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

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

NASA

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Book II - Part 1
Avionics & Systems

# Cycle Ø(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

260 p

N93-23176

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## 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.

# TABLE OF CONTENTS

## STUDY TASKS

# 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

# 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***

October 09, 1991

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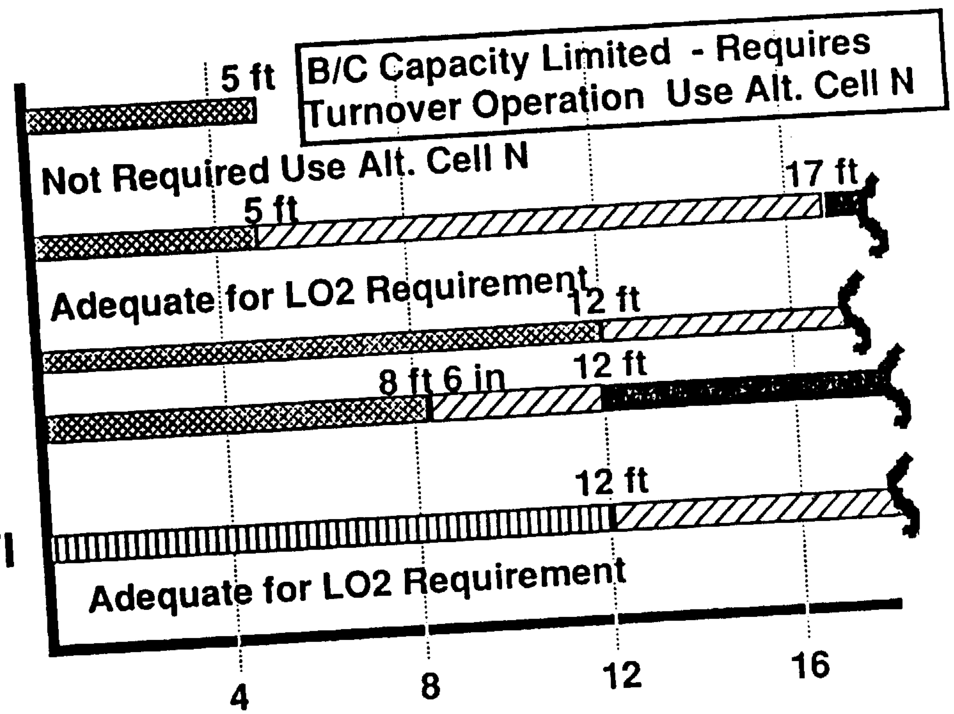
3-S-008A

# Tank Length vs Facility Impact

## Tank Processing Cells

Cells B/C LH2 SOFI
Cell D LH2 Aft Dome SOFI
Cell E LH2 Int Clean
Cell F LO2 Hydro Test
Cell P Ext Clean & Prime
Cell A Veh. Stack

Cells N (Alternative) LH2 SOFI
Cells M LO2 SOFI




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

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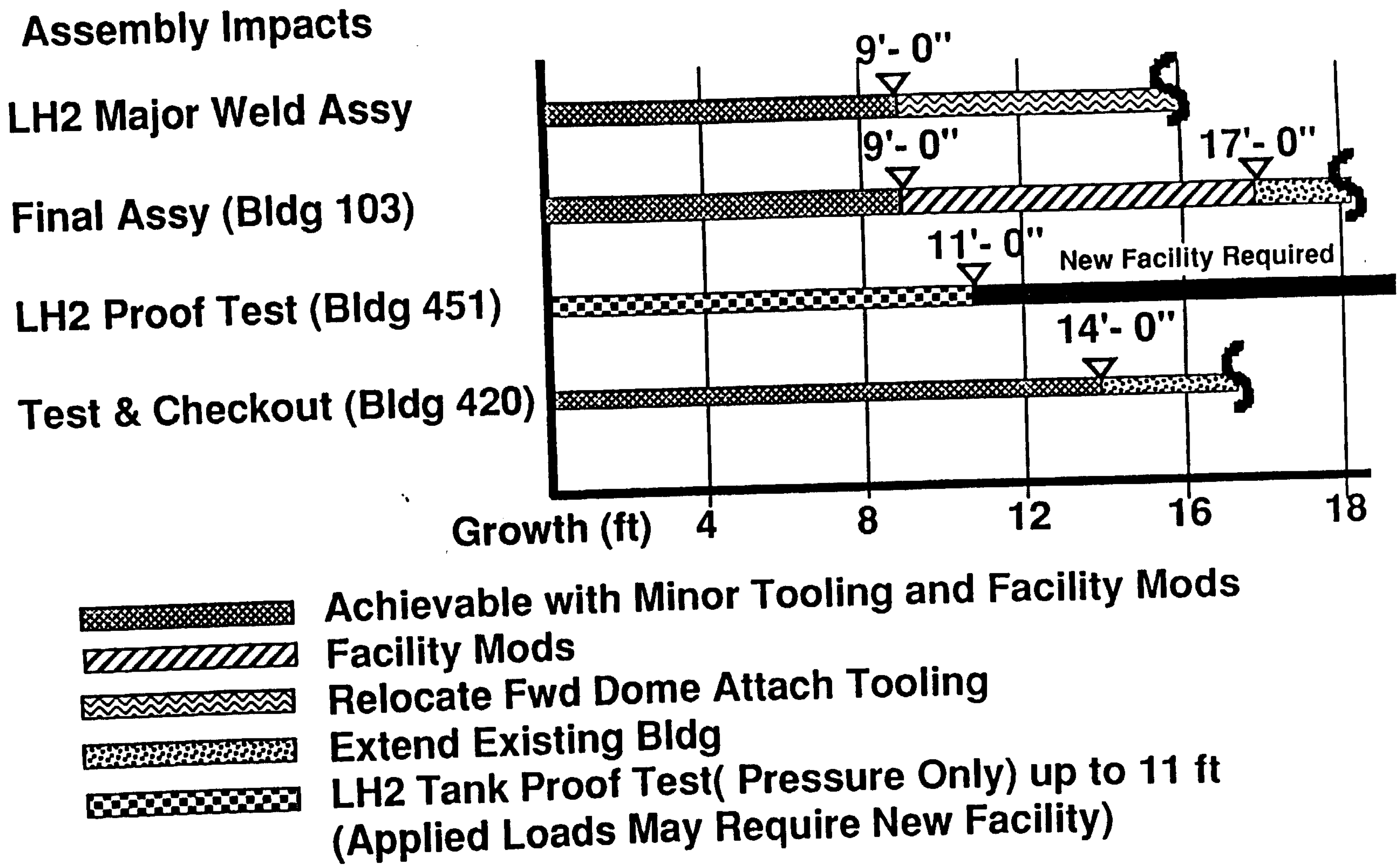
# Tank Length vs Facility Impact

3-S-008A

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# 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

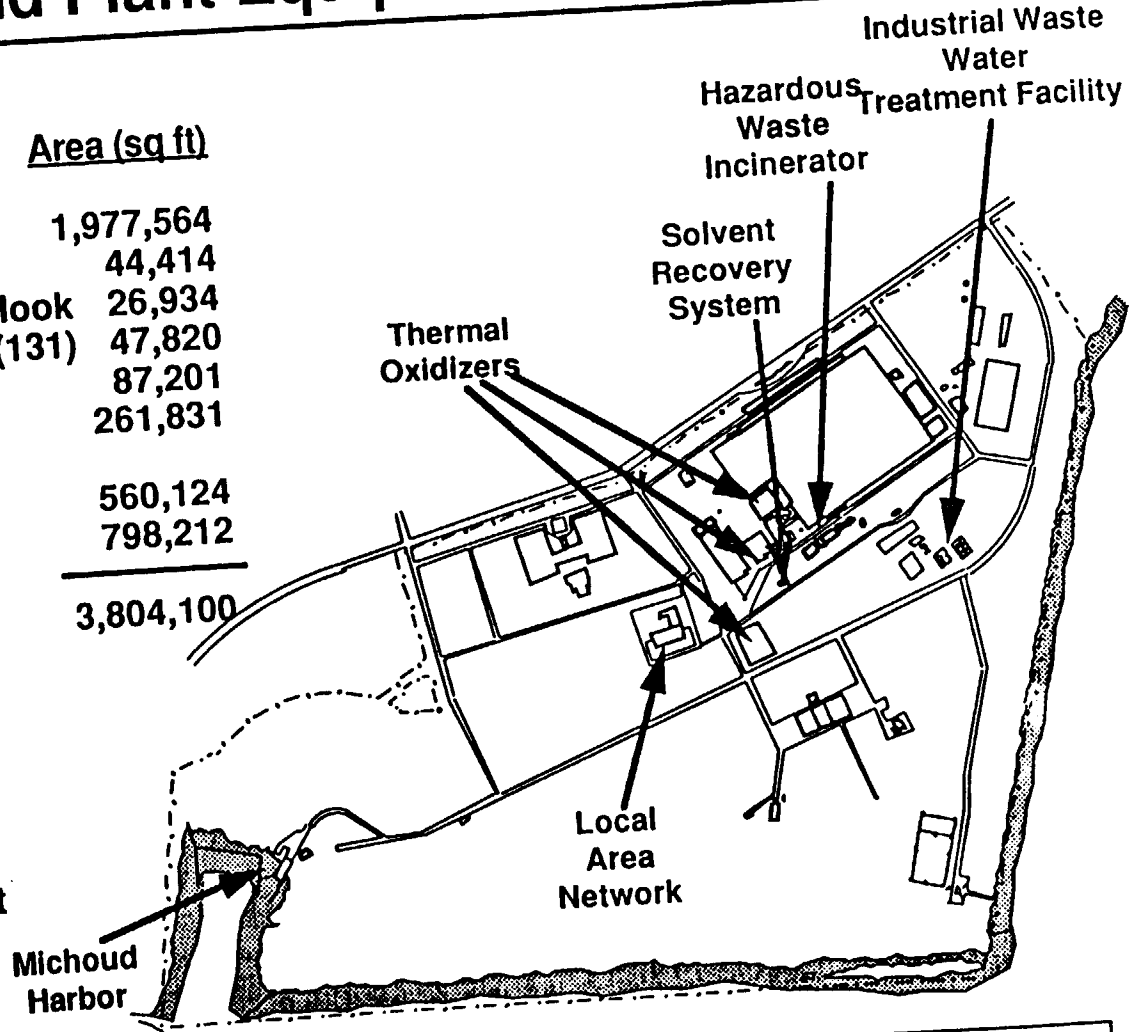
- MAF Facilities & Plant Equipment
- Tooling Cost
- Available Capacity

