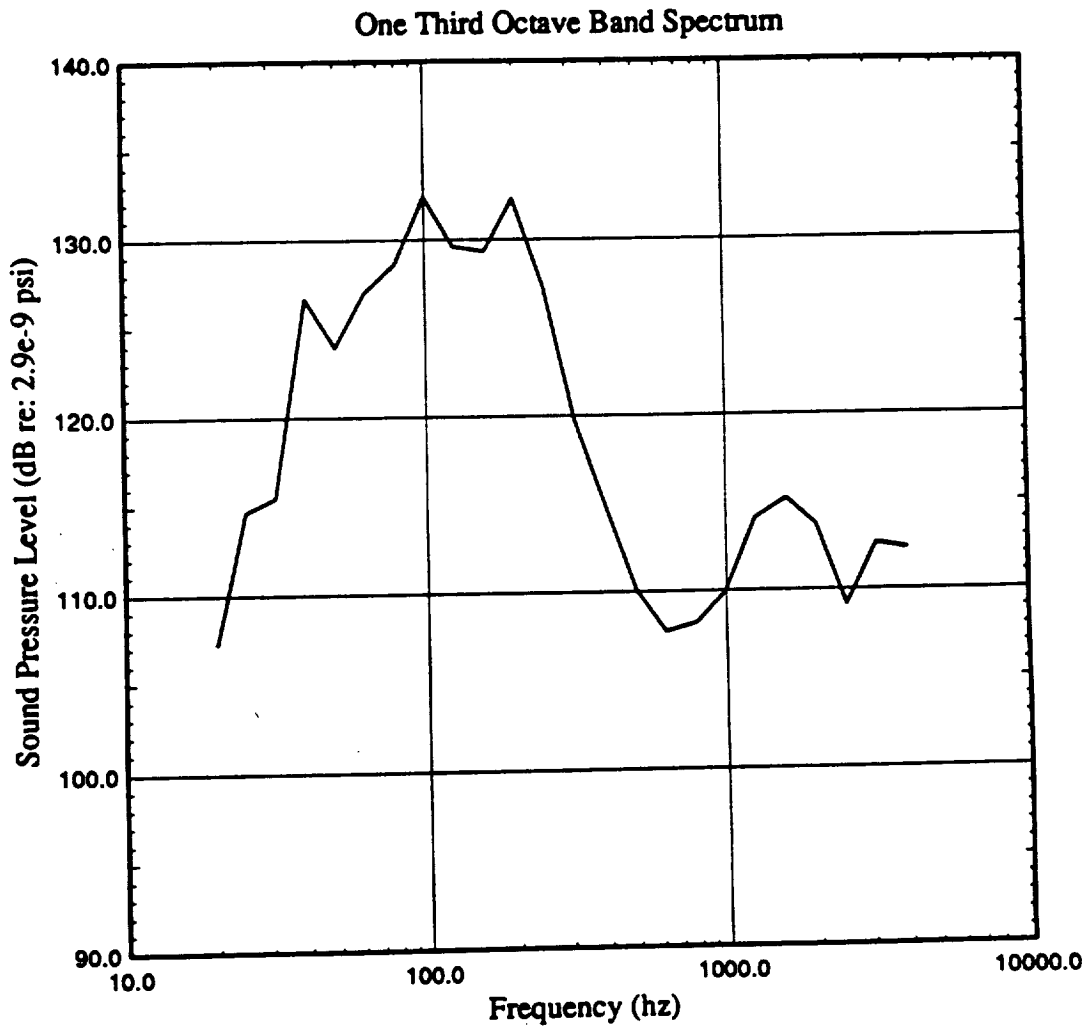


Figure 3.14
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Standard Titan-IV 3 inch PLF Blankets included
ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 139.0 dB

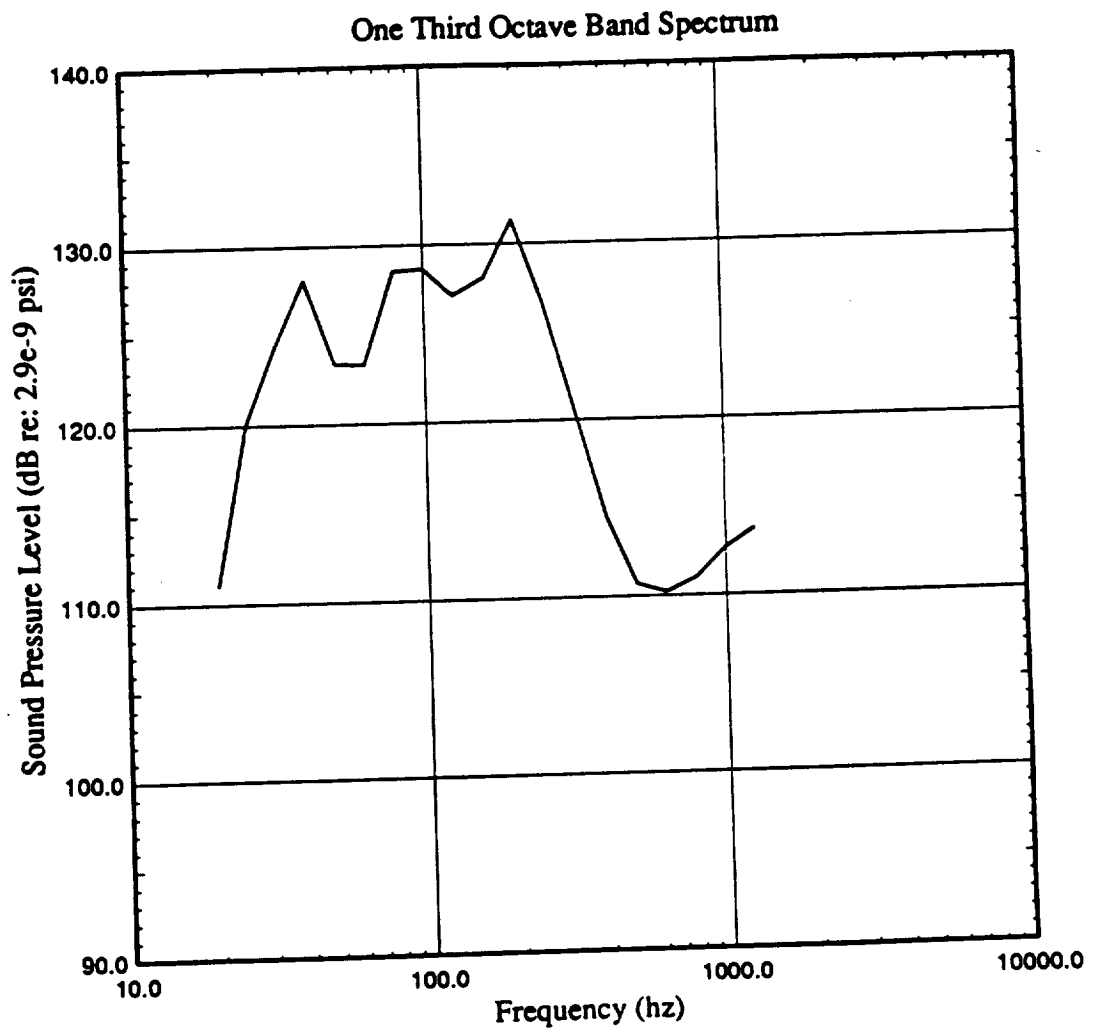


Figure 3.15
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Standard Titan-IV 3 inch PLF Blankets included
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 137.8 dB

A slightly different correction factor was calculated for 1.5 LV zones 4 and 5:

$$\begin{aligned}\text{Correction Factor} &= 20 \text{ Log } (q_{1.5\text{LV}}/q_{\text{Saturn}}) \\ &= 20 \text{ Log}(627/690) = -0.8 \text{ dB}\end{aligned}$$

3.3.3 Results

The external levels during ascent were calculated after incorporating the corrections from the previous paragraph. The results are plotted in Figures 3.16 through 3.21.

3.4 Internal Environments During Ascent

3.4.1 Method of Analysis

The same approach was followed here as for the HLLV analysis, as described in Section 2.4.1.

3.4.2 Numerical Correction Factors

An acoustic impedance correction of -0.8 dB was applied to zones 1, 2, 3a and 3b. This accounted for the difference between HLLV and 1.5 LV trajectories. For zones 4 and 5 the correction was +3.2 dB, arising from the difference between the Saturn and 1.5 LV trajectories. The correction factors to modify the liftoff NR curve were identical to those shown in Table 2.1.

3.4.3 Results

The predicted internal environments for ascent were obtained by subtracting the appropriate NR spectra from the external levels, incorporating the corrections just discussed. The results are shown in Figures 3.22 through 3.27, for zones 1, 2, 3a, 3b, 4 and 5. The modified internal levels for the PLF with a 3 inch blanket are plotted in Figures 3.28 and 3.29.

Plots of the worst case internal levels, obtained by enveloping the liftoff and ascent cases, are shown in Figures 3.30 through 3.33, for the bare and blanketed conditions. The baseline requirements, from Titan IV and STS, are included for comparison; these are discussed in the next section.

Tabulated values of the acoustic environments for the 1.5 Launch Vehicle are provided in Tables 3.1 through 3.4

Table 3.1

NLS 1.5-Stage Predicted External Acoustic Levels for Liftoff

ZONE 1 OASPL= 152.7 dB	
Freq(Hz)	SPL(dB)
20.0	136.5
25.0	137.5
31.5	139.0
40.0	141.5
50.0	142.5
63.0	142.5
80.0	142.0
100.0	142.0
125.0	141.5
160.0	141.0
200.0	140.5
250.0	139.5
315.0	138.5
400.0	138.0
500.0	137.0
630.0	136.5
800.0	135.5
1000.0	134.5
1250.0	133.5
1600.0	132.0
2000.0	131.0
2500.0	129.5
3150.0	128.0
4000.0	126.0

ZONE 2 OASPL= 154.7 dB	
Freq(Hz)	SPL(dB)
20.0	138.5
25.0	139.5
31.5	141.0
40.0	143.5
50.0	144.5
63.0	144.5
80.0	144.0
100.0	144.0
125.0	143.5
160.0	143.0
200.0	142.5
250.0	141.5
315.0	140.5
400.0	140.0
500.0	139.0
630.0	138.5
800.0	137.5
1000.0	136.5
1250.0	135.5
1600.0	134.0
2000.0	133.0
2500.0	131.5
3150.0	130.0
4000.0	128.0

ZONE 3 OASPL= 155.7 dB	
Freq(Hz)	SPL(dB)
20.0	139.5
25.0	140.5
31.5	142.0
40.0	144.5
50.0	145.5
63.0	145.5
80.0	145.0
100.0	145.0
125.0	144.5
160.0	144.0
200.0	143.5
250.0	142.5
315.0	141.5
400.0	141.0
500.0	140.0
630.0	139.5
800.0	138.5
1000.0	137.5
1250.0	136.5
1600.0	135.0
2000.0	134.0
2500.0	132.5
3150.0	131.0
4000.0	129.0

ZONE 4 OASPL= 158.7 dB	
Freq(Hz)	SPL(dB)
20.0	142.5
25.0	143.5
31.5	145.0
40.0	147.5
50.0	148.5
63.0	148.5
80.0	148.0
100.0	148.0
125.0	147.5
160.0	147.0
200.0	146.5
250.0	145.5
315.0	144.5
400.0	144.0
500.0	143.0
630.0	142.5
800.0	141.5
1000.0	140.5
1250.0	139.5
1600.0	138.0
2000.0	137.0
2500.0	135.5
3150.0	134.0
4000.0	132.0

ZONE 5 OASPL= 166.6 dB	
Freq(Hz)	SPL(dB)
20.0	132.0
25.0	134.0
31.5	139.0
40.0	143.0
50.0	146.0
63.0	148.0
80.0	150.0
100.0	151.0
125.0	152.0
160.0	153.0
200.0	154.0
250.0	155.0
315.0	156.0
400.0	156.0
500.0	156.0
630.0	156.0
800.0	156.0
1000.0	155.0
1250.0	154.0
1600.0	153.0
2000.0	153.0
2500.0	152.0
3150.0	150.0
4000.0	148.0

Table 3.2
NLS 1.5-Stage Predicted Internal Liftoff Acoustic Levels

ZONE 1 OASPL= 143.6 dB Bare and Empty PLF		ZONE 1 OASPL= 139.0 dB 3 inch Blanket		ZONE 2 OASPL= 145.6 dB Bare and Empty PLF		ZONE 2 OASPL= 137.8 dB 3 inch Blanket	
Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)
20.0	122.0	20.0	107.2	20.0	124.0	20.0	111.0
25.0	130.5	25.0	114.7	25.0	132.5	25.0	120.0
31.5	133.0	31.5	115.5	31.5	135.0	31.5	124.3
40.0	130.1	40.0	128.7	40.0	132.1	40.0	128.1
50.0	132.4	50.0	123.9	50.0	134.5	50.0	123.4
63.0	132.5	63.0	127.0	63.0	132.3	63.0	123.3
80.0	130.3	80.0	128.6	80.0	133.7	80.0	128.5
100.0	131.7	100.0	132.4	100.0	134.6	100.0	128.6
125.0	132.6	125.0	129.8	125.0	135.2	125.0	127.1
160.0	133.2	160.0	129.3	160.0	135.9	160.0	128.1
200.0	133.9	200.0	132.3	200.0	135.2	200.0	131.3
250.0	133.2	250.0	127.3	250.0	135.2	250.0	126.6
315.0	131.8	315.0	119.8	315.0	133.8	315.0	120.6
400.0	129.8	400.0	114.8	400.0	131.8	400.0	114.5
500.0	126.7	500.0	110.1	500.0	128.7	500.0	110.7
630.0	125.2	630.0	107.7	630.0	127.2	630.0	110.2
800.0	122.1	800.0	108.2	800.0	124.1	800.0	111.0
1000.0	123.3	1000.0	109.9	1000.0	125.3	1000.0	112.6
1250.0	124.3	1250.0	114.1	1250.0	126.3	1250.0	113.7
1600.0	121.9	1600.0	115.2	1600.0	123.9	1600.0	
2000.0	120.9	2000.0	113.7	2000.0	122.9	2000.0	
2500.0	118.4	2500.0	109.1	2500.0	118.4	2500.0	
3150.0	110.7	3150.0	112.6	3150.0	112.7	3150.0	
4000.0	110.9	4000.0	112.3	4000.0	112.9	4000.0	

Table 3.2
NLS 1.5-Stage Predicted Internal Liftoff Acoustic Levels (Continued)

ZONE 3a OASPL= 141.7 dB		ZONE 3b OASPL= 141.2 dB		ZONE 4 OASPL= 143.9 dB		ZONE 5 OASPL= 146.6 dB	
Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)
20.0	121.0	20.0	123.0	20.0	126.0	20.0	115.5
25.0	124.0	25.0	123.5	25.0	126.5	25.0	117.0
31.5	125.0	31.5	127.0	31.5	130.0	31.5	124.0
40.0	129.5	40.0	131.0	40.0	134.0	40.0	129.5
50.0	132.5	50.0	132.0	50.0	135.0	50.0	132.5
63.0	133.5	63.0	132.0	63.0	135.0	63.0	134.5
80.0	132.5	80.0	131.5	80.0	134.4	80.0	136.5
100.0	131.5	100.0	132.5	100.0	135.5	100.0	137.5
125.0	132.0	125.0	130.5	125.0	133.5	125.0	138.0
160.0	130.5	160.0	132.0	160.0	135.0	160.0	141.0
200.0	132.0	200.0	130.0	200.0	130.5	200.0	134.8
250.0	129.0	250.0	128.5	250.0	126.0	250.0	133.3
315.0	125.5	315.0	123.0	315.0	121.5	315.0	131.8
400.0	122.5	400.0	121.0	400.0	119.5	400.0	130.3
500.0	120.0	500.0	120.0	500.0	118.5	500.0	130.3
630.0	119.5	630.0	118.5	630.0	117.0	630.0	129.3
800.0	117.5	800.0	116.0	800.0	114.5	800.0	127.3
1000.0	115.0	1000.0	113.5	1000.0	112.0	1000.0	125.3
1250.0	112.5	1250.0	111.0	1250.0	109.5	1250.0	122.8
1600.0	109.5	1600.0	108.0	1600.0	106.5	1600.0	120.8
2000.0	107.0	2000.0	105.5	2000.0	104.0	2000.0	118.8
2500.0	104.0	2500.0	102.5	2500.0	101.0	2500.0	116.3
3150.0	101.0	3150.0	99.5	3150.0	98.0	3150.0	112.5
4000.0	97.5	4000.0	95.5	4000.0	94.0	4000.0	108.8