# MAF Facilities and Plant Equipment Overview

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

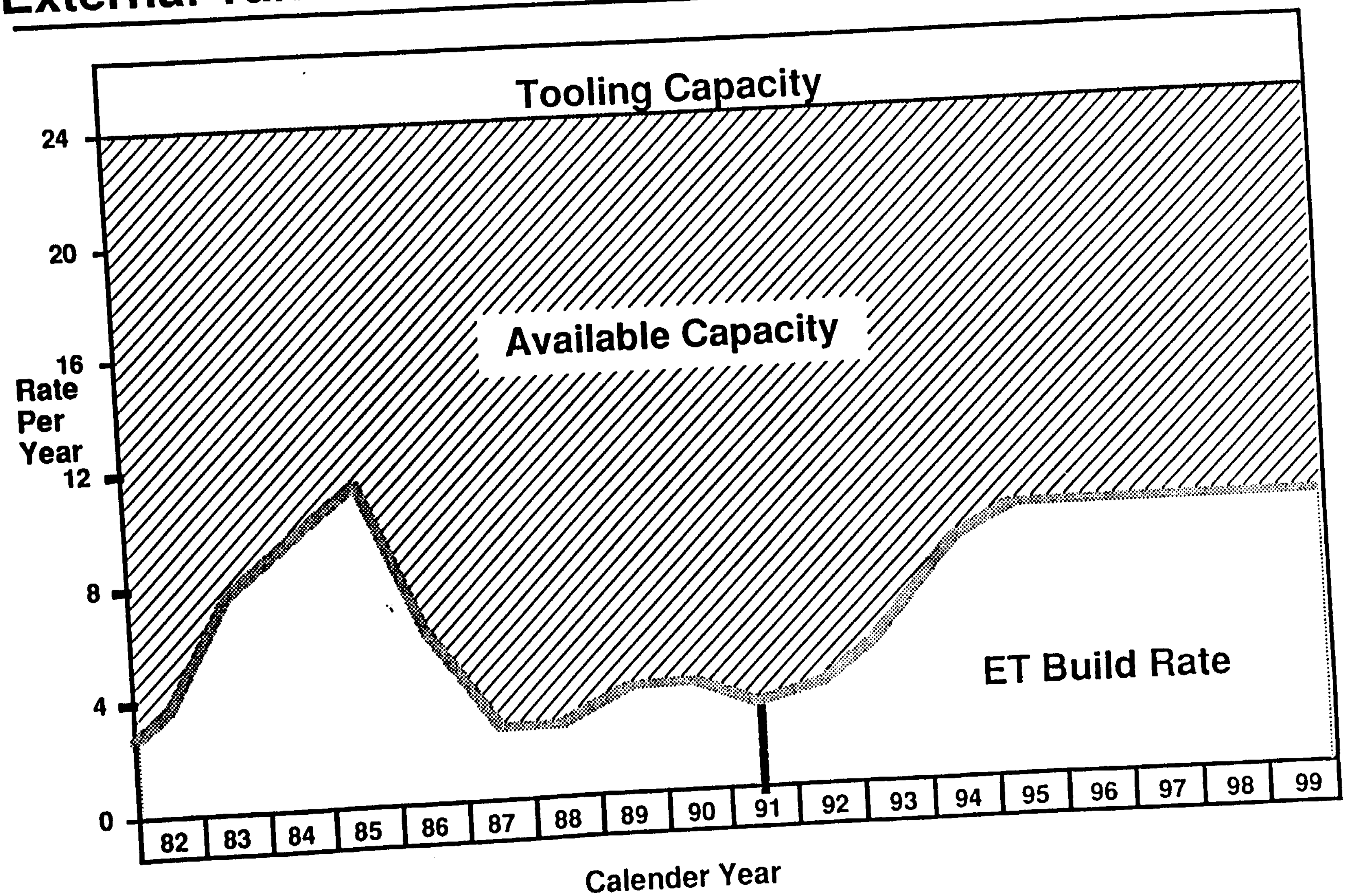
## 1991 Dollars in Millions

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

* 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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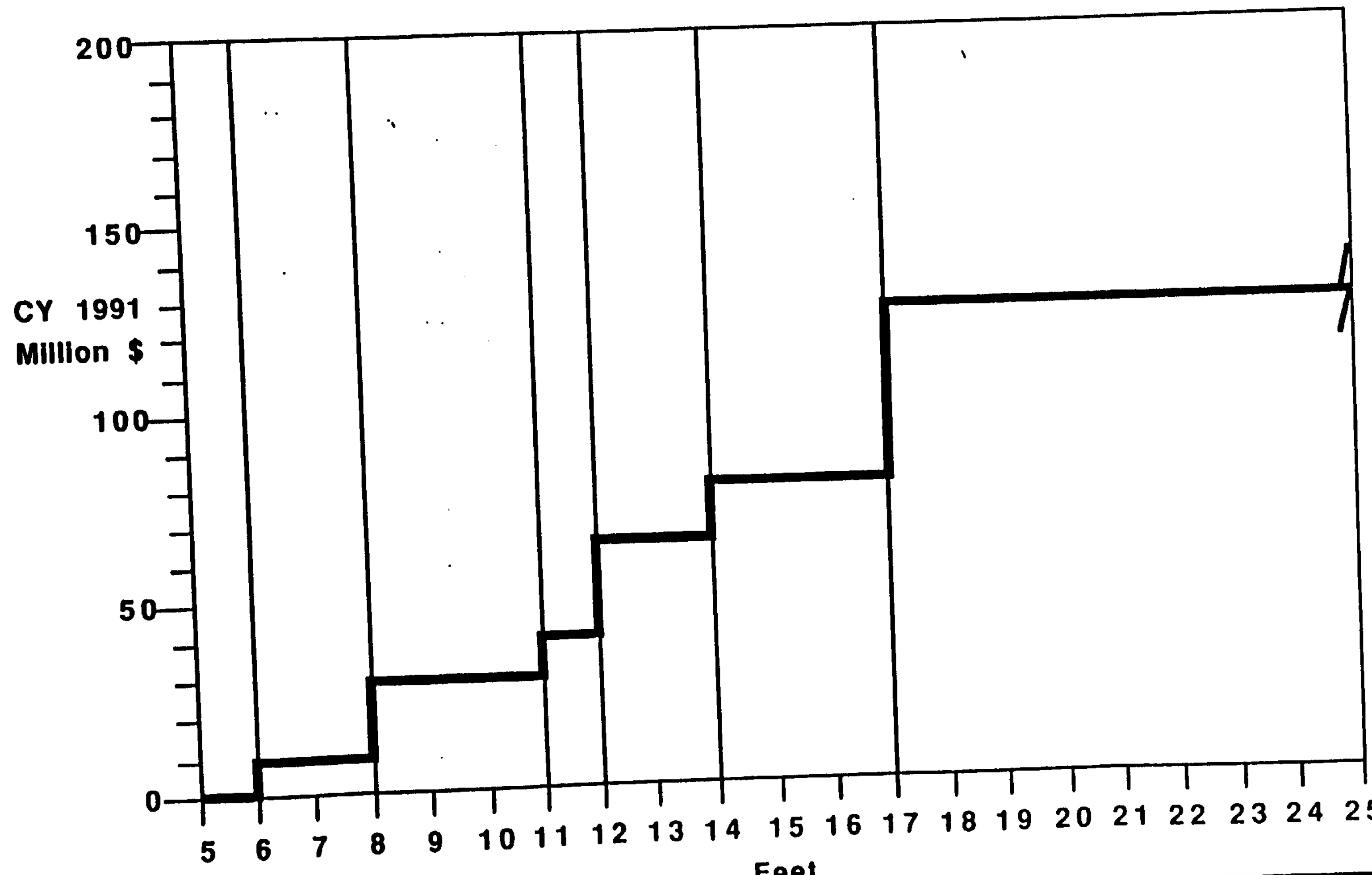
# Groundrules And Assumptions

- 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 Adressed

# NLS Core Tankage Stretch Summary



# Benefits of an ET-Derived Core at MAF

## Facilities & Tooling

- **Proven Core Fabrication Facilities & Tooling Available**
  - 6404 Tooling & STE Items in Place -Value $475M
  - 3.8 Million Square feet of facilities in Place -Value $909M
  - 91,599 Plant Equipment items in Place -Value $266M
- **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

MARTIN MARIETTA

Date: January 7, 1992

To: Mar[illegible] Harr[illegible]
Jon Patterson

From: [illegible]

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 real-time embedded avionics software. This evaluation was performed by SPC. Below is a brief summary of some of the key results.

| Criteria \ [illegible] | ALS CAT | MATRIX | GALA |
|---|---|---|---|
| Deterministic | + | + | - |
| Parameter Passing | + | + | - |
| Global References | - | + | + |
| Compiles Correctly | + | + | - |
| Efficiency | - | + | - |
| Reverse Engineering | - | - | - |
| 2167A Document Std | + | - | - |

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SOFTWARE PRODUCTIVITY CONSORTIUM

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 DelFosse
Vice President
Technology Transfer

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| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | NLS AVIONICS SIZING & TIMING | | | | |
| 2 | BACKGROUND DATA FROM SHUTTLE-C ESTIMATES | | | | |
| 3 | | | | | |
| 4 | FUNCTION | SLOCS | KBYTES | FREQ. (HZ) | |
| 5 | | | | | |
| 6 | FLIGHT CONTROL | 4709 | 141 | 20 | |
| 7 | GUIDANCE | 3062 | 92 | 10 | |
| 8 | NAVIGATION | 1715 | 51 | 5 | |
| 9 | REDUNDANCY MANAGEMENT | 792 | 24 | 20 | |
| 10 | SUBSYTEM OPERATING PROGRAM | 1807 | 54 | 5 | |
| 11 | SEQUENCING | 1276 | 38 | 5 | |
| 12 | SYSTEM CONTROL | 5391 | 162 | 10 | |
| 13 | SYSTEM MANAGEMENT | 1130 | 34 | 1 | |
| 14 | VEHICLE UTILITY | 8726 | 262 | 1 | |
| 15 | AUTOMATED CREW FUNCTIONS | 545 | 16 | 1 | |
| 16 | OPERATING SYSTEM | 10000 | 160 | 20 | |
| 17 | | | | | |
| 18 | | | | | |
| 19 | TOTALS | 39153 | 1034 | | |
| 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 Funtions

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

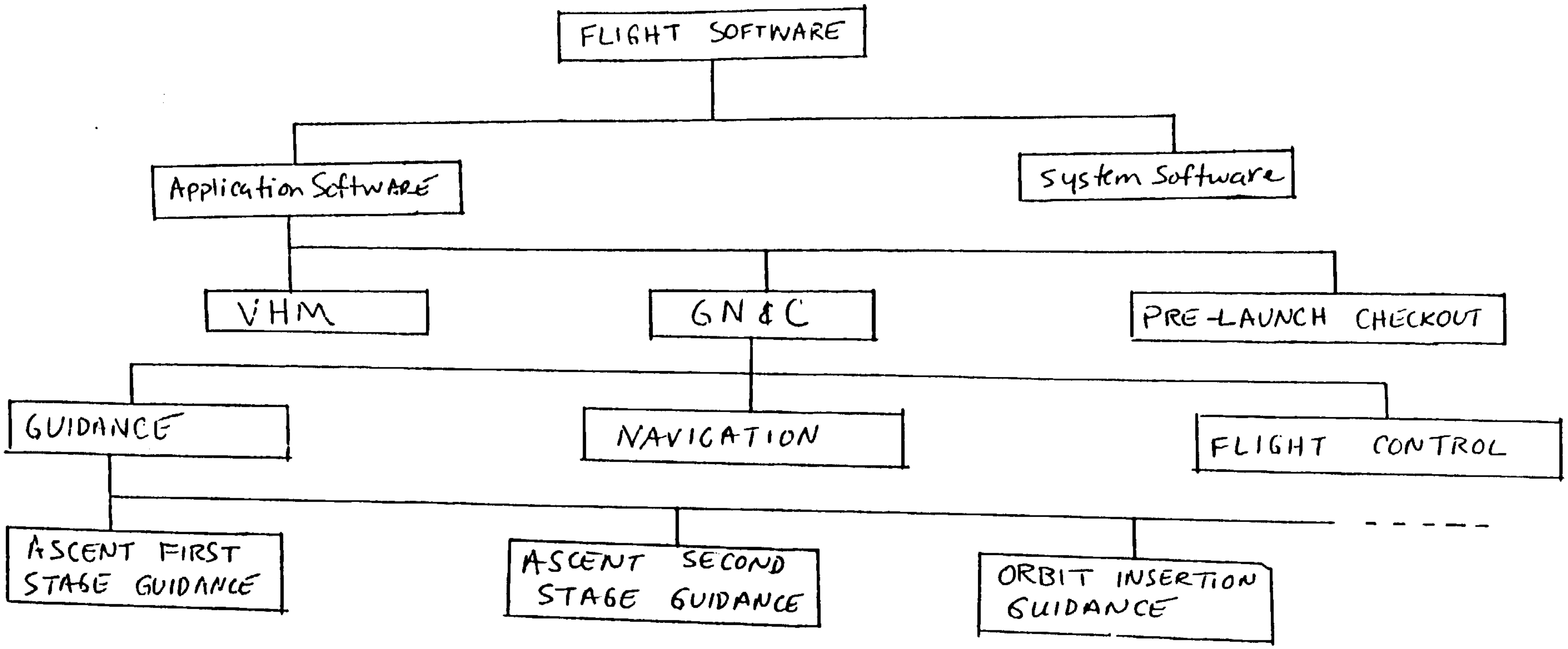
7. Systems Management
   - Data Acquisition
   - Fault Detection and Annunciation
   - Special Processes

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

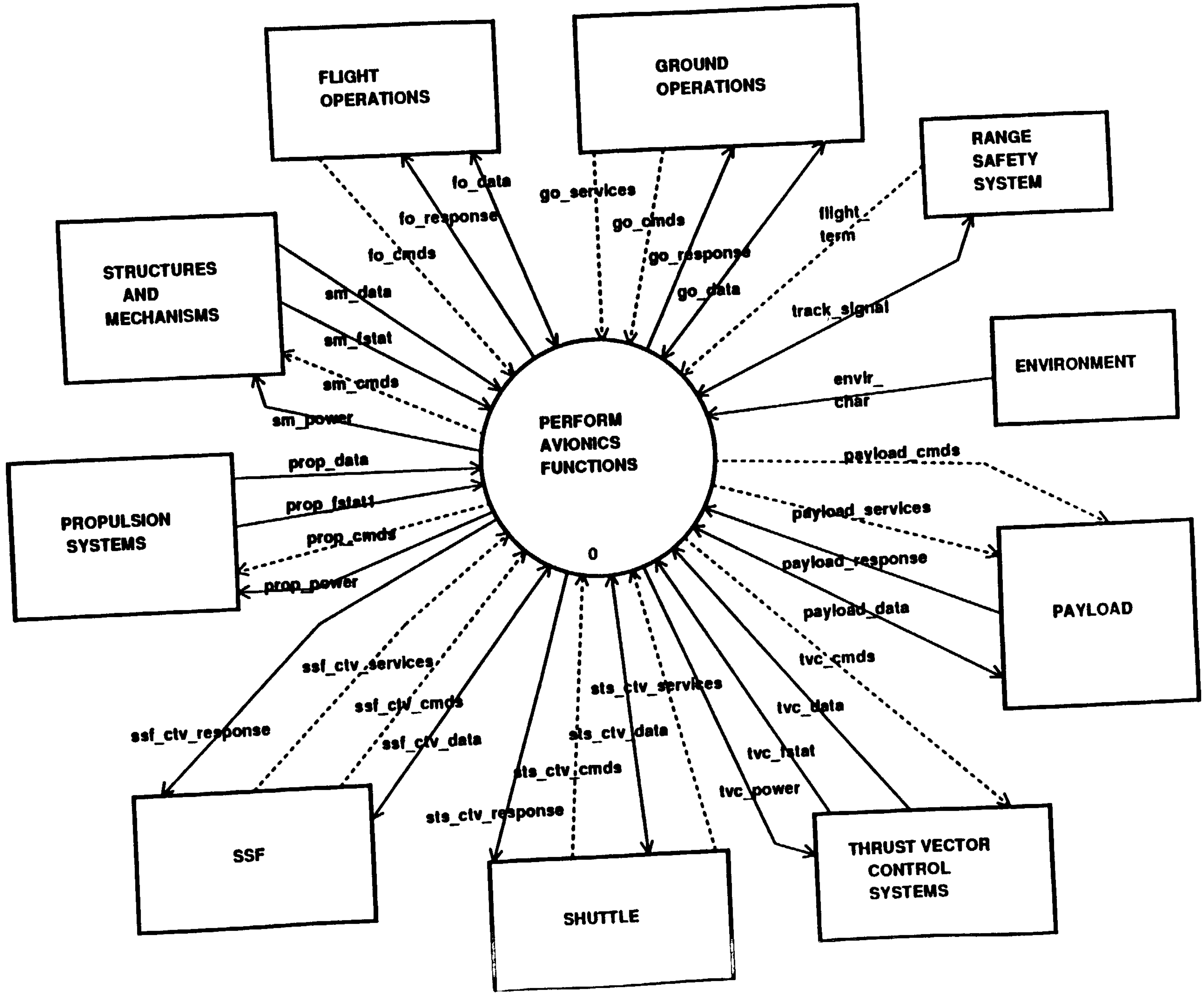
Fault-based diagnostics fall between model-based reasoning and rule-based reasoning. Individual components are modeled, but only with respect to causing or propagating fault symptoms. The avionics system is described in the computer as a network of component models. The connectivity of the model is analyzed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

Context Diagram;19
PERFORM AVIONICS ·TIONS

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# 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 commnads 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 tvc_cmds page 1

tvc_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 tvc_data page 1

tvc_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 tvc_fstat page 1

tvc_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 tvc_power page 1

tvc_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).".