Table 3.3
NLS 1.5-Stage Predicted External Aerodynamic Acoustic Levels

ZONE 1 OASPL= 174.5 dB	
Freq(Hz)	SPL(dB)
20.0	159.6
25.0	160.6
31.5	161.6
40.0	163.2
50.0	164.1
63.0	163.8
80.0	164.9
100.0	164.1
125.0	163.2
160.0	162.7
200.0	162.6
250.0	162.0
315.0	160.6
400.0	159.5
500.0	158.0
630.0	157.0
800.0	155.9
1000.0	154.5
1250.0	154.0
1600.0	153.4
2000.0	152.4
2500.0	151.9
3150.0	150.7
4000.0	148.4

ZONE 2 OASPL= 154.7 dB	
Freq(Hz)	SPL(dB)
20.0	132.0
25.0	134.0
31.5	136.0
40.0	137.5
50.0	139.8
63.0	141.1
80.0	143.0
100.0	143.3
125.0	143.3
160.0	143.5
200.0	144.0
250.0	143.9
315.0	142.5
400.0	142.1
500.0	141.0
630.0	140.8
800.0	140.7
1000.0	140.1
1250.0	140.4
1600.0	139.7
2000.0	139.0
2500.0	138.8
3150.0	137.2
4000.0	135.9

ZONE 3a OASPL= 166.5 dB	
Freq(Hz)	SPL(dB)
20.0	152.4
25.0	153.2
31.5	154.8
40.0	155.4
50.0	156.6
63.0	156.2
80.0	155.8
100.0	155.6
125.0	155.7
160.0	155.4
200.0	153.6
250.0	152.8
315.0	151.4
400.0	150.7
500.0	149.7
630.0	148.6
800.0	147.9
1000.0	147.2
1250.0	146.1
1600.0	145.0
2000.0	143.5
2500.0	141.6
3150.0	140.0
4000.0	138.0

ZONE 3b OASPL= 160.5 dB	
Freq(Hz)	SPL(dB)
20.0	155.5
25.0	150.0
31.5	151.4
40.0	149.0
50.0	148.9
63.0	143.9
80.0	147.4
100.0	146.0
125.0	143.1
160.0	140.9
200.0	141.1
250.0	143.5
315.0	143.7
400.0	145.9
500.0	144.5
630.0	144.8
800.0	141.9
1000.0	140.8
1250.0	142.3
1600.0	140.4
2000.0	138.4
2500.0	136.7
3150.0	134.0
4000.0	132.0

ZONE 4&5 OASPL= 153.1 dB	
Freq(Hz)	SPL(dB)
20.0	116.2
25.0	118.7
31.5	121.7
40.0	125.2
50.0	127.7
63.0	130.7
80.0	133.2
100.0	134.7
125.0	136.2
160.0	138.2
200.0	140.2
250.0	141.2
315.0	142.2
400.0	143.2
500.0	143.7
630.0	144.2
800.0	143.7
1000.0	142.2
1250.0	141.2
1600.0	139.2
2000.0	137.2
2500.0	135.2
3150.0	134.2
4000.0	129.2

Table 3.4
NLS 1.5-Stage Predicted Internal Aerodynamic Acoustic Levels

ZONE 1 OASPL= 164.8 dB Bare and Empty PLF	
Freq(Hz)	SPL(dB)
20.0	147.5
25.0	156.2
31.5	150.8
40.0	150.5
50.0	150.8
63.0	154.1
80.0	156.9
100.0	151.9
125.0	153.8
160.0	154.9
200.0	153.0
250.0	150.2
315.0	153.7
400.0	149.4
500.0	145.1
630.0	142.5
800.0	137.9
1000.0	138.6
1250.0	143.9
1600.0	144.5
2000.0	137.6
2500.0	136.5
3150.0	135.5
4000.0	134.6

ZONE 1 OASPL= 132.1 dB 3 Inch Blanket	
Freq(Hz)	SPL(dB)
20.0	108.4
25.0	109.4
31.5	109.6
40.0	117.2
50.0	113.0
63.0	120.3
80.0	121.3
100.0	120.5
125.0	121.0
160.0	122.0
200.0	124.0
250.0	122.6
315.0	122.3
400.0	119.9
500.0	115.0
630.0	112.4
800.0	112.5
1000.0	109.8
1250.0	108.8
1600.0	113.6
2000.0	116.9
2500.0	110.6
3150.0	110.4
4000.0	109.7

ZONE 2 OASPL= 144.5 dB Bare and Empty PLF	
Freq(Hz)	SPL(dB)
20.0	119.9
25.0	129.6
31.5	125.2
40.0	124.8
50.0	125.5
63.0	131.4
80.0	135.0
100.0	131.1
125.0	133.9
160.0	135.7
200.0	134.4
250.0	132.1
315.0	135.6
400.0	132.0
500.0	128.1
630.0	126.3
800.0	122.7
1000.0	124.2
1250.0	130.3
1600.0	130.8
2000.0	124.2
2500.0	125.4
3150.0	122.0
4000.0	122.1

ZONE 2 OASPL= 130.9 dB 3 Inch Blanket	
Freq(Hz)	SPL(dB)
20.0	110.7
25.0	117.3
31.5	120.4
40.0	115.3
50.0	119.0
63.0	118.6
80.0	119.5
100.0	121.9
125.0	120.3
160.0	120.8
200.0	118.6
250.0	122.2
315.0	116.1
400.0	114.0
500.0	108.8
630.0	108.0
800.0	110.5
1000.0	111.3
1250.0	112.1
1600.0	112.8
2000.0	113.8

Table 3.4
NLS 1.5-Stage Predicted Internal Aerodynamic Acoustic Levels (Cont.)

ZONE 3a OASPL= 152.4 dB		ZONE 3b OASPL= 145.4 dB		ZONE 4 OASPL= 135.5 dB		ZONE 5 OASPL= 135.0 dB	
Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)	Freq(Hz)	SPL(dB)
20.0	138.3	20.0	141.4	20.0	106.1	20.0	106.1
25.0	139.3	25.0	135.6	25.0	108.3	25.0	108.3
31.5	133.0	31.5	131.6	31.5	105.9	31.5	105.9
40.0	139.1	40.0	134.2	40.0	114.4	40.0	114.4
50.0	140.4	50.0	132.2	50.0	115.0	50.0	115.0
63.0	144.5	63.0	130.7	63.0	121.5	63.0	121.5
80.0	147.0	80.0	137.6	80.0	127.4	80.0	127.4
100.0	140.2	100.0	131.6	100.0	124.3	100.0	124.3
125.0	142.7	125.0	128.6	125.0	125.7	125.0	125.7
160.0	141.9	160.0	128.9	160.0	130.2	160.0	130.2
200.0	139.1	200.0	124.6	200.0	125.2	200.0	122.0
250.0	133.8	250.0	122.0	250.0	120.2	250.0	118.0
315.0	135.2	315.0	125.0	315.0	123.0	315.0	121.8
400.0	130.3	400.0	124.0	400.0	120.6	400.0	119.6
500.0	127.1	500.0	121.9	500.0	120.6	500.0	119.4
630.0	125.4	630.0	120.6	630.0	119.5	630.0	118.3
800.0	122.3	800.0	114.8	800.0	116.1	800.0	114.9
1000.0	120.0	1000.0	112.1	1000.0	113.0	1000.0	111.8
1250.0	121.2	1250.0	115.9	1250.0	114.3	1250.0	113.1
1600.0	120.7	1600.0	114.6	1600.0	112.9	1600.0	111.7
2000.0	111.8	2000.0	105.2	2000.0	103.5	2000.0	102.3
2500.0	112.8	2500.0	106.4	2500.0	104.4	2500.0	103.2
3150.0	112.1	3150.0	104.6	3150.0	104.3	3150.0	103.1
4000.0	107.8	4000.0	99.8	4000.0	96.5	4000.0	95.3

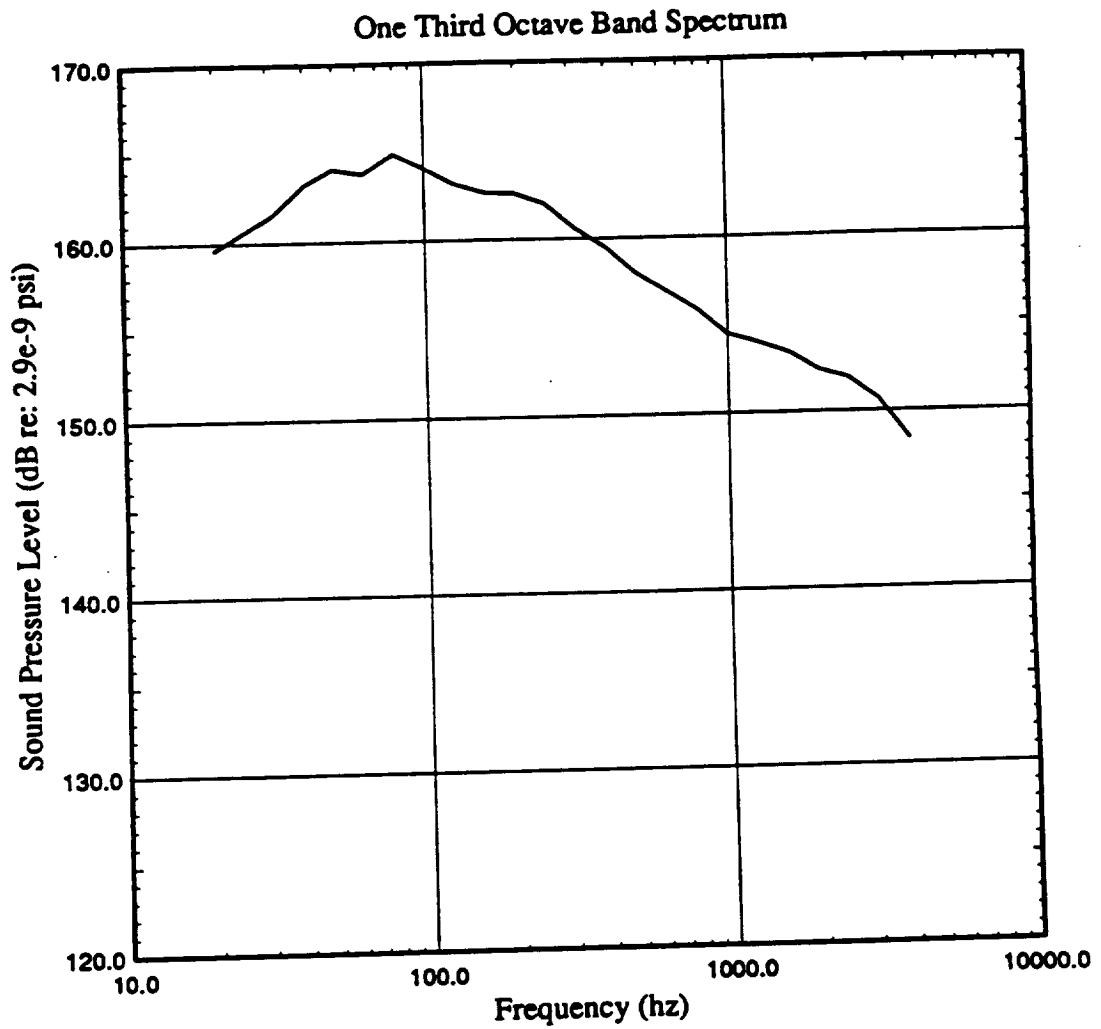


Figure 3.16
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 174.5 dB

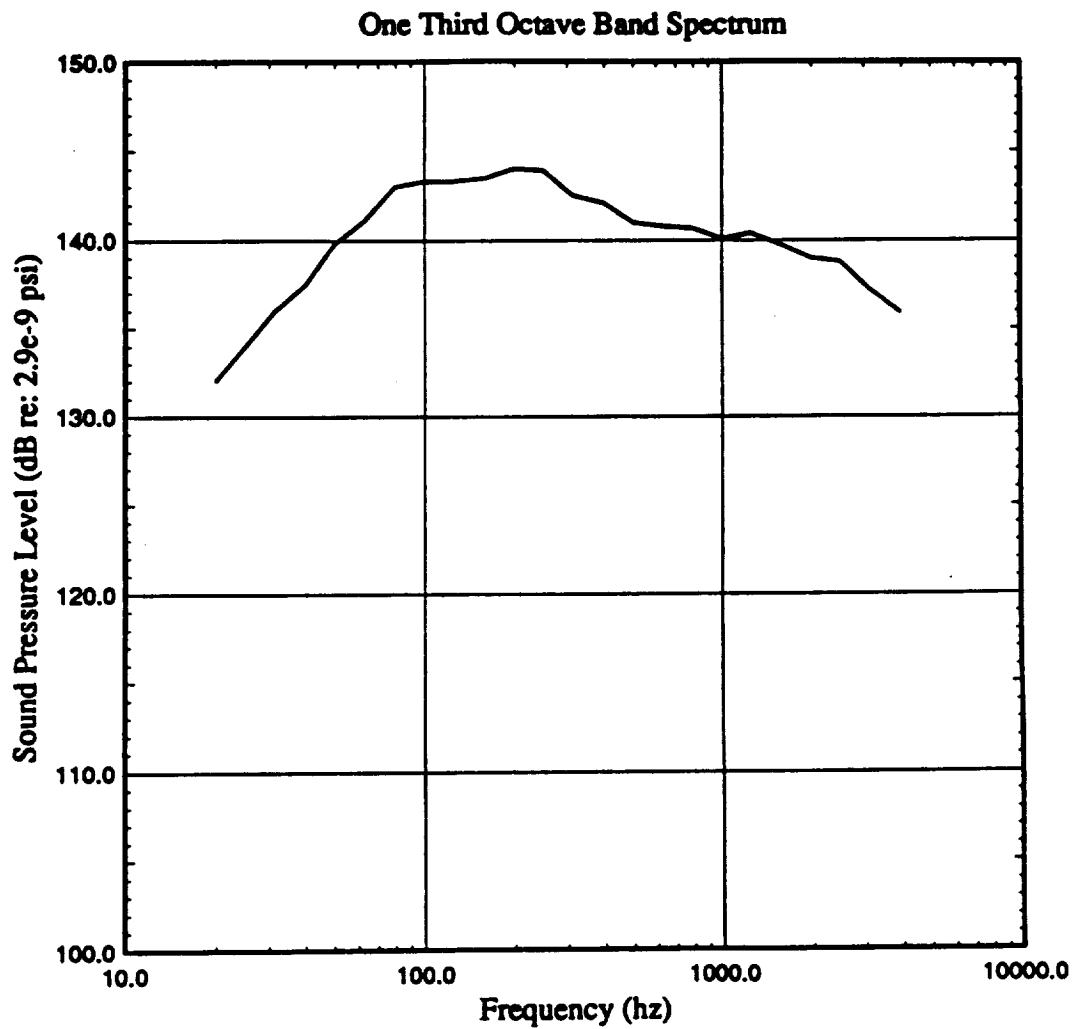


Figure 3.17

NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
 ZONE 2: PLF-Aft, PLF/Adapter Junction OASPL = 154.7 dB

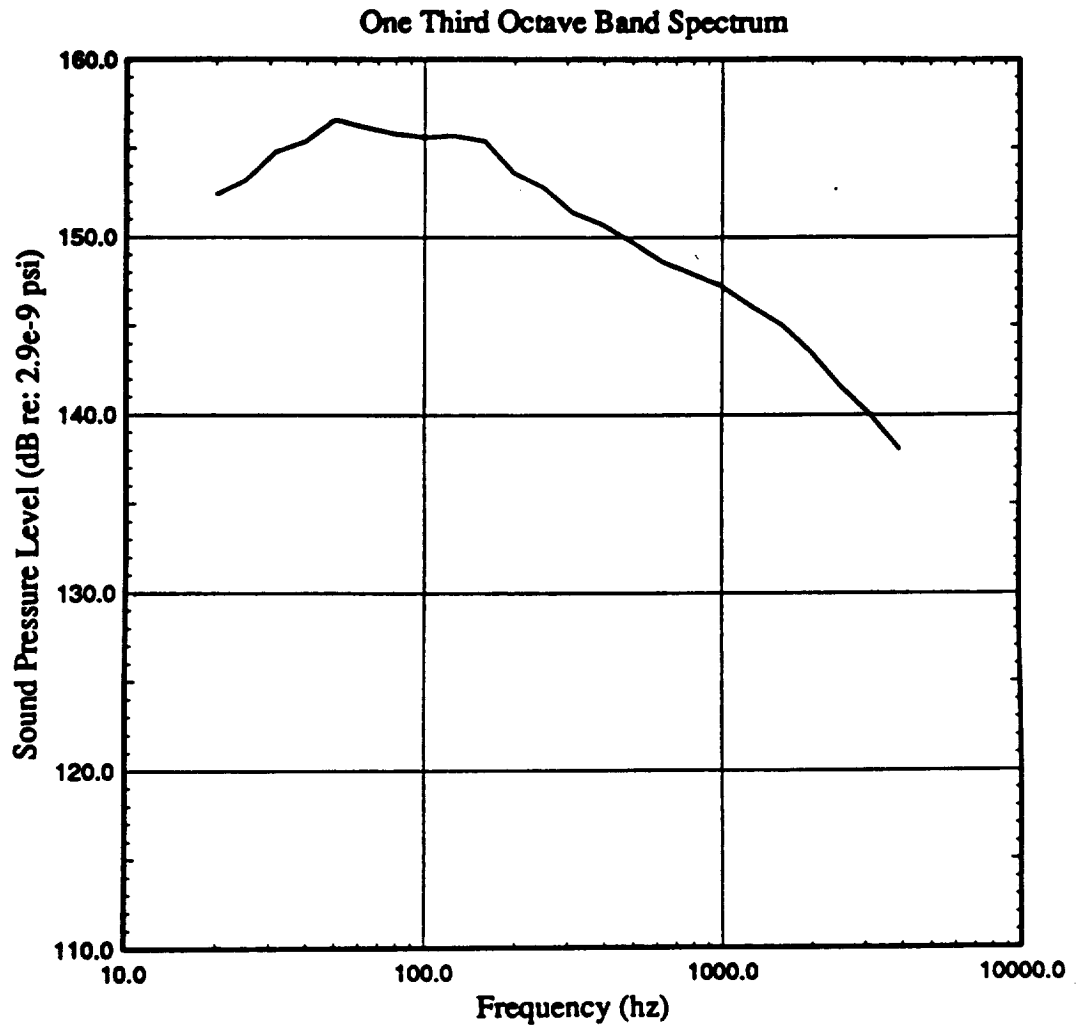


Figure 3.18
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 3a: PLF/Core Adapter, Conic Frustrum OASPL = 166.5 dB

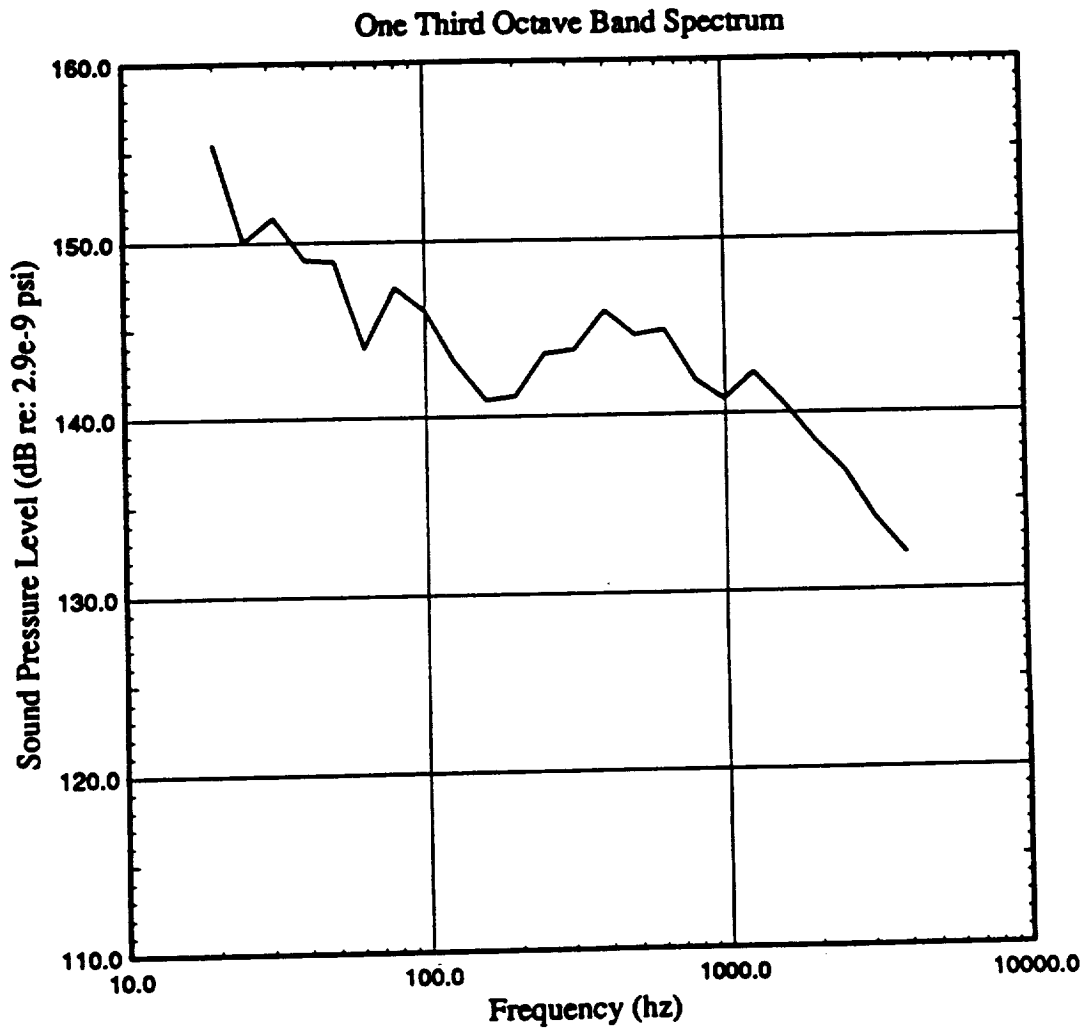


Figure 3.19
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 3b: Core Forward Skirt, Aft of Adapter OASPL = 160.5 dB

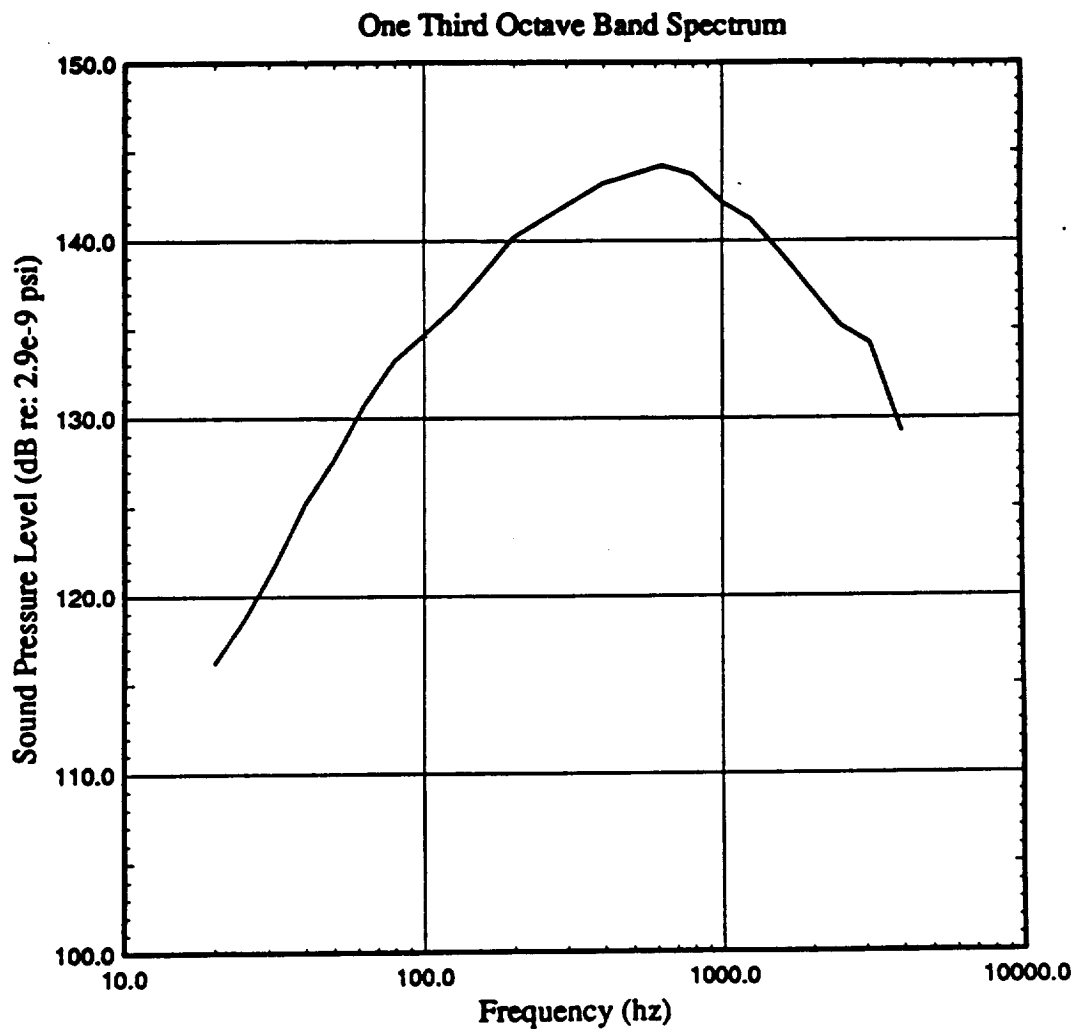


Figure 3.20
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 4: Core Intertank Skirt OASPL = 153.1 dB

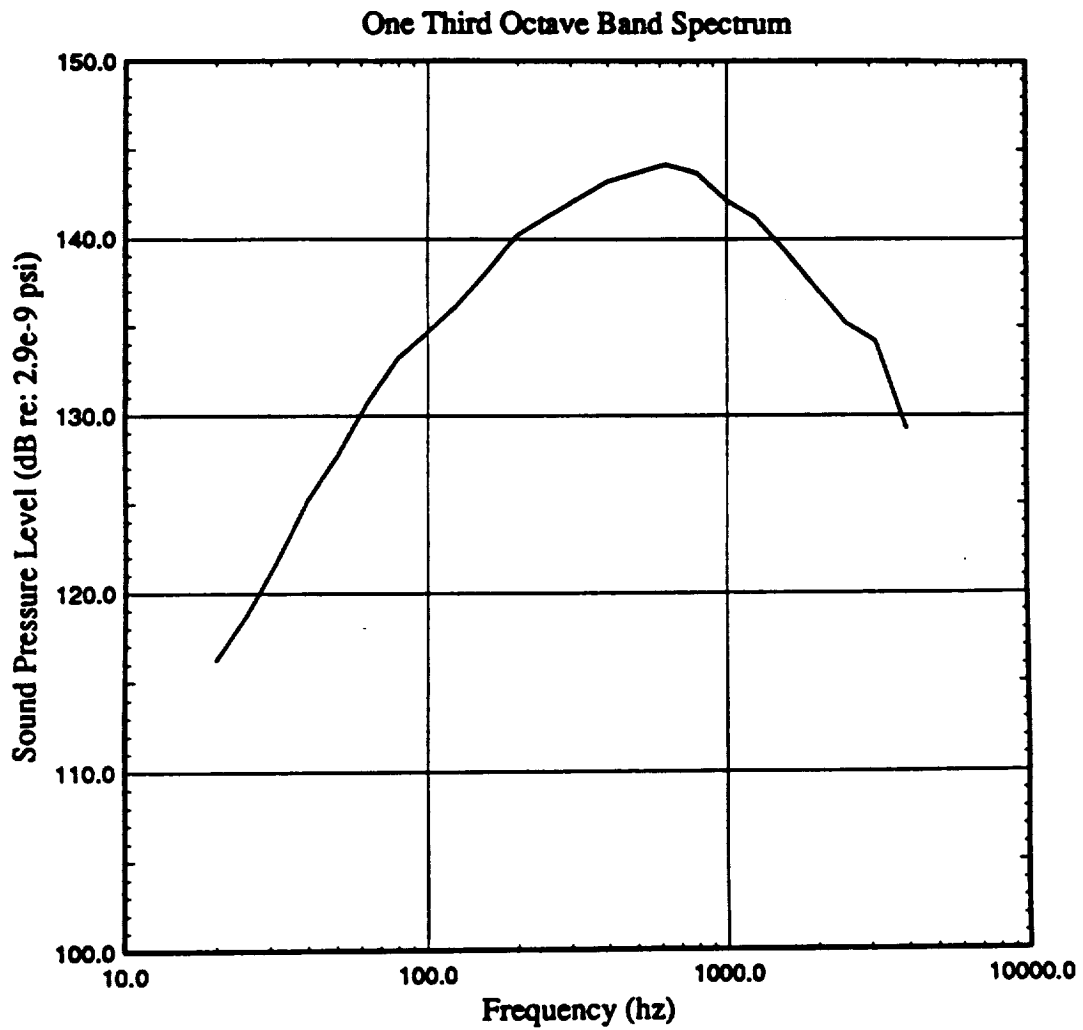


Figure 3.21
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 5: Aft Skirt and Prop. Module OASPL = 153.1 dB