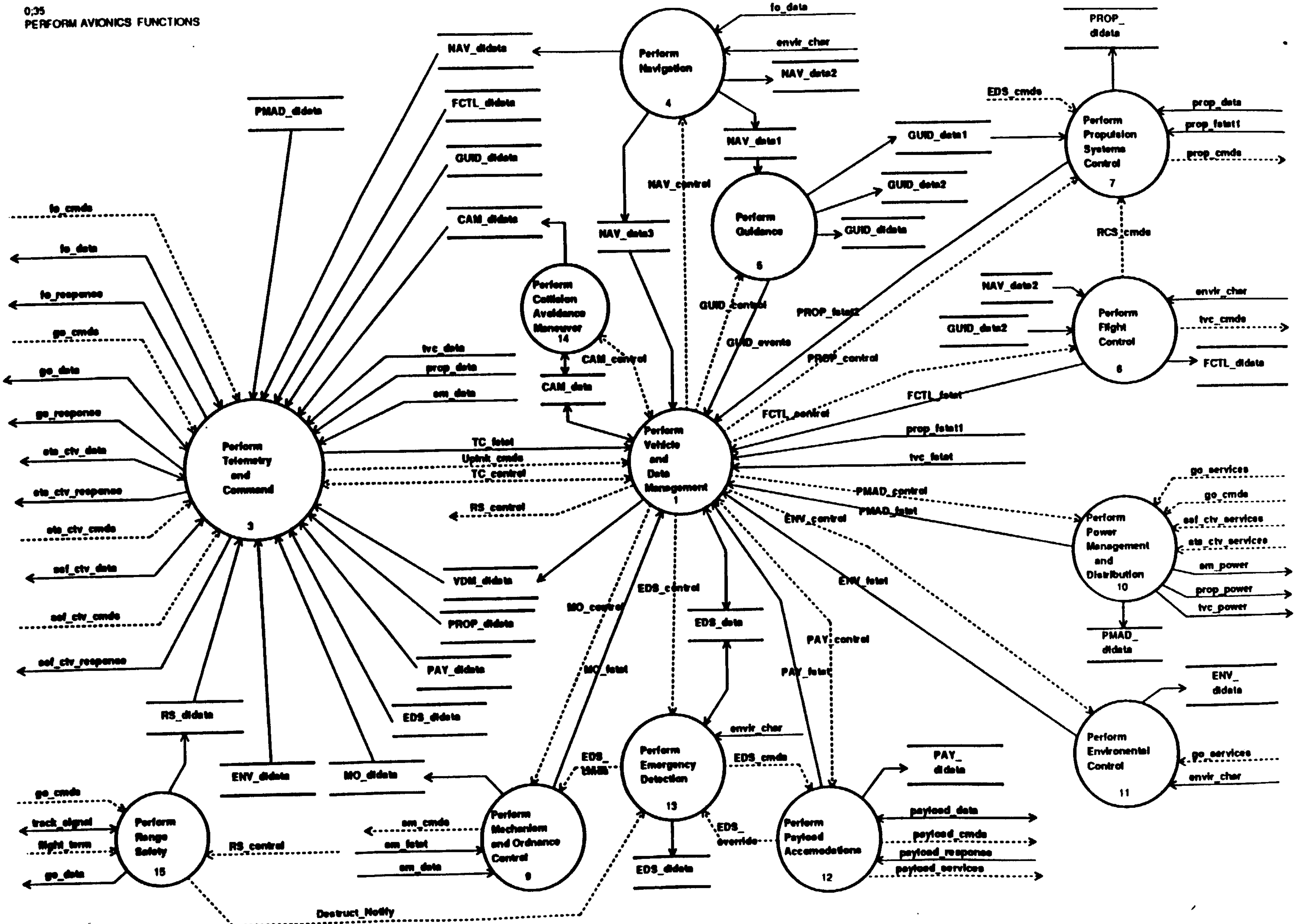
18:14:09 6 Nov 91 nls_avionics Data Dictionary Entry go_data page 1

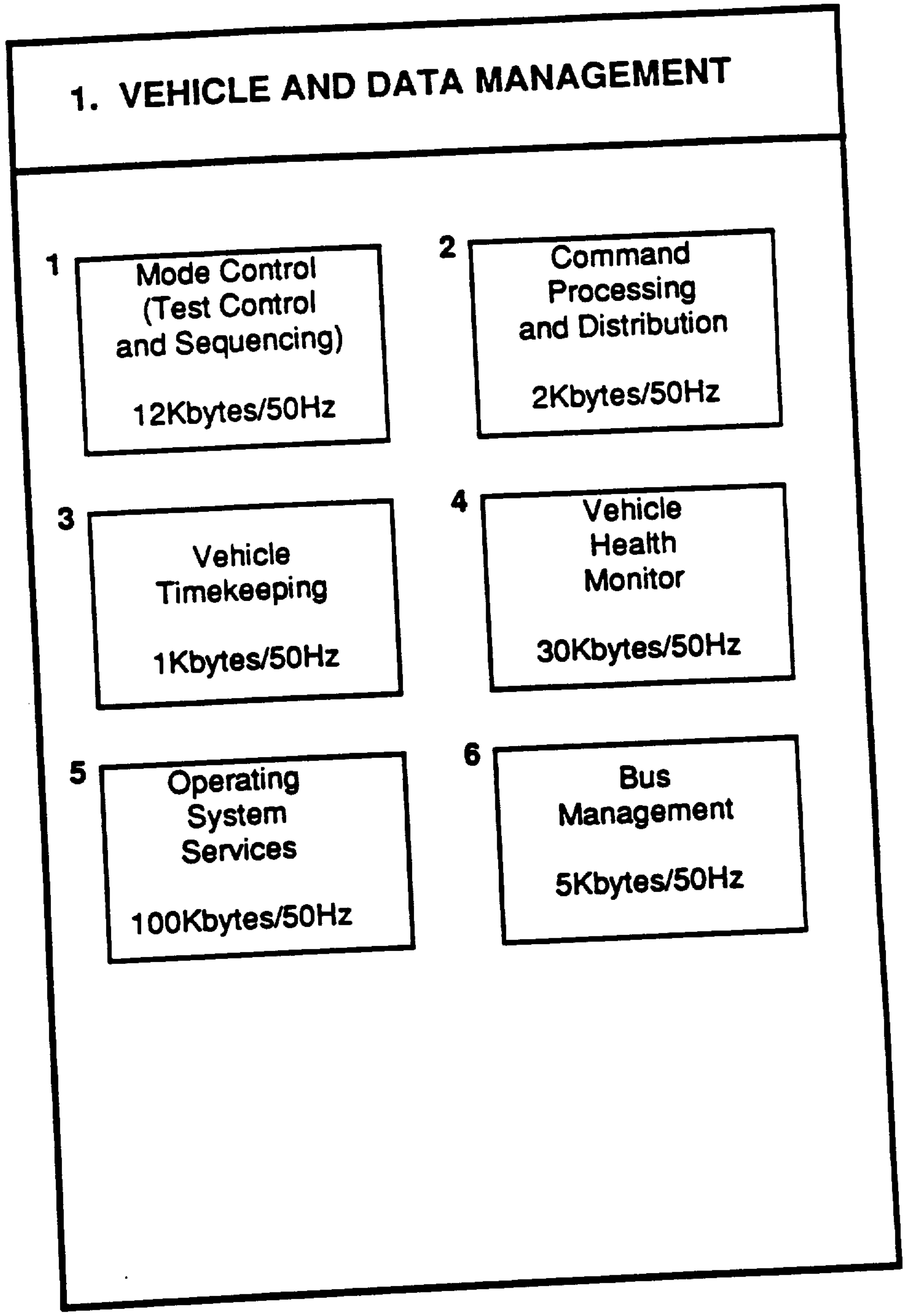
go_data (data flow) =
"Ground Operations Data includes data being sent to the vehicle, as well as data coming from the vehicle. Data being sent to the vehicle includes data loads for any purpose - day-of-launch wind profiles, programmable telemetry formats, mission or test characteristics and limits, 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

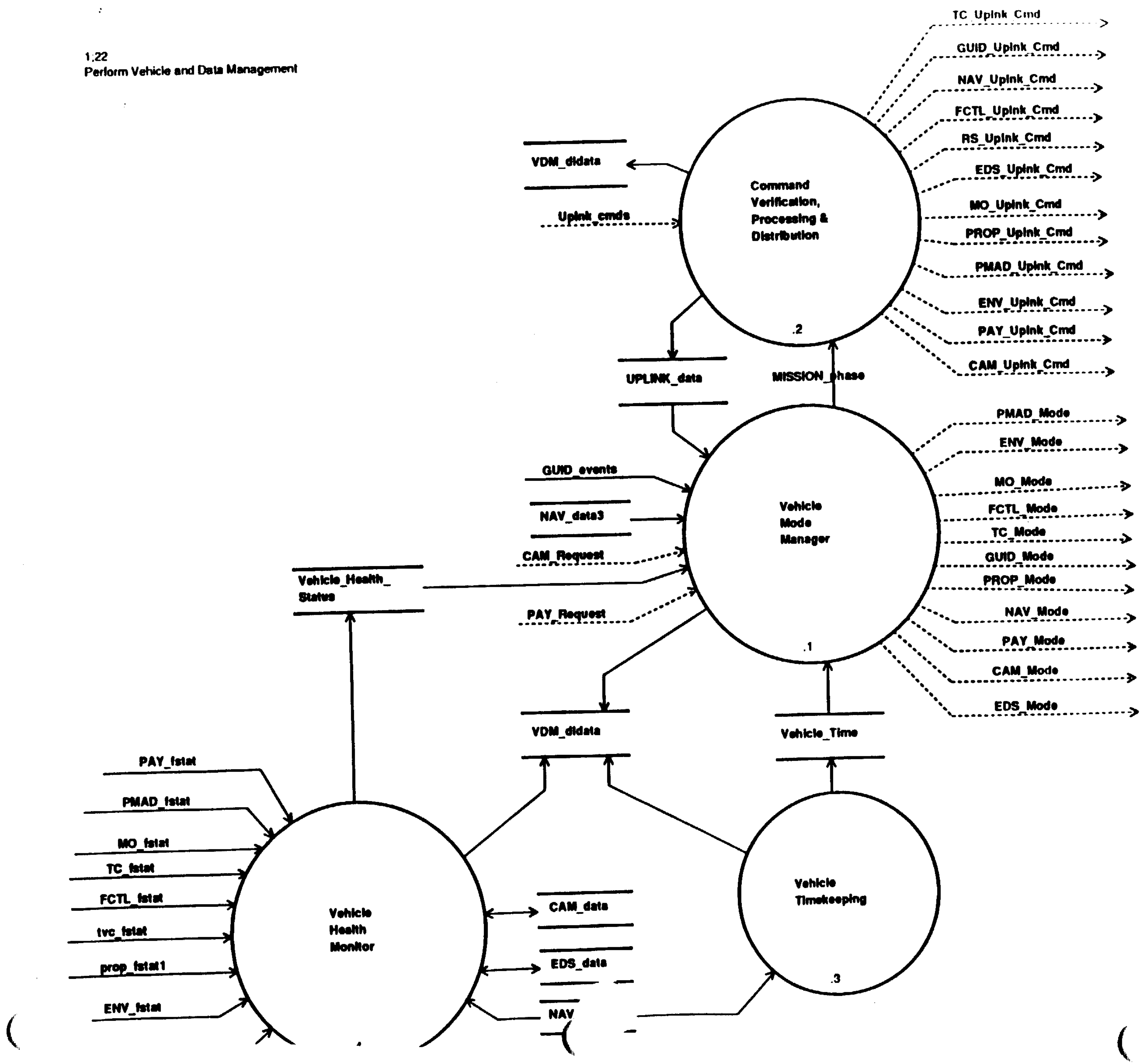
go_services (control flow) =
"Ground Operations Services are those services including electrical power, air or GN2 purge, and air conditioning needed before launch.".

0;35
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

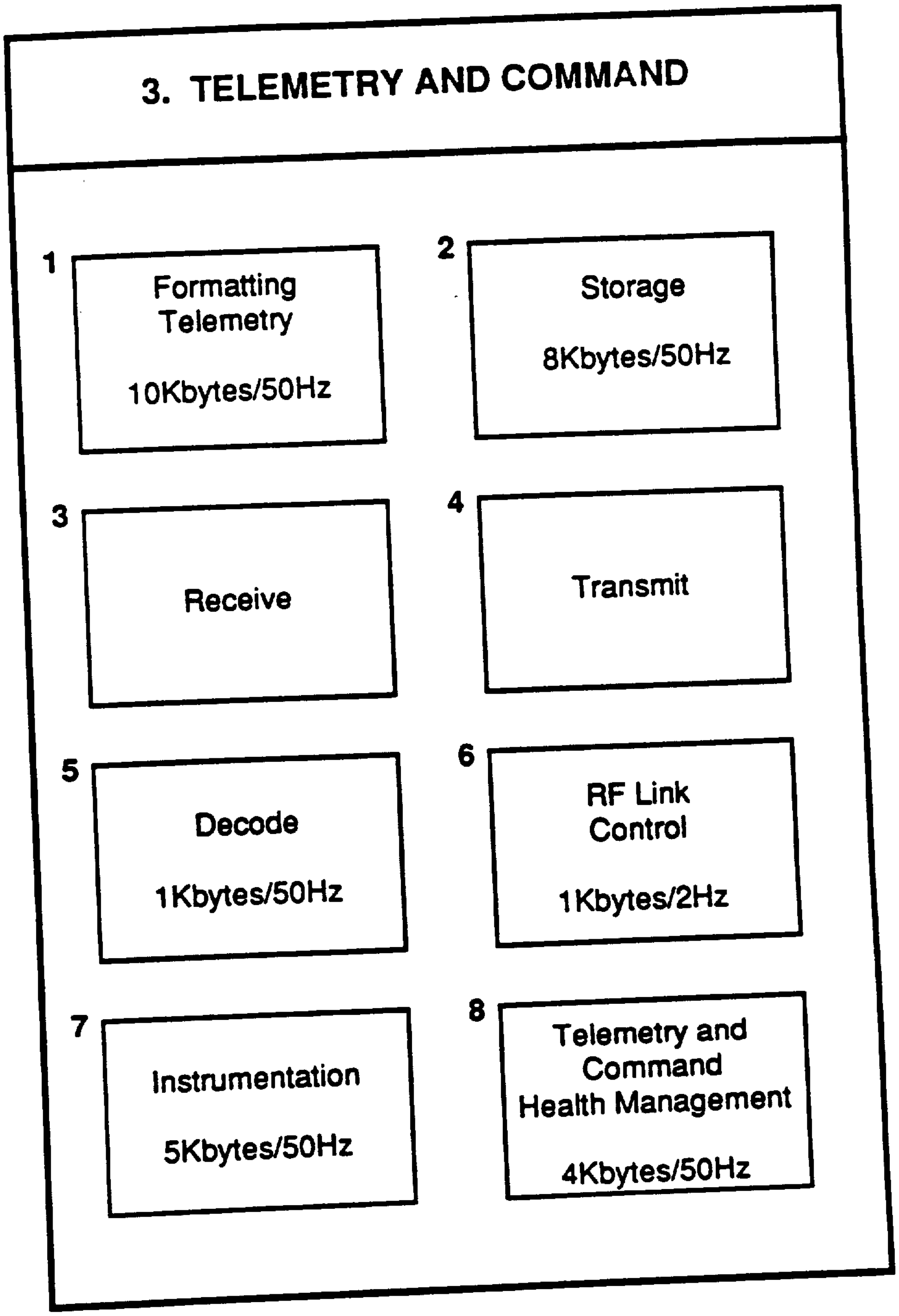
Vehicle timekeeping monitors the master time pulse and maintains and updates as necessary the current time for the vehicle. This function is also responsible for synchronizing the other timing functions including other processors to assure the vehicle units do not become skewed.

### 3.1.1.4 Vehicle Health Monitor

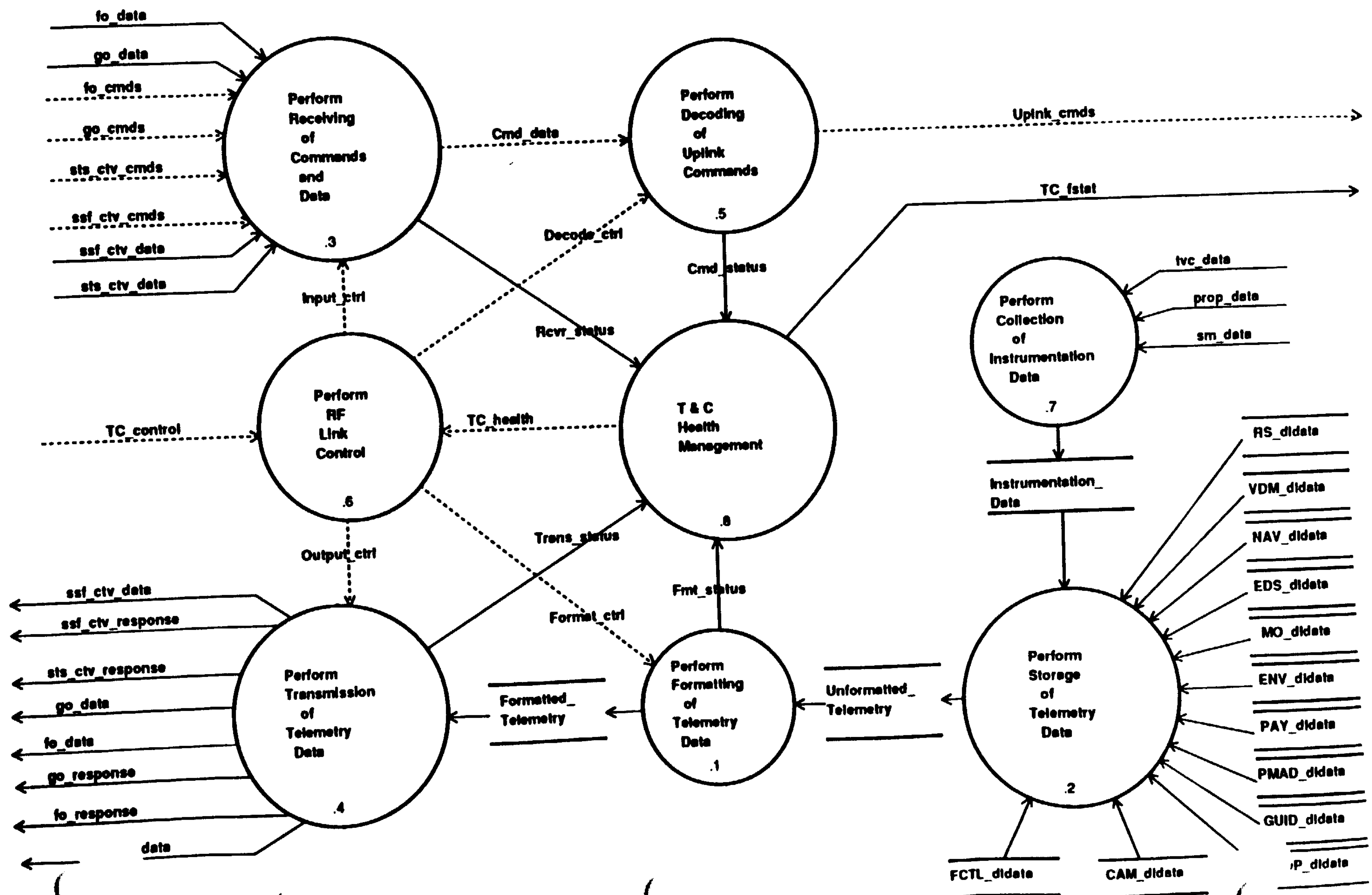
Vehicle Health Monitor correlates the vehicle health status from all subfunctions, remains cognizant of the status of similar signals from the terminators, and relays information to other subfunctions that may be affected. Vehicle Health Monitor is also responsible for hazard detection. It shall determine 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

3.18
Perform Telemetry and Command



### 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 formating 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