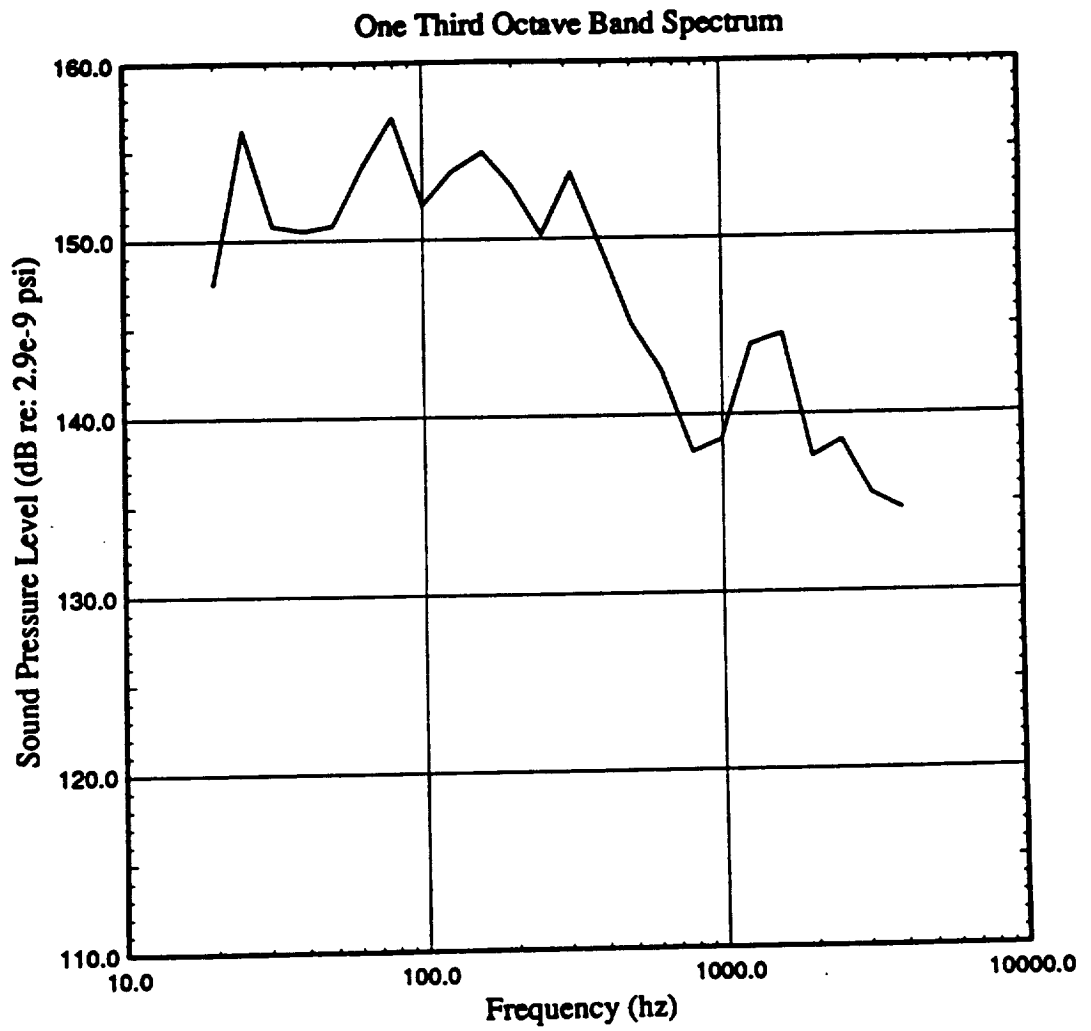


Figure 3.22
NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 164.8 dB

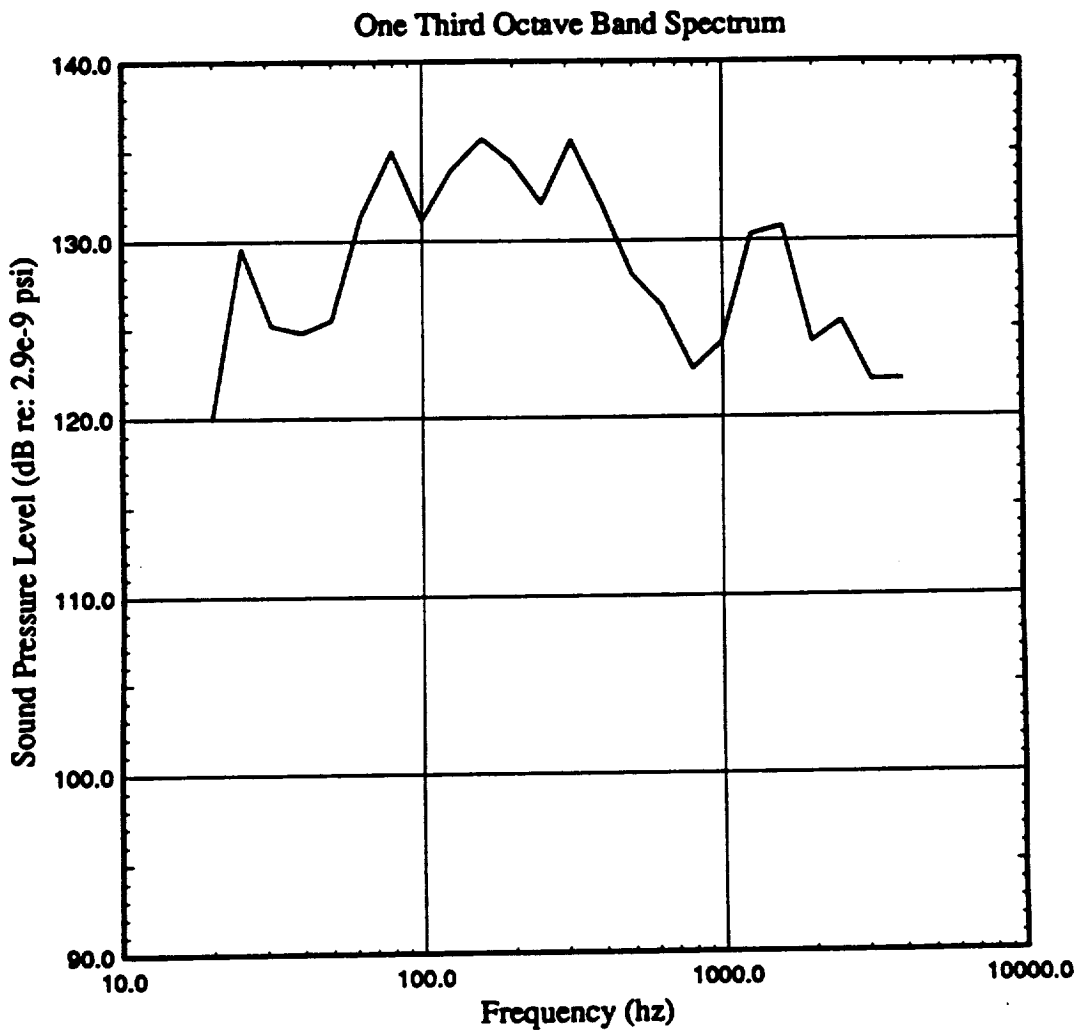


Figure 3.23
NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 144.5 dB

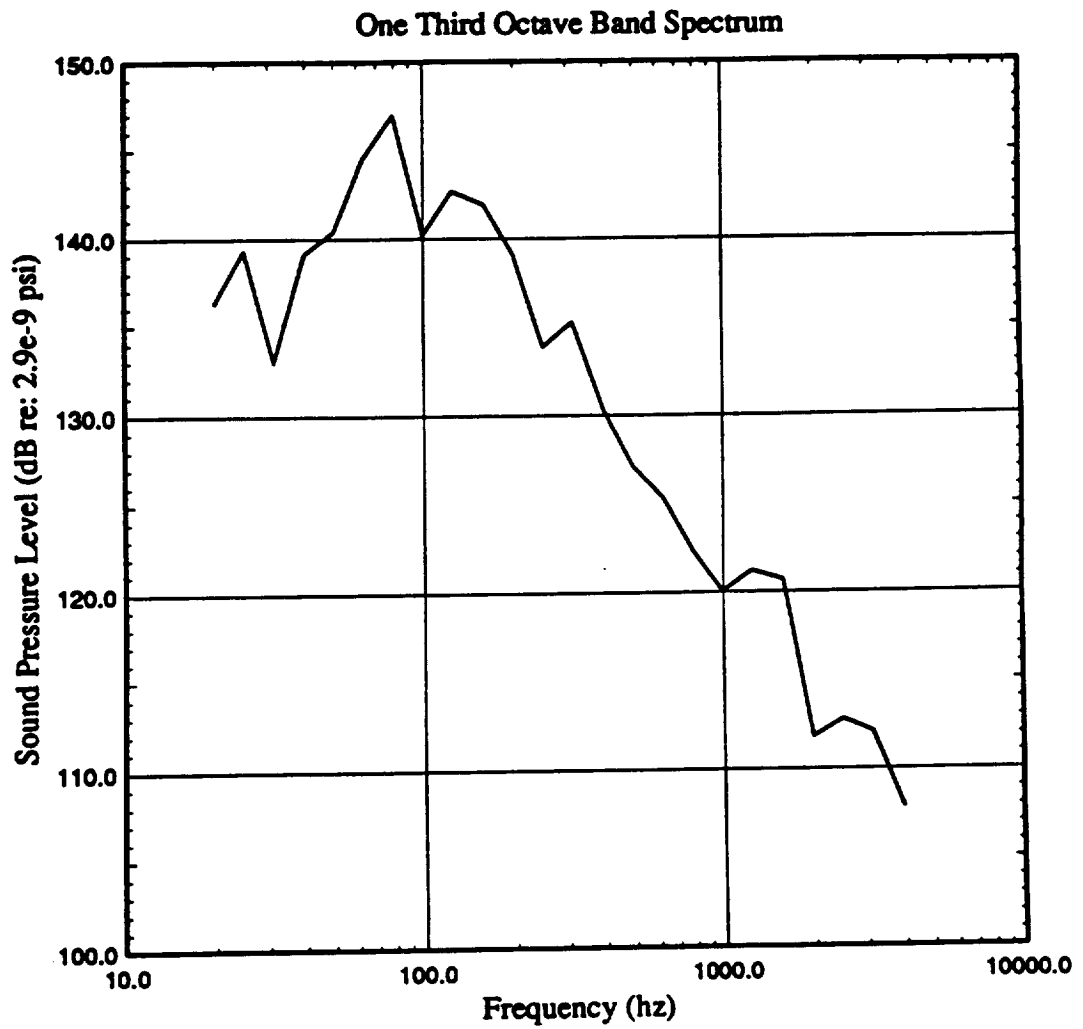


Figure 3.24

NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
 ZONE 3a: PLF/Core Adapter, Conic Frustrum OASPL = 152.4 dB

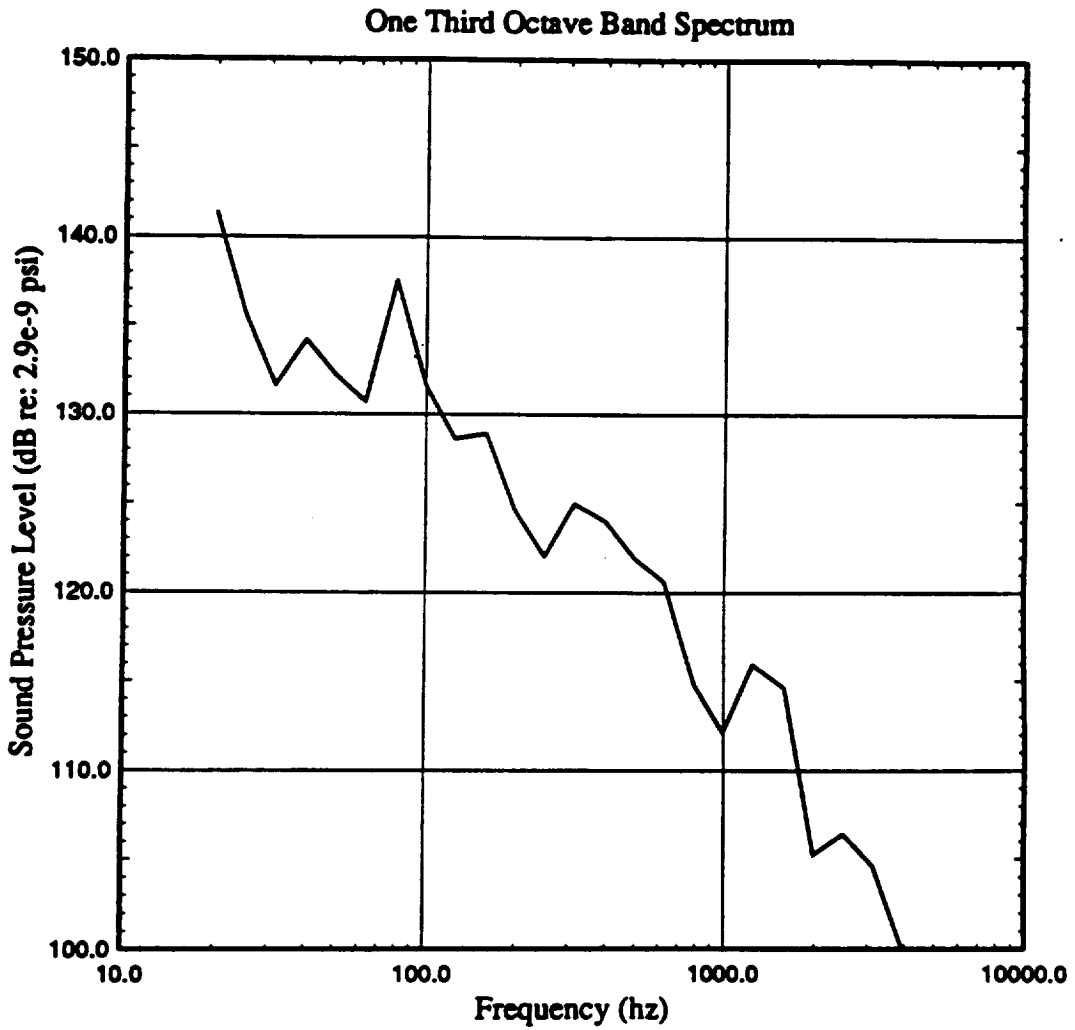


Figure 3.25

NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
 ZONE 3b: Core Forward Skirt, Aft of Adapter OASPL = 145.4 dB

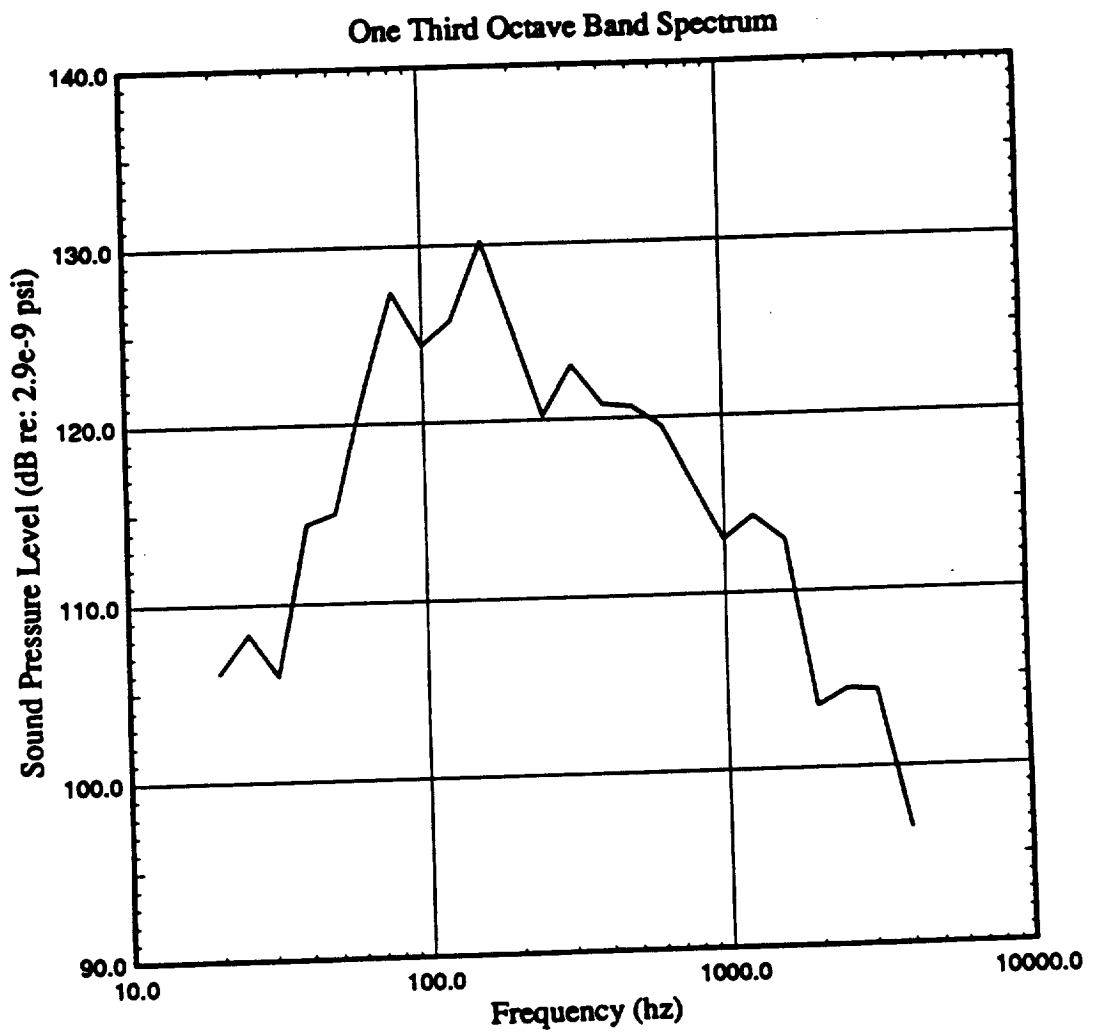


Figure 3.26
NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
ZONE 4: Core Intertank Skirt OASPL = 135.5 dB