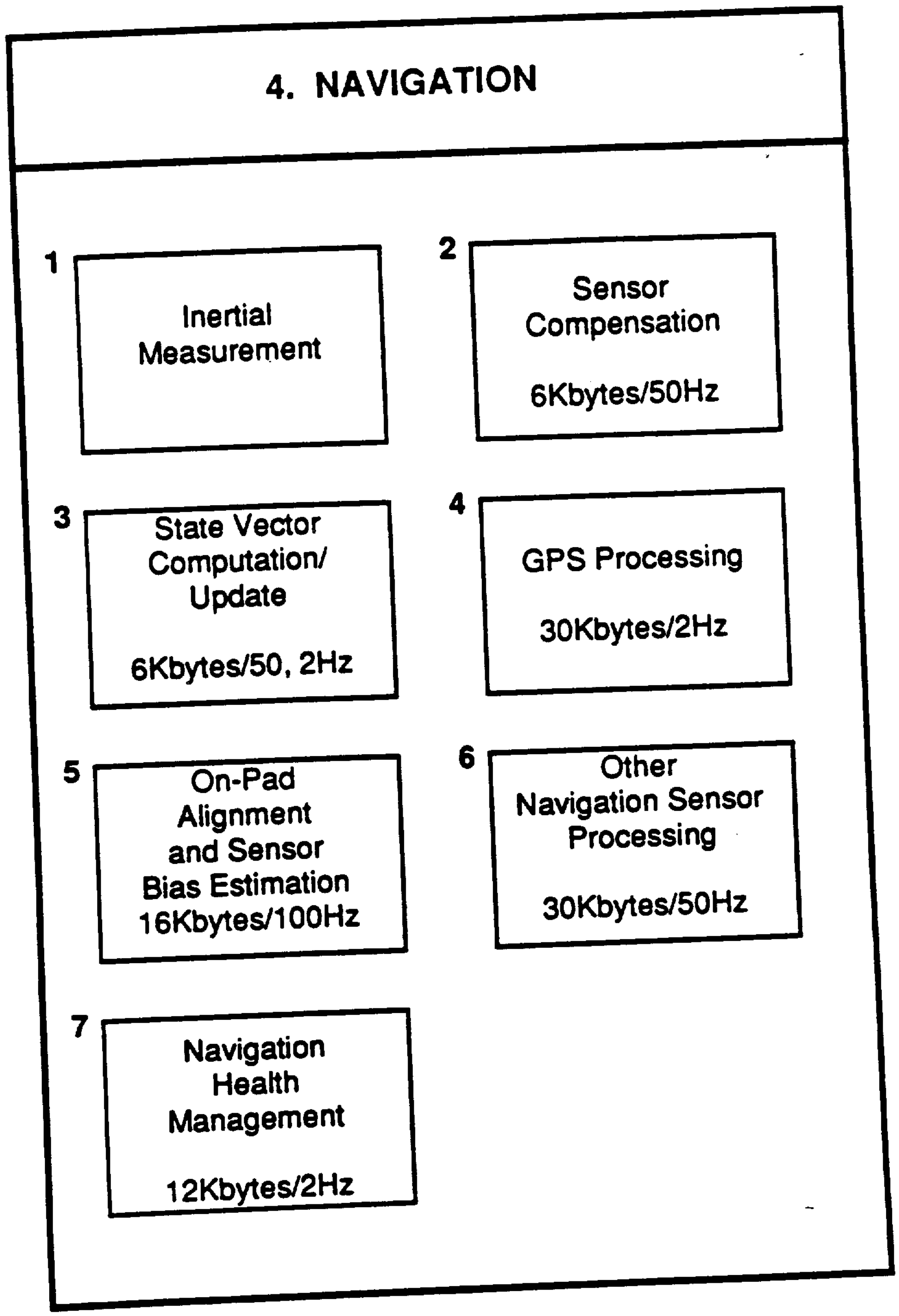
The RF link control subfunction configeures the on-board transmitters.

### 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.

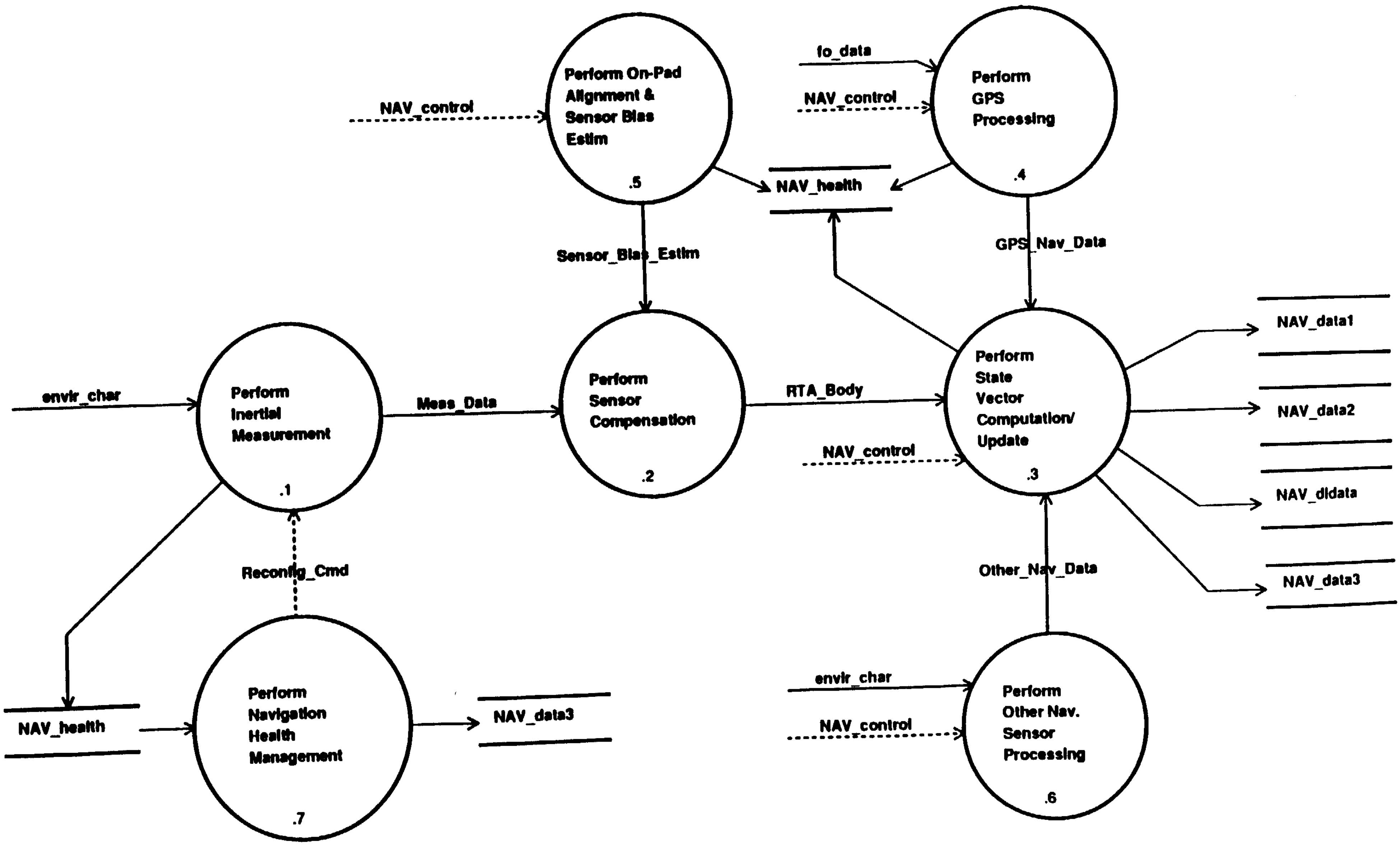
### 3.1.3.8 T&C Health Management

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

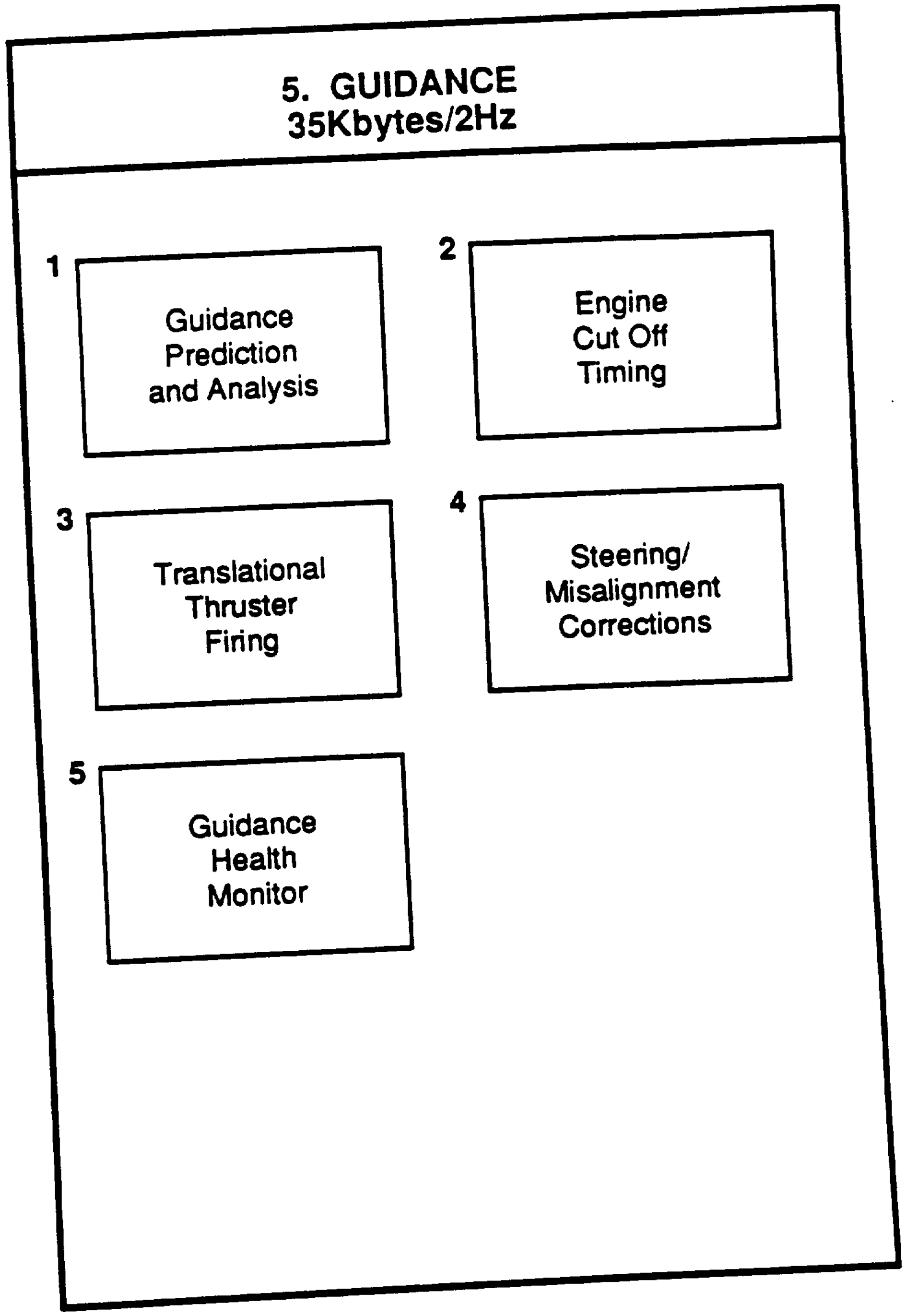
The on-pad alignment and sensor bias estimation subfunction performs acceleration coupled leveling and azimuth alignment needed to initialize the vehicle rotational states. (During pad alignment, the steady state angular rate on the IMU is earth rate. Alignment measurements different from earth rate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

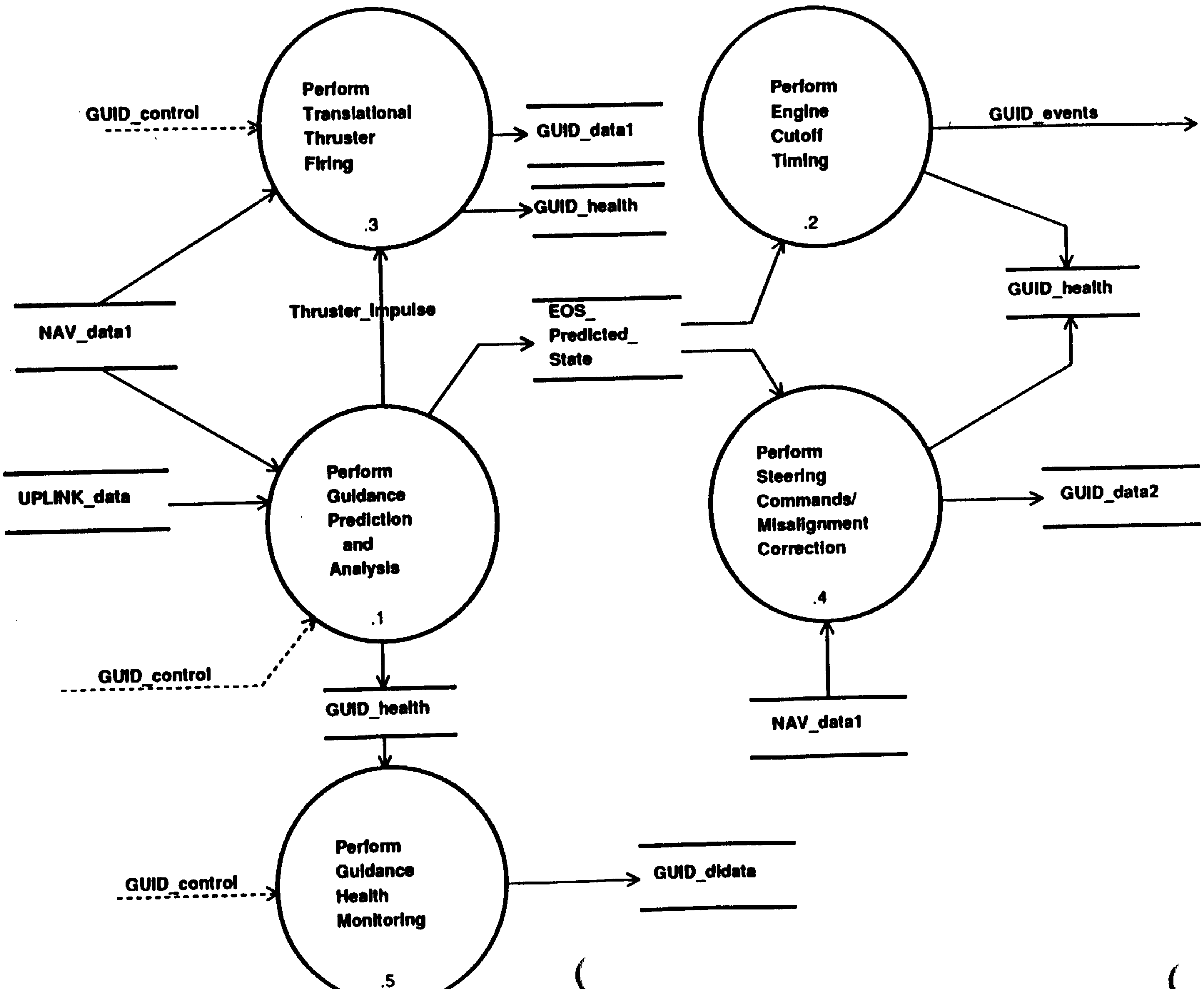
The other navigation sensor processing subfunction includes other navigational sensors (e.g. sun sensors, star trackers, horizon sensors).used to update the rotational states for execution of all CTV operations. The sensor data is processed and provided for state vector computation/ update.

### 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

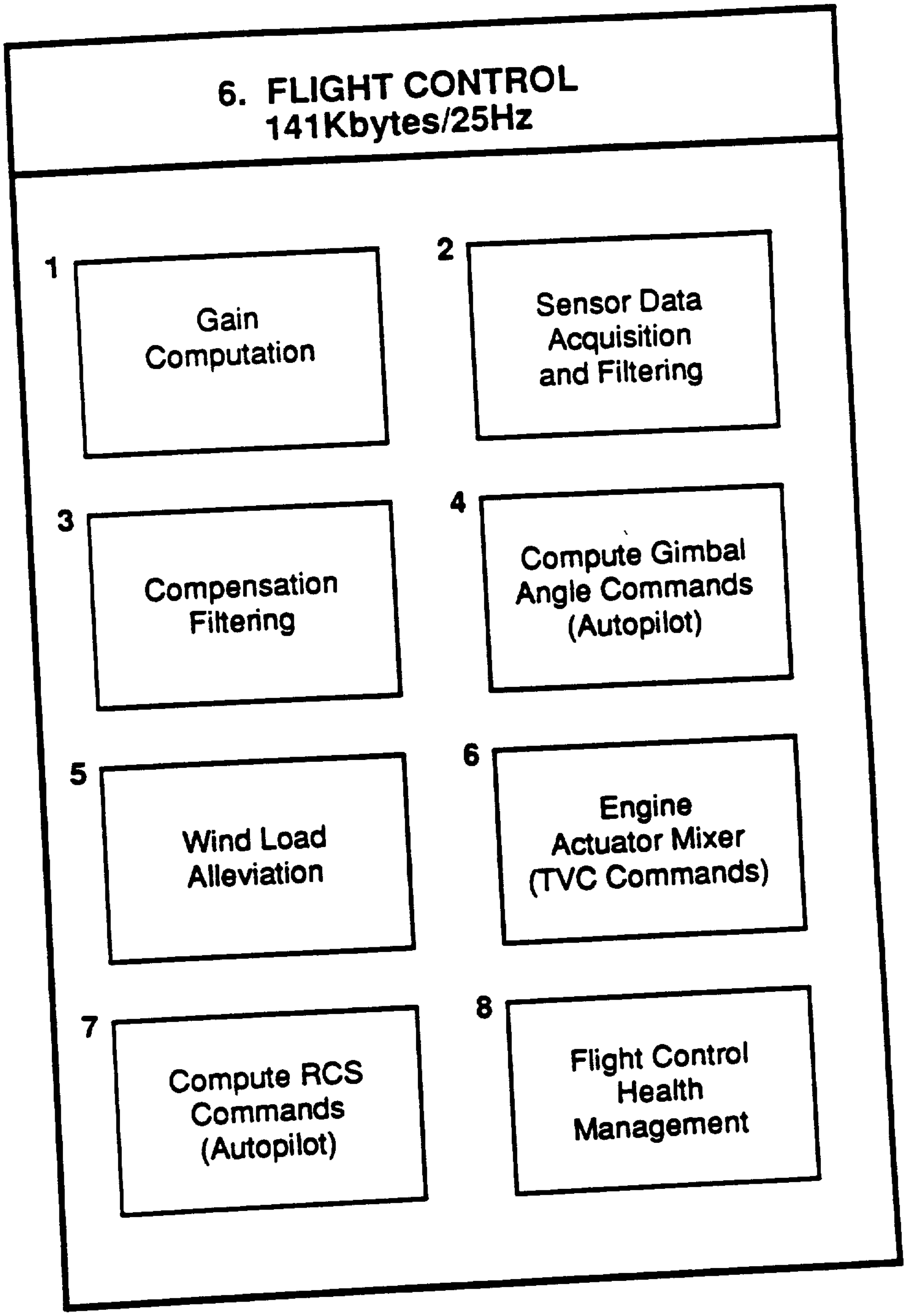
The Translational Thruster Firing subfunction generates thruster on-times required for on-orbit operations. These translational delta velocity burns are required for CTV orbit adjust, proximity operation, and deorbit.