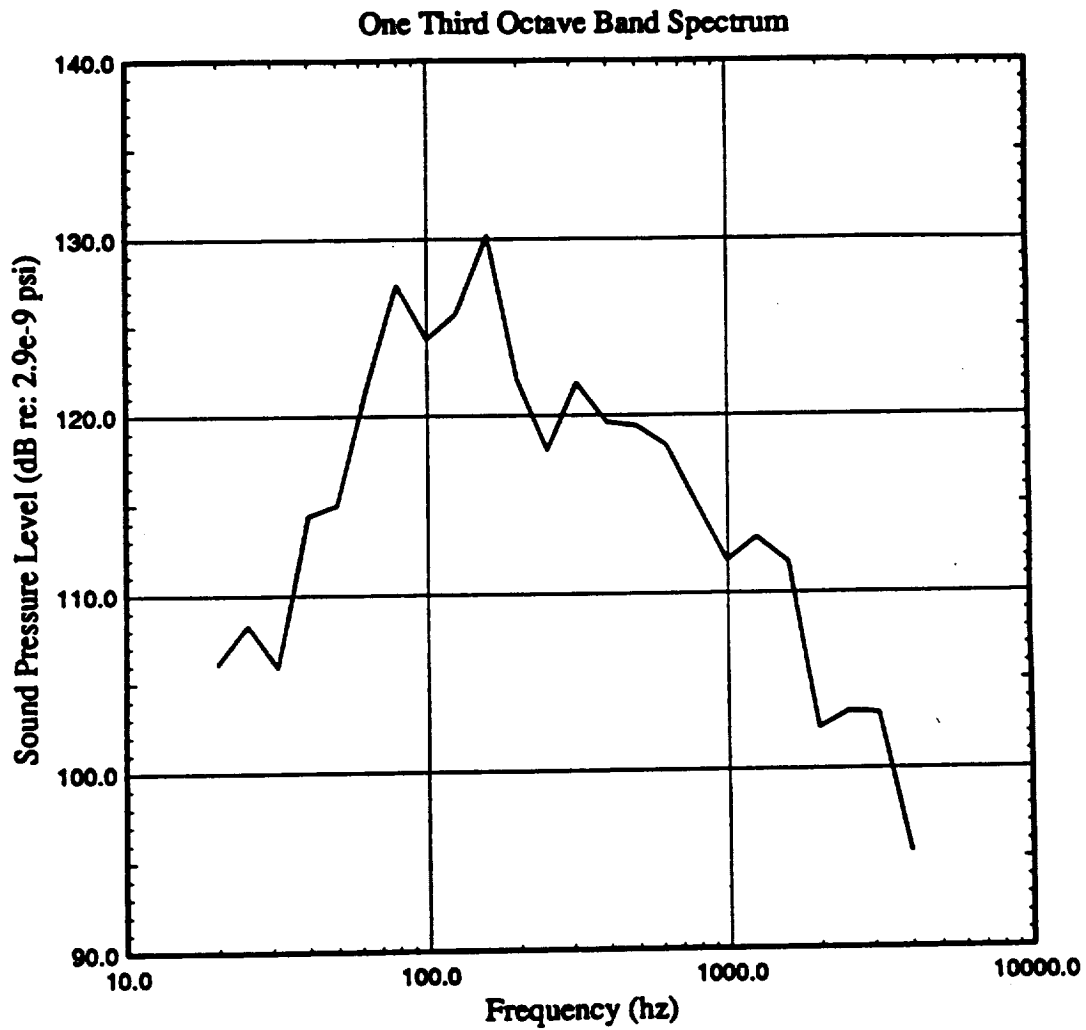


Figure 3.27

**NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
 ZONE 5: Aft Skirt and Prop. Module OASPL = 135.0 dB**

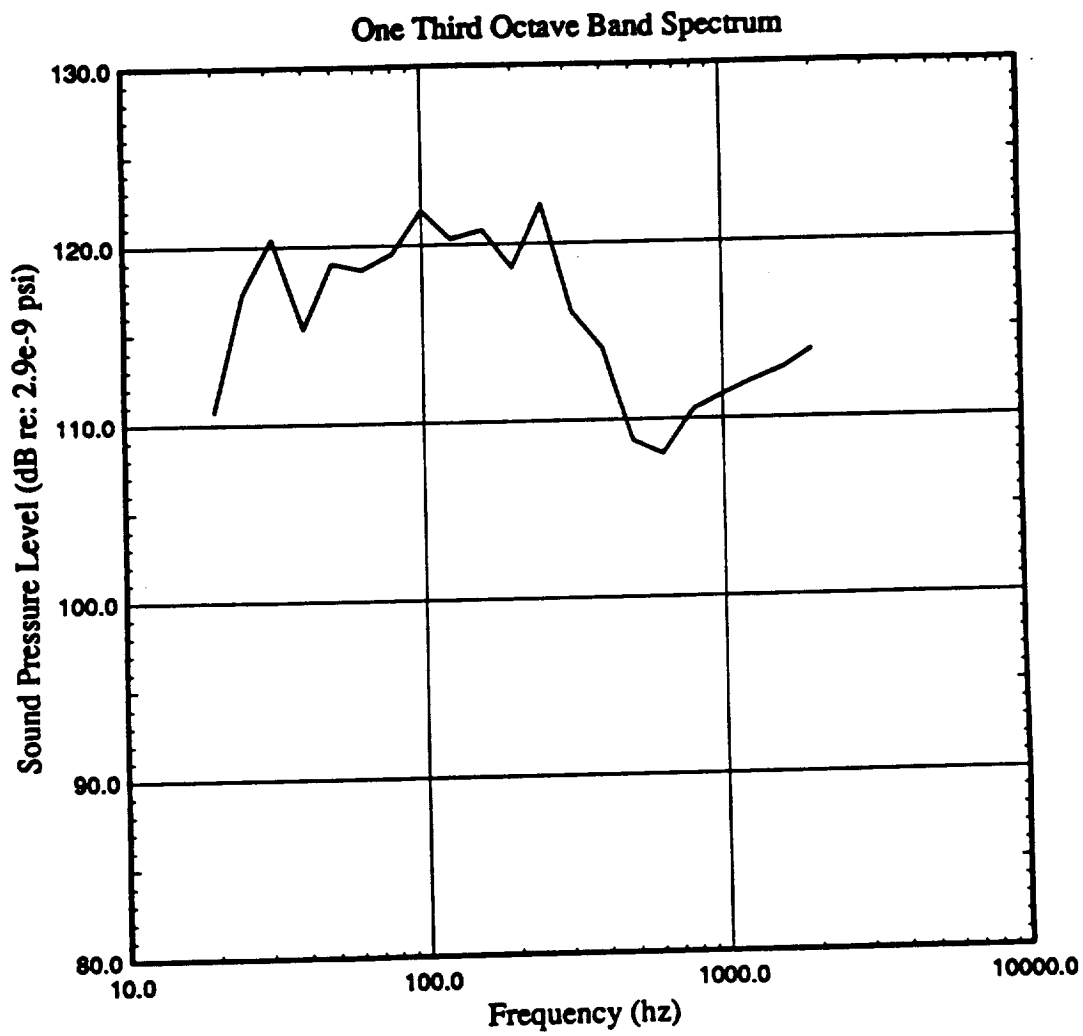


Figure 3.28
NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
Standard Titan-IV 3 inch PLF Blankets included
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 130.9 dB

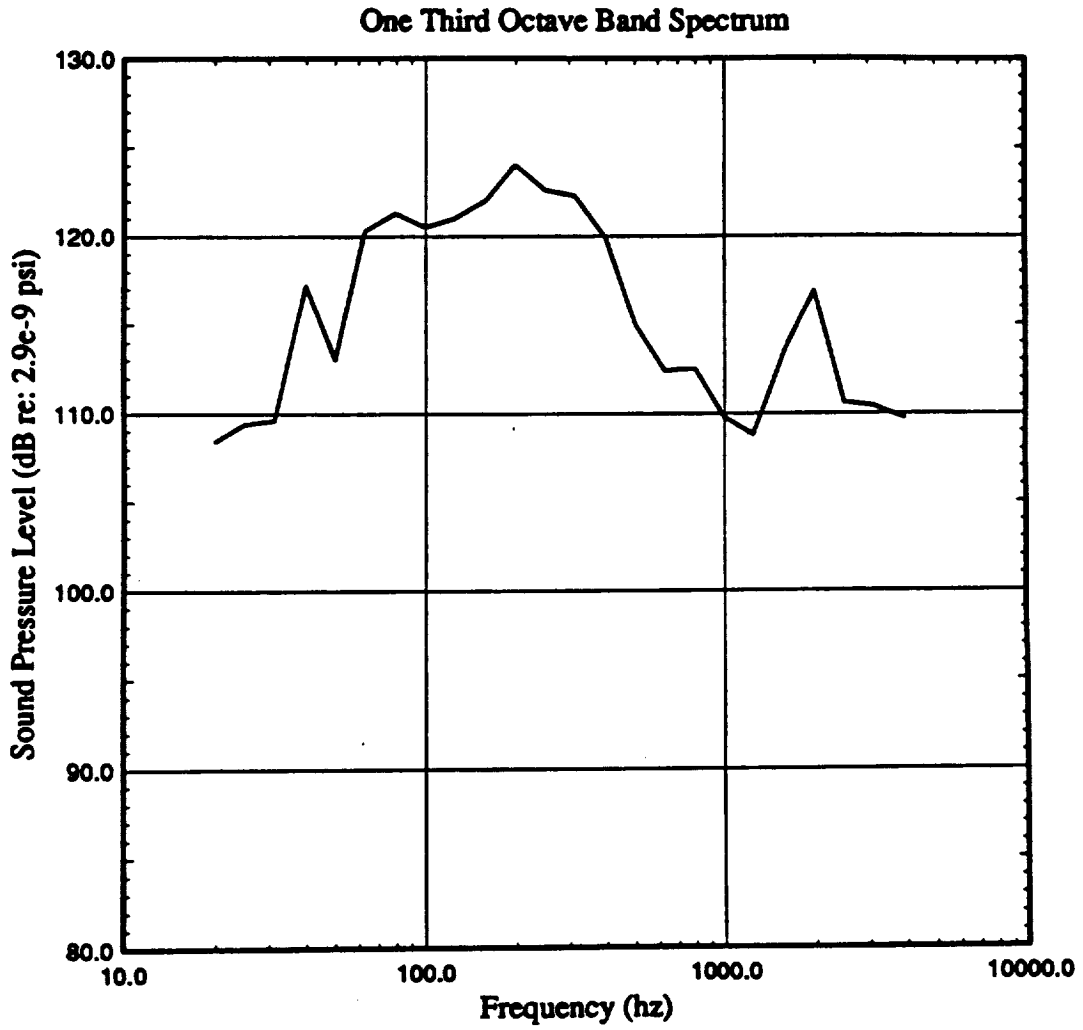
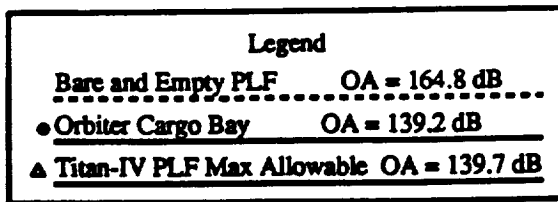


Figure 3.29

**NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
 Standard Titan-IV 3 inch PLF Blankets included
 ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 132.1 dB**



LIFTOFF AND AERODYNAMIC ENVELOPE

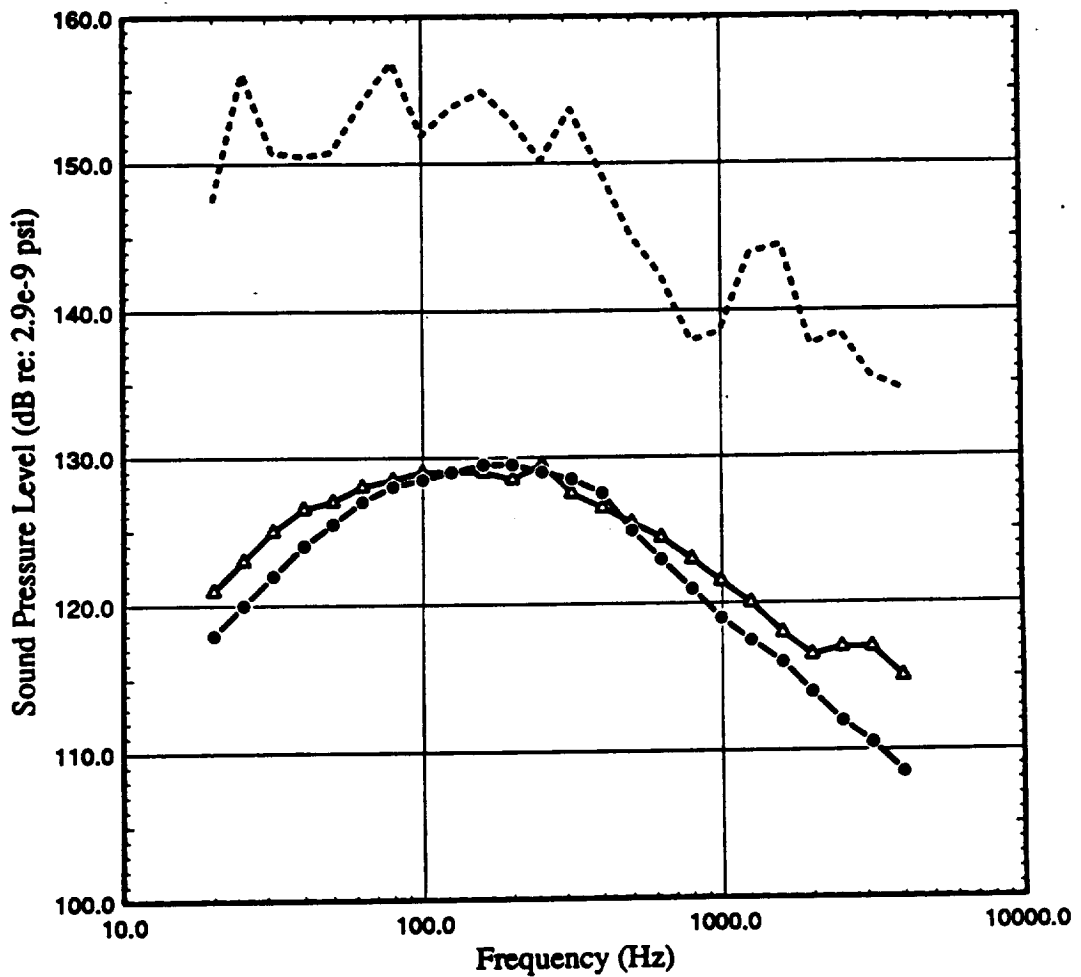


Figure 3.30
Comparison of Internal Acoustic Levels for 1.5 LV Zone 1
With Titan-IV and STS Orbiter Payload Requirements

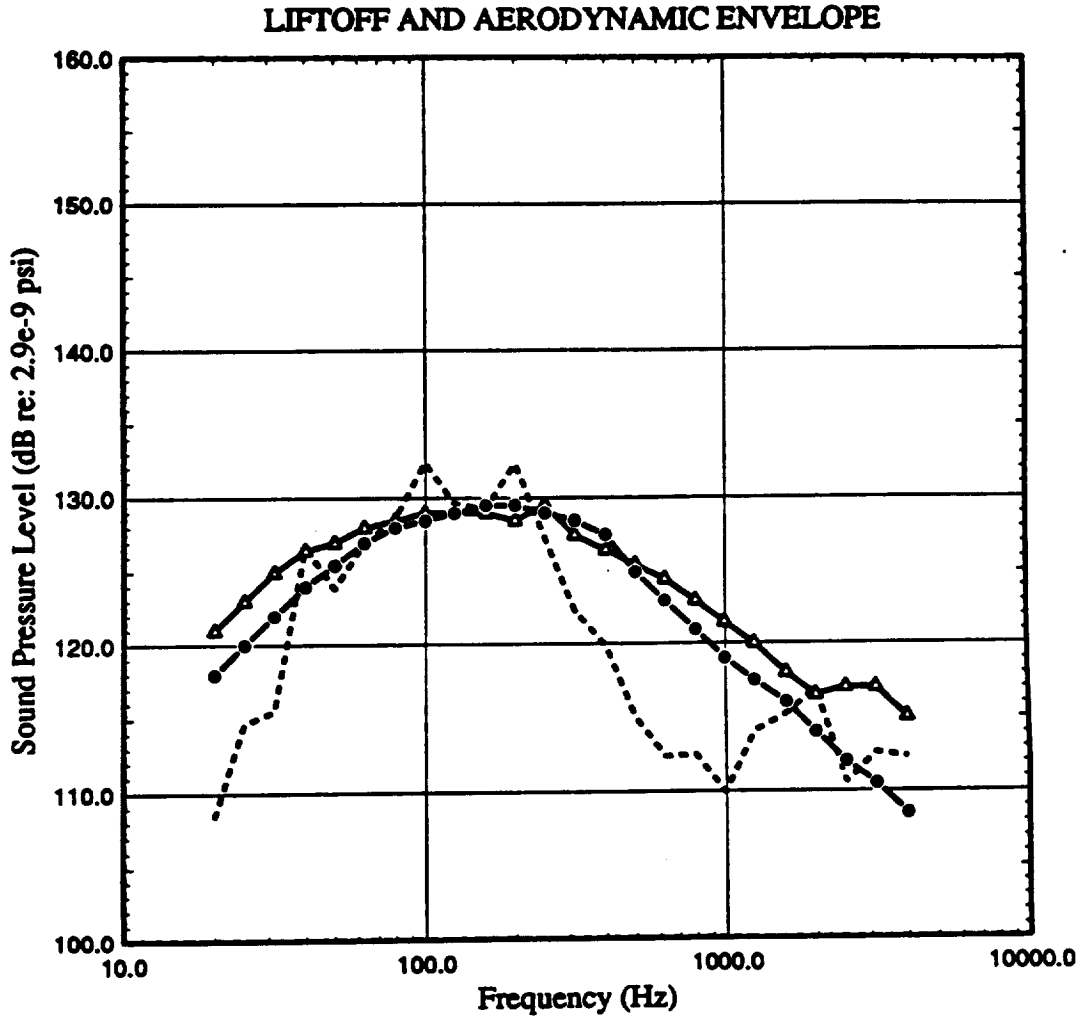
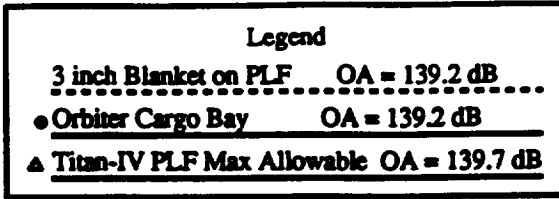


Figure 3.31
 Comparison of Internal Acoustic Levels for 1.5 LV Zone 1
 With Titan-IV and STS Orbiter Payload Requirements

Legend	
.....	Bare and Empty PLF OA = 146.2 dB
●	Orbiter Cargo Bay OA = 139.2 dB
▲	Titan-IV PLF Max Allowable OA = 139.7 dB

LIFTOFF AND AERODYNAMIC ENVELOPE

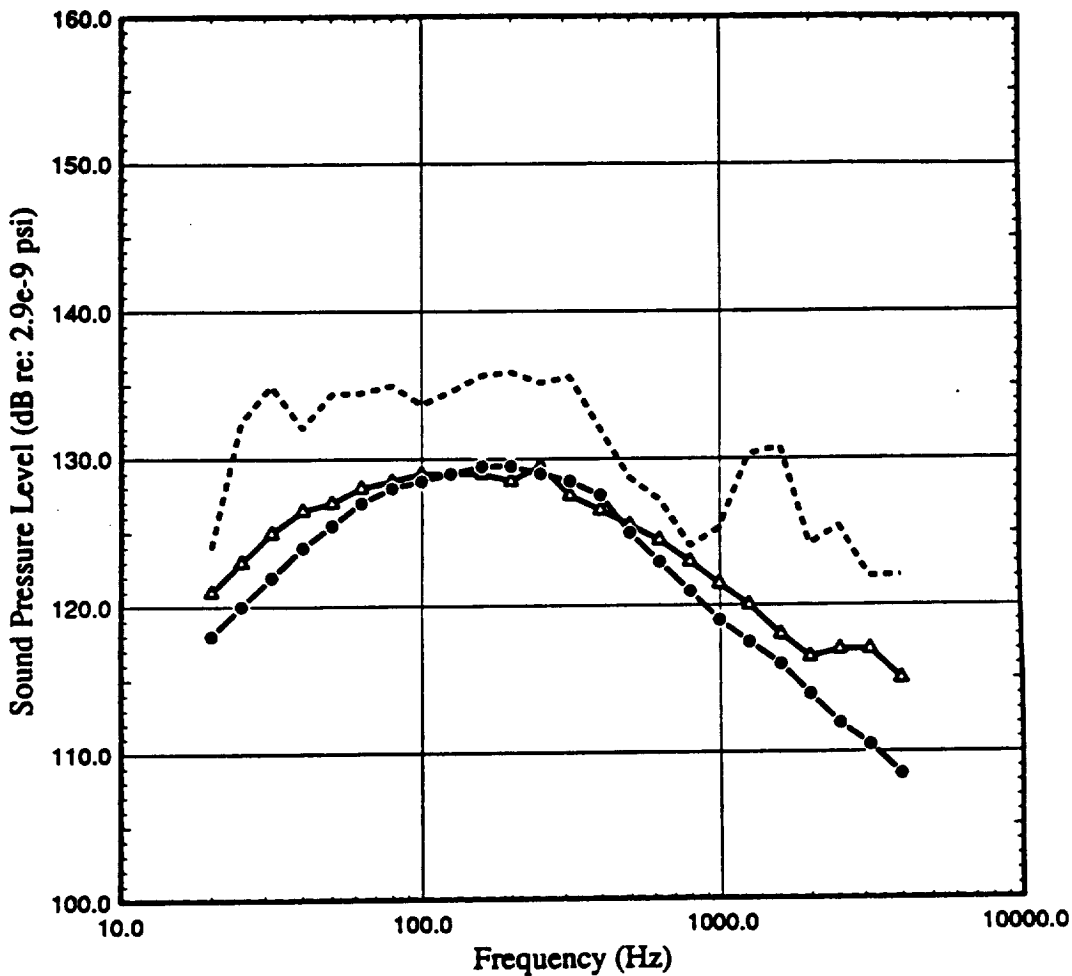
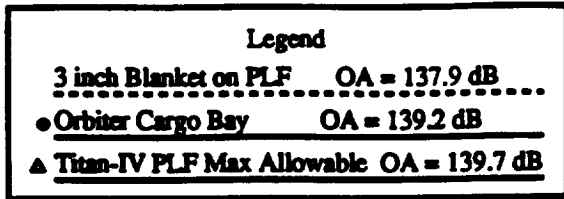


Figure 3.32

Comparison of Internal Acoustic Levels for 1.5 LV Zone 2 With Titan-IV and STS Orbiter Payload Requirements



LIFTOFF AND AERODYNAMIC ENVELOPE

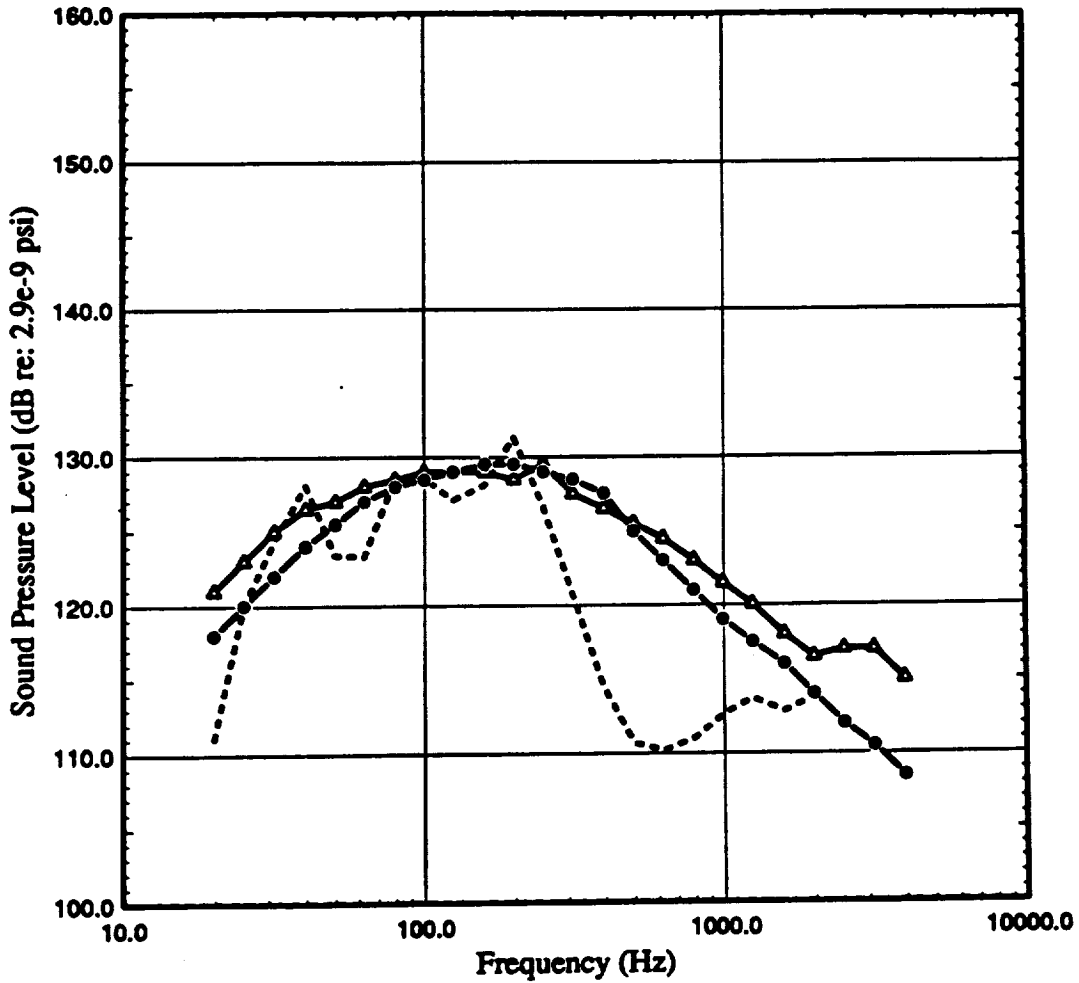


Figure 3.33
 Comparison of Internal Acoustic Levels for 1.5 LV Zone 2
 With Titan-IV and STS Orbiter Payload Requirements

4.0 Comparison with Requirements

4.1 HLLV

Figures 2.17 and 2.18 show that the predicted spectra within the bare HLLV PLF exceed the two baseline requirement curves over the full frequency range, by margins ranging from about 2 to 16 dB. The exceedance is greater for Zone C, at the forward end of the fairing; however, the Zone D comparison is probably more significant since most payloads will occupy the aft half of the PLF. The OASPL for Zone C is 152.7 dB, well above the requirement of 139 dB. For Zone D the overall level is 146.9 dB.

The addition of the standard Titan IV blanket (3" thick fiberglass) improved the situation considerably. For Zone C the OASPL was reduced to 139 dB, matching the requirement, although exceedances were still visible in a few frequency bands, primarily in the range below 100 Hz. In Zone D the bare OASPL of 146.9 dB was reduced to 140.8 dB by the blanket. Again, exceedances were noted to remain below 250 Hz.

The apparent improvement credited to the blanket is typical and believable for the upper frequencies--say above 300 Hz or so--but is questionable in the lower range, where very thick blankets would be required to provide the implied degree of absorption. The calculations leading to the results were based on data measured during a Titan 34D acoustic chamber test for the bare condition, and on Titan IV flight data for the blanketed condition. It is concluded that the differences in ambient conditions reduces the validity of the bare versus blanketed comparison, for the low frequencies. We would tend to have more confidence in the flight data, suggesting that the T-34D data might be excessively high in the low frequencies, where problems are often encountered in accurately measuring the average environment in an acoustic chamber. It would be useful if flight data could be obtained to determine the NR properties of a bare fairing, but we have not been able to locate any such data so far.

4.2 1.5 LV

The comparison of 1.5 LV internal PLF predictions with Titan IV and STS leads to conclusions similar to those discussed above. Figure 3.30 shows that the envelope of liftoff and ascent predictions inside the PLF (forward part, Zone 1) exceeds the specification curves by a margin of 15 to 20 dB. Adding a 3 inch blanket (Figure 3.31) essentially cures the problem -- the only remaining exceedances are in the 100 to 200 Hz bands and these are only 3 dB or so. However, this again would require the blanket to be very effective in the low frequencies, whereas experience indicates otherwise. Figure 3.32 makes the prediction versus specification comparison for the aft part of the PLF (Zone 2). The exceedance here still covers the whole frequency range, but is much less--1 to 13 dB. Figure 3.33 shows that adding the blanket brings the environment down to the point where the specification is only exceeded by 2 dB at 40 Hz and 200 Hz.

5.0 CONCLUSIONS

The acoustic predictions developed for the two NLS launch vehicles should provide a useful basis from which to develop specific acoustic and vibration environments inside the payload fairings and various vehicle compartments.

When the predicted internal acoustic levels for the payload region were compared with the specified environments for Titan IV and STS payloads, significant exceedances were found. The NLS levels were generally higher than the allowable spectra, over a wide range of frequencies. This conclusion applied to both NLS configurations. The situation was improved to some degree when the predictions were repeated with a standard Titan blanket (three inches thick) installed in the payload fairings, but the improvements can only be expected with confidence in the higher frequencies. It was concluded that other noise reduction methods should be investigated with the objective of lowering the low frequency environments. A number of possible approaches were discussed as subjects for follow-on work.

6.0 RECOMMENDATIONS FOR FOLLOW-ON EFFORT

The results of this study, when viewed in the context of our experience on other launch vehicle programs, indicate a number of areas in which we believe further effort should be expended. They are discussed in this section.

6.1 Methods of Attenuating Levels to Meet Requirements

There are two basic methods of reducing the acoustic environment inside the PLF: (i) improve the noise reduction performance of the fairing, and (ii) decrease the acoustic level emanating from the engine exhausts. Both methods would help the situation at liftoff, but the aerodynamic noise would only be reduced by the first approach.

(i) The addition of a 3" blanket was shown to increase the high frequency noise reduction properties of the PLF quite significantly (see, for example, Figure XXX) but it did not cause much improvement in the low frequencies. In other programs we have found that attaching constrained-layer viscoelastic damping to the inside surface of the PLF enhances its noise reduction properties across a wide frequency range, though the improvement is generally not large and the dimensions and stiffness of the damping system must be selected very carefully to maximize performance and justify the accompanying weight penalty. Effective treatment of the lower frequencies can result from using a dense limp barrier, installed inside the PLF so as to incorporate the optimum air gap between the barrier and the fairing to simulate a "double wall" structure.

The acoustic protection afforded by the PLF itself can be maximized if this requirement is incorporated into the structural design early enough. The noise reduction curve, shown in Figure ZZZ for a typical fairing, is strongly dependent on the circumferential stiffness, which defines the ring frequency of the cylinder. This is the frequency associated with the "breathing mode", in which the cylinder expands and contracts while maintaining a circular cross-section. The value of the ring frequency coincides with the minimum value of the curve, since it is the frequency at which the fairing tends to become acoustically transparent. If the ring frequency is increased over the initial value, the noise reduction curve will move to the right, along the frequency axis. This causes the low frequency noise reduction to increase while the high frequency noise reduction decreases. The loss in high frequency performance can readily be compensated for, with the use of absorptive blankets.

(ii) The acoustic levels generated by the engines at liftoff can be reduced to some degree by the use of water suppression and by designing the pad geometry to minimize reflection effects. Techniques

such as lengthening the exhaust duct have been investigated by MMAG in recent years and research is continuing in this area. We have demonstrated that subscale testing, in which the liftoff is simulated using cold gas jets, can provide valuable information on the acoustical impacts of pad design changes. This approach is reasonably low cost and gives repeatable results.

It must be emphasized that these techniques should be incorporated into the design process as early as possible, for maximum benefit to be realized.

6.2 Special Purpose Development Tests

There are several potential mitigation techniques in which analysis should be backed up by testing, to support the goal of achieving acoustic attenuation, including the following:

(i) The selection of optimum blanket/barrier/damping treatments, using panels mounted in a Transmission Loss acoustic chamber.

(ii) The development of local acoustic attenuation shrouds, used inside the payload fairing to protect subsystems which may have been previously qualified to a lower environment; this could be a cost-effective alternative to re-qualifying and/or re-designing the subsystem for the NLS environment.

(iii) The development of vibration isolation techniques for large subsystems, using off-the-shelf isolators selected on the basis of the subsystem frequencies and the shape of the acoustic spectrum inside the NLS payload fairing.

6.3 Vibration Studies

Even before NLS payloads are defined in detail, there are a number of general vibration problem areas that should be addressed. Recently developed techniques for estimating acoustically-induced vibration environments, such as the VAPEPS and PROXIMODE methods, should be evaluated in terms of their applicability to the NLS program. The development of a cost-effective flight instrumentation plan, which would integrate flight data with development testing and analysis could be started quite early in the program. Standardized flight instrumentation brackets should be developed, having appropriate frequency characteristics which will avoid data pollution caused by dynamic problems in the brackets themselves.

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8.0 APPENDICES

8.1 Appendix A: Bibliography.

The following publications were consulted during the study and found to provide useful insight into the acoustic prediction process. In some cases they were actually cited as reference material and are listed in Section 7.0. The remainder are included in this appendix for future reference.

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22. R. C. Potter and M. J. Crocker, "Acoustic Prediction Methods for Rocket Engines, Including the Effects of Clustered Engines and Deflected Exhaust Flow," NASA CR-566, October 1966.

8.2 Appendix B: Data Base From Previous Programs

This appendix provides tables of the Saturn program information which was utilized in the derivation of the 1.5 LV environmental estimates.

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0028-402, Time: T=2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 151.0 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	135.6
63.0	137.6
80.0	140.1
100.0	142.1
125.0	139.6
160.0	141.6
200.0	141.6
250.0	139.1
315.0	139.1
400.0	140.1
500.0	139.1
630.0	137.6
800.0	137.1
1000.0	132.1
1250.0	133.2
1600.0	130.7
2000.0	131.2
2500.0	126.2
3150.0	124.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0029-402, Time: T=2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 149.7 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	137.1
63.0	139.1
80.0	140.1
100.0	140.1
125.0	138.1
160.0	139.6
200.0	140.1
250.0	135.6
315.0	136.6
400.0	138.1
500.0	136.1
630.0	135.6
800.0	135.6
1000.0	135.6
1250.0	132.7
1600.0	129.2
2000.0	128.7
2500.0	125.7
3150.0	125.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0030-402, Time: T-2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 148.5 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	136.6
63.0	138.1
80.0	138.6
100.0	139.1
125.0	135.6
160.0	138.6
200.0	138.6
250.0	132.1
315.0	135.1
400.0	136.1
500.0	134.1
630.0	135.6
800.0	135.6
1000.0	135.1
1250.0	132.2
1600.0	128.7
2000.0	128.7
2500.0	126.2
3150.0	125.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0031-402, Time: T-2 seconds
Fwd end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 148.2 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	135.6
63.0	137.1
80.0	137.1
100.0	136.6
125.0	133.1
160.0	135.6
200.0	137.1
250.0	135.6
315.0	133.6
400.0	136.6
500.0	134.1
630.0	135.6
800.0	137.1
1000.0	137.1
1250.0	136.2
1600.0	132.7
2000.0	132.2
2500.0	130.7
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0032-402, Time: T-2 seconds
Fwd end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 149.4 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	135.6
63.0	137.6
80.0	138.1
100.0	139.6
125.0	138.1
160.0	139.1
200.0	138.6
250.0	135.6
315.0	130.1
400.0	134.6
500.0	137.1
630.0	137.1
800.0	137.1
1000.0	138.6
1250.0	135.7
1600.0	133.7
2000.0	133.2
2500.0	131.7
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0033-402, Time: T-2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 155.2 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	143.6
63.0	147.1
80.0	144.6
100.0	146.6
125.0	143.1
160.0	144.6
200.0	144.6
250.0	142.1
315.0	142.1
400.0	141.6
500.0	139.6
630.0	139.6
800.0	139.6
1000.0	140.1
1250.0	138.2
1600.0	134.2
2000.0	134.7
2500.0	135.2
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0034-402, Time: T=2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 152.4 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	137.1
63.0	141.6
80.0	141.6
100.0	142.6
125.0	139.6
160.0	143.1
200.0	143.6
250.0	139.6
315.0	139.6
400.0	139.6
500.0	138.6
630.0	139.6
800.0	138.6
1000.0	137.1
1250.0	137.2
1600.0	134.2
2000.0	134.2
2500.0	134.2
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0035-402, Time: T=2 seconds
Aft end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 152.6 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	138.1
63.0	142.6
80.0	142.6
100.0	141.6
125.0	138.6
160.0	143.1
200.0	141.6
250.0	141.1
315.0	140.6
400.0	140.6
500.0	138.6
630.0	139.1
800.0	139.6
1000.0	138.6
1250.0	136.2
1600.0	135.2
2000.0	134.7
2500.0	135.2
3150.0	130.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0036-402, Time: T=2 seconds
Fwd end of S-II / S-IVB Interstage, Forward Facing Conic Frustrum
OASPL = 153.0 dB (Ref 2.9e-09 psi)

50.0	139.6
63.0	143.6
80.0	142.6
100.0	142.6
125.0	138.6
160.0	140.6
200.0	141.6
250.0	140.1
315.0	140.6
400.0	140.6
500.0	139.6
630.0	140.6
800.0	140.6
1000.0	139.6
1250.0	138.2
1600.0	135.2
2000.0	137.2
2500.0	136.7
3150.0	136.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0037-404, Time: T=2 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OASPL = 154.3 dB (Ref 2.9e-09 psi)

50.0	140.6
63.0	145.6
80.0	145.6
100.0	142.6
125.0	140.6
160.0	143.1
200.0	143.1
250.0	141.6
315.0	140.6
400.0	141.1
500.0	140.1
630.0	141.6
800.0	139.6
1000.0	139.1
1250.0	140.2
1600.0	137.7
2000.0	136.7
2500.0	139.7
3150.0	131.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0038-404, Time: T=2 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OASPL = 153.2 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	138.1
63.0	143.6
80.0	143.6
100.0	141.6
125.0	139.6
160.0	142.6
200.0	143.1
250.0	142.1
315.0	141.6
400.0	141.1
500.0	138.6
630.0	139.1
800.0	138.6
1000.0	138.6
1250.0	137.2
1600.0	135.7
2000.0	136.7
2500.0	135.7
3150.0	128.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0039-404, Time: T=2 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OASPL = 150.3 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	135.6
63.0	137.6
80.0	139.6
100.0	141.1
125.0	138.1
160.0	142.1
200.0	140.1
250.0	137.1
315.0	138.6
400.0	138.1
500.0	135.1
630.0	135.6
800.0	134.6
1000.0	133.1
1250.0	137.2
1600.0	133.2
2000.0	133.2
2500.0	132.2
3150.0	126.2

Saturn Acoustic Data from Apollo 10 (AS-505)
External Microphone: B0016-219, Time: T=60 seconds
S-II Forward Skirt, Aft of Forward Facing Frustrum
OAFPL = 155.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	139.1
63.0	140.6
80.0	143.6
100.0	144.1
125.0	143.6
160.0	143.6
200.0	143.6
250.0	143.6
315.0	143.6
400.0	143.1
500.0	142.6
630.0	142.1
800.0	142.1
1000.0	141.7
1250.0	141.7
1600.0	141.7
2000.0	140.7
2500.0	138.7
3150.0	132.2

Saturn Acoustic Data from Apollo 10 (AS-505)
External Microphone: B0037-200, Time: T=80 seconds
S-II Aft Skirt, Barrell section
OAFPL = 149.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	125.6
63.0	127.6
80.0	130.6
100.0	132.6
125.0	134.1
160.0	136.1
200.0	136.6
250.0	136.6
315.0	136.6
400.0	135.6
500.0	136.6
630.0	142.1
800.0	140.6
1000.0	137.7
1250.0	137.7
1600.0	135.7
2000.0	134.7
2500.0	131.7
3150.0	128.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0036-402, Time: T=79 seconds
Fwd end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 150.8 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	133.6
63.0	136.1
80.0	139.6
100.0	141.6
125.0	138.6
160.0	141.1
200.0	141.6
250.0	140.1
315.0	140.1
400.0	138.1
500.0	137.6
630.0	136.6
800.0	137.1
1000.0	137.1
1250.0	134.7
1600.0	131.7
2000.0	130.2
2500.0	129.7
3150.0	119.2

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0037-404, Time: T=79 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OAFPL = 147.3 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	126.1
63.0	128.1
80.0	131.1
100.0	133.1
125.0	133.1
160.0	137.1
200.0	136.1
250.0	136.6
315.0	137.1
400.0	137.1
500.0	135.1
630.0	136.6
800.0	136.6
1000.0	136.1
1250.0	134.7
1600.0	131.7
2000.0	130.7
2500.0	130.2
3150.0	123.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0038-404, Time: T=79 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OAFPL = 148.3 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	127.1
63.0	130.1
80.0	132.6
100.0	134.1
125.0	133.6
160.0	137.6
200.0	137.1
250.0	138.1
315.0	138.1
400.0	137.6
500.0	136.1
630.0	137.1
800.0	136.6
1000.0	137.1
1250.0	136.7
1600.0	133.7
2000.0	131.7
2500.0	130.2
3150.0	125.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0039-404, Time: T=79 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OAFPL = 153.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	138.6
63.0	140.1
80.0	140.6
100.0	142.1
125.0	140.6
160.0	143.1
200.0	142.6
250.0	142.1
315.0	141.1
400.0	142.6
500.0	139.6
630.0	140.1
800.0	139.1
1000.0	140.1
1250.0	139.7
1600.0	136.7
2000.0	136.7
2500.0	136.7
3150.0	130.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0029-402, Time: T=77 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 147.5 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	126.1
63.0	125.1
80.0	125.6
100.0	128.6
125.0	128.1
160.0	133.1
200.0	134.1
250.0	132.1
315.0	135.6
400.0	136.6
500.0	135.1
630.0	137.1
800.0	137.6
1000.0	137.6
1250.0	138.2
1600.0	136.7
2000.0	136.7
2500.0	135.2
3150.0	127.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0030-402, Time: T=77 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 150.0 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	131.6
63.0	134.6
80.0	136.1
100.0	138.6
125.0	138.6
160.0	140.1
200.0	140.1
250.0	136.1
315.0	138.6
400.0	139.6
500.0	137.1
630.0	138.6
800.0	138.6
1000.0	136.6
1250.0	135.7
1600.0	132.7
2000.0	134.7
2500.0	132.7
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0034-402, Time: T=77 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 142.9 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	126.1
63.0	125.6
80.0	126.1
100.0	130.6
125.0	128.1
160.0	131.1
200.0	131.6
250.0	130.1
315.0	131.1
400.0	132.1
500.0	128.6
630.0	132.6
800.0	131.6
1000.0	130.6
1250.0	129.7
1600.0	128.7
2000.0	131.2
2500.0	130.2
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0035-402, Time: T=77 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 150.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	131.6
63.0	133.1
80.0	136.1
100.0	138.1
125.0	137.6
160.0	140.1
200.0	140.6
250.0	138.6
315.0	139.6
400.0	139.1
500.0	136.1
630.0	137.6
800.0	138.1
1000.0	137.6
1250.0	137.7
1600.0	133.7
2000.0	135.2
2500.0	133.2
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0036-402, Time: T=77 seconds
Fwd end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 152.4 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	136.6
63.0	138.6
80.0	140.6
100.0	142.1
125.0	140.6
160.0	142.6
200.0	143.1
250.0	140.1
315.0	140.1
400.0	140.1
500.0	138.6
630.0	140.1
800.0	140.1
1000.0	139.1
1250.0	139.2
1600.0	133.7
2000.0	135.2
2500.0	133.2
3150.0	126.2

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0037-404, Time: T=77 seconds
Aft end of S-IVB Aft Skirt, Cylinder Fwd of Frustrum
OAFPL = 146.6 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	127.6
63.0	130.1
80.0	133.6
100.0	133.6
125.0	131.6
160.0	134.6
200.0	135.1
250.0	134.6
315.0	133.6
400.0	133.6
500.0	130.1
630.0	131.6
800.0	132.6
1000.0	133.6
1250.0	137.7
1600.0	132.2
2000.0	133.2
2500.0	138.7
3150.0	128.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0038-404, Time: T=77 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OAFPL = 149.7 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	131.1
63.0	131.6
80.0	135.1
100.0	135.6
125.0	133.6
160.0	138.6
200.0	140.1
250.0	139.6
315.0	139.1
400.0	139.1
500.0	136.1
630.0	137.1
800.0	138.1
1000.0	138.6
1250.0	137.2
1600.0	134.7
2000.0	135.7
2500.0	135.7
3150.0	125.7

Saturn Acoustic Data from Apollo 12 (AS-507)
External Microphone: B0039-404, Time: T=77 seconds
Aft end of S-IVB Skirt, Cylinder Fwd of Frustrum
OAFPL = 151.0 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	134.6
63.0	136.1
80.0	137.1
100.0	138.1
125.0	138.1
160.0	142.6
200.0	143.1
250.0	140.1
315.0	140.1
400.0	139.6
500.0	137.6
630.0	137.1
800.0	137.1
1000.0	136.6
1250.0	136.2
1600.0	133.2
2000.0	134.7
2500.0	134.7
3150.0	126.2

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0028-402, Time: T=82 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 144.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	120.6
63.0	123.1
80.0	126.1
100.0	130.6
125.0	130.6
160.0	134.1
200.0	136.1
250.0	136.1
315.0	135.6
400.0	132.1
500.0	130.1
630.0	130.6
800.0	130.6
1000.0	130.1
1250.0	128.7
1600.0	127.7
2000.0	127.7
2500.0	125.7
3150.0	118.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0029-402, Time: T=82 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 150.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	128.6
63.0	131.6
80.0	135.6
100.0	137.6
125.0	137.6
160.0	140.6
200.0	140.6
250.0	141.1
315.0	140.6
400.0	138.6
500.0	136.6
630.0	137.1
800.0	137.6
1000.0	135.1
1250.0	135.2
1600.0	135.7
2000.0	133.2
2500.0	132.7
3150.0	122.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0030-402, Time: T=82 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 149.0 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	130.1
63.0	131.6
80.0	134.1
100.0	135.6
125.0	137.1
160.0	139.1
200.0	139.6
250.0	139.6
315.0	138.6
400.0	138.1
500.0	136.6
630.0	137.1
800.0	137.1
1000.0	135.6
1250.0	134.2
1600.0	132.2
2000.0	131.2
2500.0	129.7
3150.0	121.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0031-402, Time: T=82 seconds
Fwd end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 145.1 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	132.6
63.0	133.1
80.0	132.6
100.0	131.6
125.0	131.1
160.0	133.6
200.0	134.1
250.0	133.6
315.0	133.1
400.0	132.6
500.0	132.1
630.0	133.6
800.0	135.1
1000.0	134.1
1250.0	130.7
1600.0	128.7
2000.0	128.2
2500.0	126.2
3150.0	122.2

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0032-402, Time: T=82 seconds
Fwd end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 138.6 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	124.1
63.0	122.1
80.0	123.6
100.0	123.1
125.0	120.6
160.0	123.6
200.0	125.1
250.0	126.6
315.0	126.6
400.0	126.6
500.0	127.1
630.0	129.6
800.0	130.1
1000.0	128.1
1250.0	126.7
1600.0	123.7
2000.0	123.7
2500.0	122.7
3150.0	118.7

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0033-402, Time: T=75 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 144.2 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	130.6
63.0	132.1
80.0	131.1
100.0	132.1
125.0	129.1
160.0	132.1
200.0	131.6
250.0	132.6
315.0	135.1
400.0	132.1
500.0	131.1
630.0	132.1
800.0	132.1
1000.0	131.6
1250.0	131.2
1600.0	130.2
2000.0	130.2
2500.0	127.7
3150.0	122.2

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0034-402, Time: T=82 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 144.3 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	124.6
63.0	125.6
80.0	127.1
100.0	128.6
125.0	129.6
160.0	132.6
200.0	133.6
250.0	132.6
315.0	134.1
400.0	134.1
500.0	133.1
630.0	134.1
800.0	133.6
1000.0	132.6
1250.0	132.7
1600.0	129.7
2000.0	129.7
2500.0	127.7
3150.0	122.2

Saturn Acoustic Data from Apollo 13 (AS-508)
External Microphone: B0035-402, Time: T=75 seconds
Aft end of S-II / S-IVB Interstage Skirt, Forward Facing Conic Frustrum
OAFPL = 145.9 dB (Ref 2.9e-09 psi)

Freq (Hz)	SPL (dB)
50.0	127.6
63.0	129.1
80.0	132.1
100.0	134.6
125.0	131.6
160.0	134.6
200.0	135.6
250.0	135.6
315.0	136.1
400.0	136.1
500.0	134.1
630.0	135.1
800.0	133.6
1000.0	132.1
1250.0	131.7
1600.0	127.7
2000.0	128.2
2500.0	126.2
3150.0	123.2

8.3 Appendix C: NLS Launch Vehicle Information Used In Study

This appendix contains a compilation of the NLS physical properties and tabulated trajectory information, as a means of providing a convenient access to the data for future applications.

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psf)	Mach Number
44	1,251	25,213	798	1.180
45	1,277	26,294	802	1.210
46	1,303	27,388	804	1.240
47	1,330	28,496	805	1.271
48	1,356	29,618	806	1.302
49	1,383	30,752	806	1.334
50	1,411	31,899	805	1.367
51	1,439	33,058	803	1.401
52	1,468	34,231	801	1.437
53	1,498	35,416	798	1.473
54	1,528	36,613	794	1.511
55	1,559	37,824	790	1.550
56	1,591	39,047	784	1.589
57	1,624	40,283	778	1.630
58	1,658	41,532	770	1.671
59	1,693	42,795	762	1.714
60	1,729	44,071	756	1.762
61	1,766	45,360	749	1.810
62	1,804	46,663	741	1.860
63	1,843	47,979	732	1.910
64	1,884	49,309	721	1.961
65	1,925	50,653	709	2.013
66	1,968	52,011	697	2.064
67	2,012	53,383	683	2.116
68	2,058	54,769	668	2.168
69	2,104	56,168	652	2.220
70	2,152	57,582	635	2.272
71	2,201	59,010	614	2.317
72	2,251	60,452	596	2.368
73	2,302	61,907	578	2.419
74	2,355	63,377	563	2.476
75	2,409	64,860	547	2.532
76	2,464	66,357	529	2.582
77	2,520	67,868	512	2.635
78	2,577	69,393	495	2.689
79	2,636	70,930	479	2.745
80	2,696	72,482	463	2.801
81	2,757	74,047	447	2.857
82	2,819	75,626	431	2.915
83	2,883	77,218	416	2.974
84	2,947	78,823	401	3.033
85	3,013	80,441	387	3.093
86	3,079	82,072	373	3.153
87	3,146	83,716	359	3.215
88	3,213	85,372	345	3.277
89	3,282	87,040	332	3.340
90	3,351	88,720	319	3.403
91	3,420	90,411	306	3.467
92	3,490	92,113	294	3.531
93	3,561	93,826	282	3.592
94	3,632	95,548	270	3.653
95	3,703	97,281	258	3.715
96	3,775	99,023	247	3.776
97	3,848	100,774	236	3.838
98	3,920	102,533	225	3.899

NASA/MSFC August-1991 Reference Trajectory for HLLV (all STMEs working)

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psf)	Mach Number
99	3,994	104,301	215	3.960
100	4,067	106,076	205	4.020
101	4,142	107,859	195	4.081
102	4,216	109,649	186	4.141
103	4,291	111,446	177	4.202
104	4,367	113,250	169	4.263
105	4,443	115,060	161	4.325
106	4,520	116,875	154	4.387
107	4,597	118,696	146	4.449
108	4,674	120,523	139	4.512
109	4,752	122,354	133	4.575
110	4,831	124,190	127	4.638
111	4,910	126,030	121	4.701
112	4,990	127,874	115	4.764
113	5,069	129,722	109	4.826
114	5,140	131,571	104	4.881
115	5,212	133,421	99	4.936
116	5,284	135,269	94	4.991
117	5,355	137,116	89	5.046
118	5,427	138,962	85	5.101
119	5,498	140,806	80	5.155
120	5,569	142,648	76	5.209
121	5,635	144,486	72	5.259
121.4	5,660	145,219	71	5.278
121.4	5,660	145,219	71	5.278
122	5,701	146,319	69	5.310
123	5,764	148,146	65	5.359
124	5,823	149,966	62	5.404
125	5,876	151,778	59	5.444
126	5,925	153,578	56	5.481
126.4	5,943	154,295	54	5.495
126.4	5,943	154,295	54	5.495
127	5,971	155,366	53	5.515
128	6,014	157,141	50	5.548
129	6,055	158,902	47	5.581
130	6,094	160,649	45	5.613
131	6,133	162,381	42	5.653
131.4	6,148	163,070	42	5.670
131.4	6,148	163,070	42	5.670
135	6,305	169,168	35	5.842
140	6,530	177,352	28	6.103
141.4	6,594	179,585	26	6.181
141.4	6,594	179,585	26	6.181
145	6,762	185,211	22	6.388
150	7,003	192,755	18	6.693
155	7,252	199,996	15	7.017
160	7,509	206,946	12	7.358
165	7,774	213,618	10	7.718
170	8,047	220,024	8	8.098
175	8,327	226,179	7	8.490
180	8,617	232,098	6	8.940
185	8,914	237,795	5	9.358
190	9,220	243,287	4	9.789
195	9,535	248,591	3	10.235
200	9,859	253,724	3	10.697

NASA/MSFC August-1991 Reference Trajectory for HLLV (all STMEs working)

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psi)	Mach Number
205	10,193	258,707	2	11.176
210	10,536	263,559	2	11.676
215	10,890	268,302	2	12.200
220	11,254	272,958	1	12.731
220	11,254	272,958	1	12.731
225	11,630	277,546	1	13.156
230	12,019	282,069	1	13.596
235	12,422	286,523	1	14.052
240	12,839	290,903	1	14.523
245	13,271	295,206	1	15.012
250	13,719	299,429	0	15.358
255	14,184	303,568	0	15.718
260	14,667	307,617	0	16.096
265	15,169	311,573	0	16.493
270	15,692	315,431	0	16.910
275	16,237	319,186	0	17.348
280	16,807	322,834	0	17.811
285	17,402	326,367	0	18.298
289.873	18,009	329,696	0	18.757
289.873	18,009	329,696	0	18.757
290	18,023	329,781	0	18.766
295	18,592	333,098	0	19.132
300	19,186	336,339	0	19.525
305	19,808	339,504	0	19.943
305.23	19,838	339,647	0	19.963
305.23	19,838	339,647	0	19.963
310	20,369	342,541	0	20.303
315	20,950	345,383	0	20.691
320	21,558	348,019	0	21.112
323.119	21,950	349,555	0	21.393
323.119	21,950	349,555	0	21.393
325	22,132	350,456	0	21.510
330	22,626	352,840	0	21.829
335	23,139	355,211	0	22.163
340	23,673	357,568	0	22.514
345	24,228	359,908	0	22.883
348.284	24,605	361,435	0	23.099

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psf)	Mach Number
0	0	95	0	0.001
0	0	95	0	0.001
1	17	103	0	0.015
2	34	129	1	0.030
3	51	171	3	0.045
4	68	231	5	0.060
5	86	308	8	0.076
6	104	403	12	0.092
7	122	516	17	0.108
7.615	134	595	20	0.118
7.615	134	595	20	0.118
8	141	648	22	0.124
9	159	798	29	0.140
10	178	966	36	0.157
11	197	1,154	43	0.174
12	217	1,361	52	0.192
13	236	1,588	62	0.209
14	256	1,834	72	0.227
15	277	2,100	83	0.245
16	297	2,386	95	0.264
17	318	2,693	108	0.283
17.615	332	2,892	116	0.294
17.615	332	2,892	116	0.294
18	340	3,021	122	0.302
19	362	3,370	136	0.321
20	384	3,740	152	0.341
21	406	4,131	168	0.362
22	429	4,544	185	0.382
23	452	4,979	203	0.403
24	476	5,437	222	0.425
25	500	5,917	241	0.447
26	525	6,420	261	0.470
27	550	6,946	282	0.493
28	575	7,496	303	0.516
29	601	8,070	325	0.540
30	628	8,667	347	0.564
31	654	9,289	370	0.589
31.426	666	9,562	380	0.600
31.426	666	9,562	380	0.600
35	767	12,026	465	0.695
36.939	824	13,500	512	0.750
36.939	824	13,500	512	0.750
40	866	15,950	521	0.793
45	943	20,164	537	0.874
50	1,031	24,651	551	0.969
55	1,126	29,410	558	1.078
60	1,230	34,425	555	1.202
63	1,300	37,553	551	1.286
63	1,300	37,553	551	1.286
65	1,387	39,720	577	1.385
70	1,619	45,584	623	1.660
75	1,871	52,071	627	1.962
80	2,144	59,153	578	2.257
85	2,439	66,798	507	2.554

NASA/MSFC August-1991 Reference Trajectory for 1.5 LV (all STMEs working)

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psi)	Mach Number
90	2,756	74,976	426	2.852
95	3,096	83,661	348	3.164
100	3,459	92,835	279	3.494
105	3,844	102,480	217	3.823
110	4,253	112,583	165	4.156
115	4,686	123,133	125	4.506
120	5,144	134,118	93	4.867
125	5,627	145,530	69	5.245
130	6,138	157,366	51	5.660
131	6,243	159,783	48	5.750
131	6,243	159,783	48	5.750
135	6,677	169,629	39	6.188
136	6,788	172,137	36	6.307
136	6,788	172,137	36	6.307
140	6,920	182,118	26	6.508
145	7,091	194,355	18	6.795
146	7,126	196,773	16	6.856
146	7,126	196,773	16	6.856
150	7,269	206,349	12	7.114
155	7,452	218,109	8	7.467
160	7,642	229,633	5	7.845
165	7,839	240,921	3	8.282
170	8,042	251,974	2	8.693
175	8,251	262,790	1	9.128
180	8,467	273,370	1	9.578
185	8,690	283,712	0	9.830
190	8,920	293,816	0	10.090
195	9,156	303,681	0	10.144
200	9,400	313,307	0	10.180
205	9,652	322,693	0	10.231
210	9,910	331,837	0	10.244
215	10,177	340,740	0	10.204
220	10,451	349,401	0	10.191
225	10,734	357,818	0	10.201
230	11,025	365,992	0	10.086
235	11,324	373,921	0	9.935
240	11,633	381,606	0	9.830
245	11,951	389,045	0	9.762
250	12,279	396,237	0	9.626
252.687	12,459	400,000	0	9.483
252.687	12,459	400,000	0	9.483
255	12,620	403,184	0	9.380
260	12,975	409,886	0	9.205
265	13,342	416,342	0	9.084
270	13,721	422,547	0	9.007
275	14,112	428,497	0	8.966
280	14,517	434,187	0	8.956
285	14,936	439,614	0	8.973
290	15,369	444,771	0	9.014
295	15,818	449,656	0	9.079
300	16,283	454,261	0	9.164
305	16,766	458,581	0	9.270
310	17,268	462,612	0	9.396
315	17,790	466,346	0	9.542
320	18,333	469,777	0	9.708

NASA/MSFC August-1991 Reference Trajectory for 1.5 LV (all STMEs working)

Time (sec)	Velocity (fps)	Altitude (ft)	Q (psi)	Mach Number
325	18,900	472,897	0	9.895
330	19,491	475,700	0	10.103
335	20,110	478,176	0	10.333
340	20,759	480,317	0	10.588
345	21,441	482,112	0	10.869
347.673	21,820	482,926	0	11.031
347.673	21,820	482,926	0	11.031
350	22,072	483,556	0	11.135
355	22,632	484,681	0	11.374
360	23,216	485,486	0	11.637
365	23,826	485,961	0	11.923
369.543	24,405	486,100	0	12.207

NASA/MSFC August-1991 Reference Trajectory for 1.5 LV (all STMEs working)

NLS Vehicle Scaling Parameters

	<u>HLLV</u>	<u>1.5 LV</u>
Thrust ASRB STME	14,680,000 (N) 2,593,000 (N)	583,000 (lb)
Exit Velocity ASRB STME	2673 (m/s) 4247 (m/s)	13,934 (ft/s)
Nozzle Diameter ASRB STME	3.78 (m) 2.21 (m)	7.25 (ft)
Core Diameter	8.4 (m)	27.5 (ft)
PLF Diameter	5.1 (m)	16.6 (ft)
Effective Nozzle Diameter (mixing related) ASRB STME	3.78 (m) 4.42 (m)	17.76 (ft)
Effective Exit Velocity (power related) ASRB STME	1711 (m/s) 1529 (m/s)	13,934 (ft/s)
Areal Weights PLF Adapter Forward Skirt Intertank Skirt Aft Skirt and Prop Modue	94.9 (Pa) 93.9 (Pa) 160.4 (Pa) 182.4 (Pa)	.013773 (psi) .013624 (psi) .023282 (psi) .026476 (psi)

Derived
Parameters