### 3.1.5.4 Steering/Misalignment Corrections

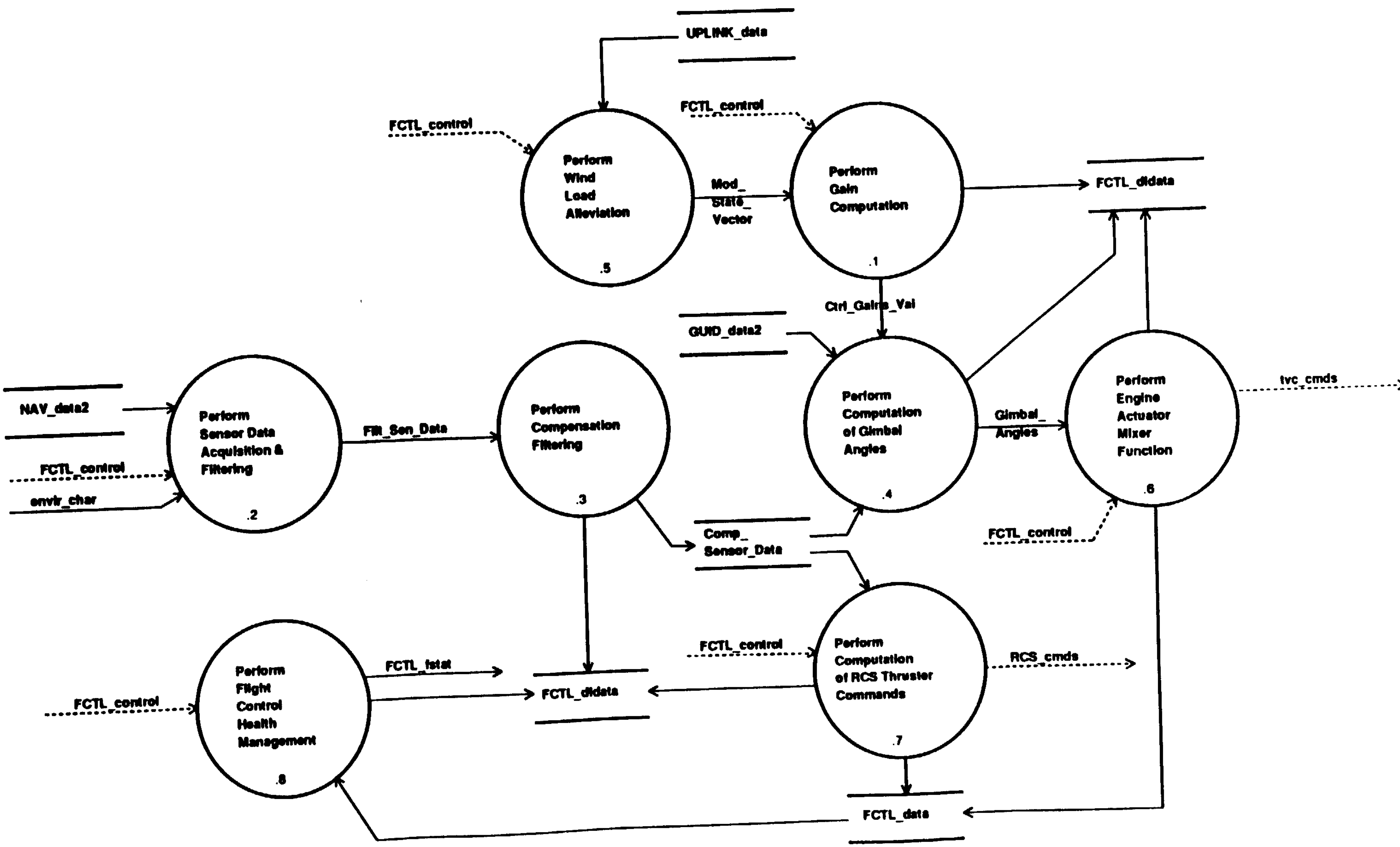
The Steering/Misalignment Corrections subfunction generates steering data based on Guidance Prediction and Analysis subfunction results. It performs steering misalignment correction to remove bias errors from the steering data. Based on the end-of-stage stage vector and the current state, this routine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

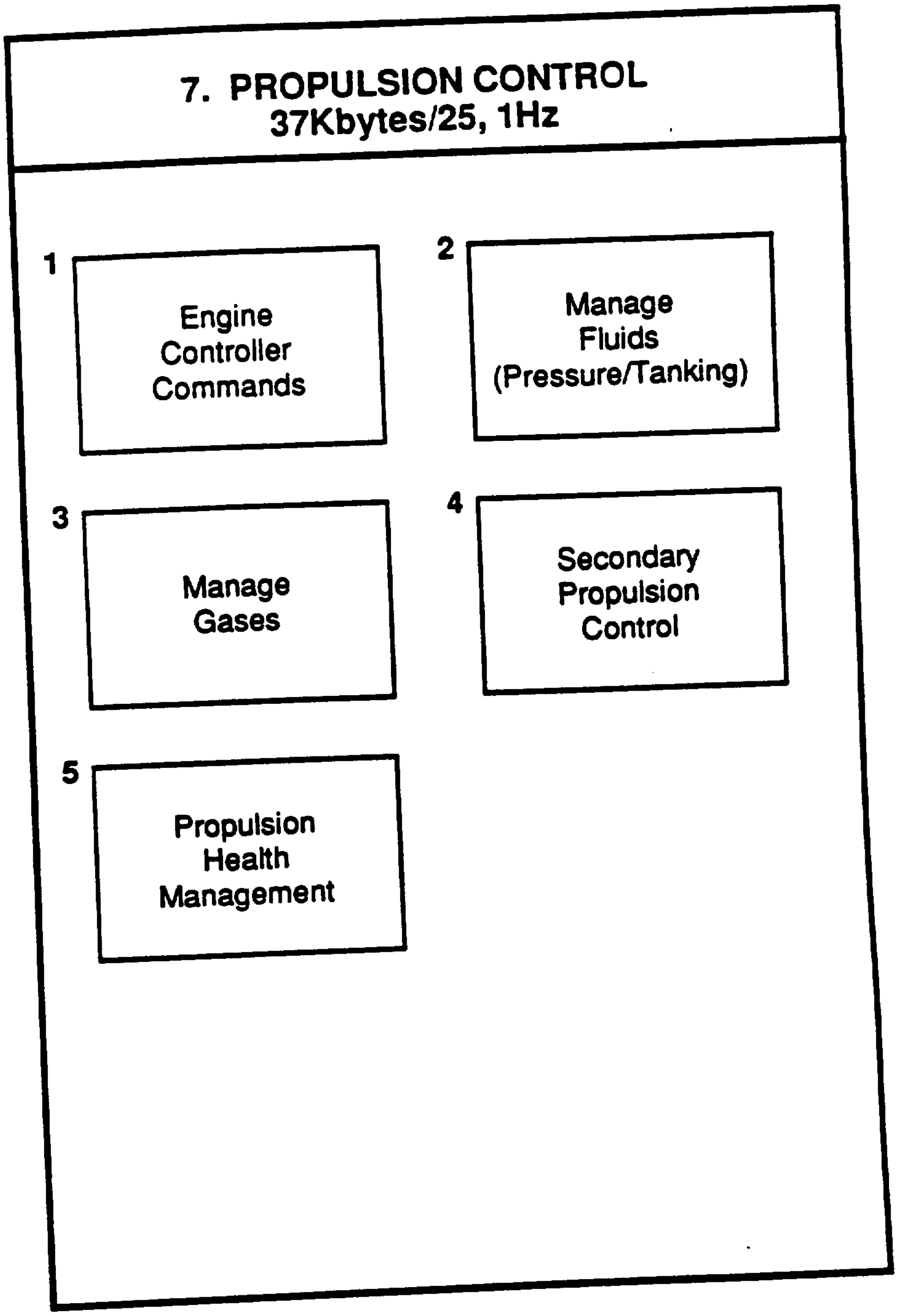
The Engine Actuator Mixer subfunction converts body axis engine commands to engine axis commands, taking into account individual engine and propulsion module status.

#### 3.1.6.7 Compute RCS Commands (Autopilot)

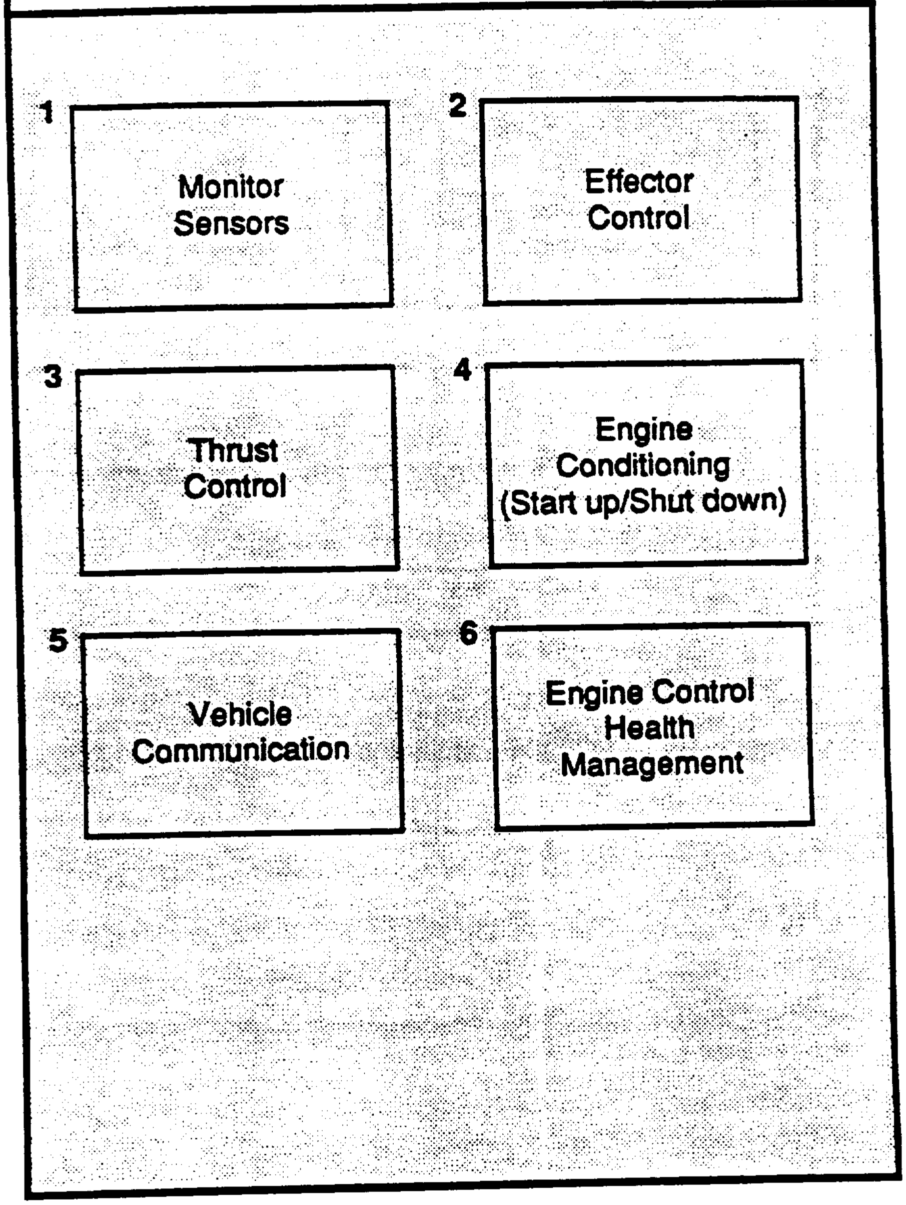
The Compute RCS Commands subfunction performs the thruster selection

### 3.1.6.8 Flight Control Health Management

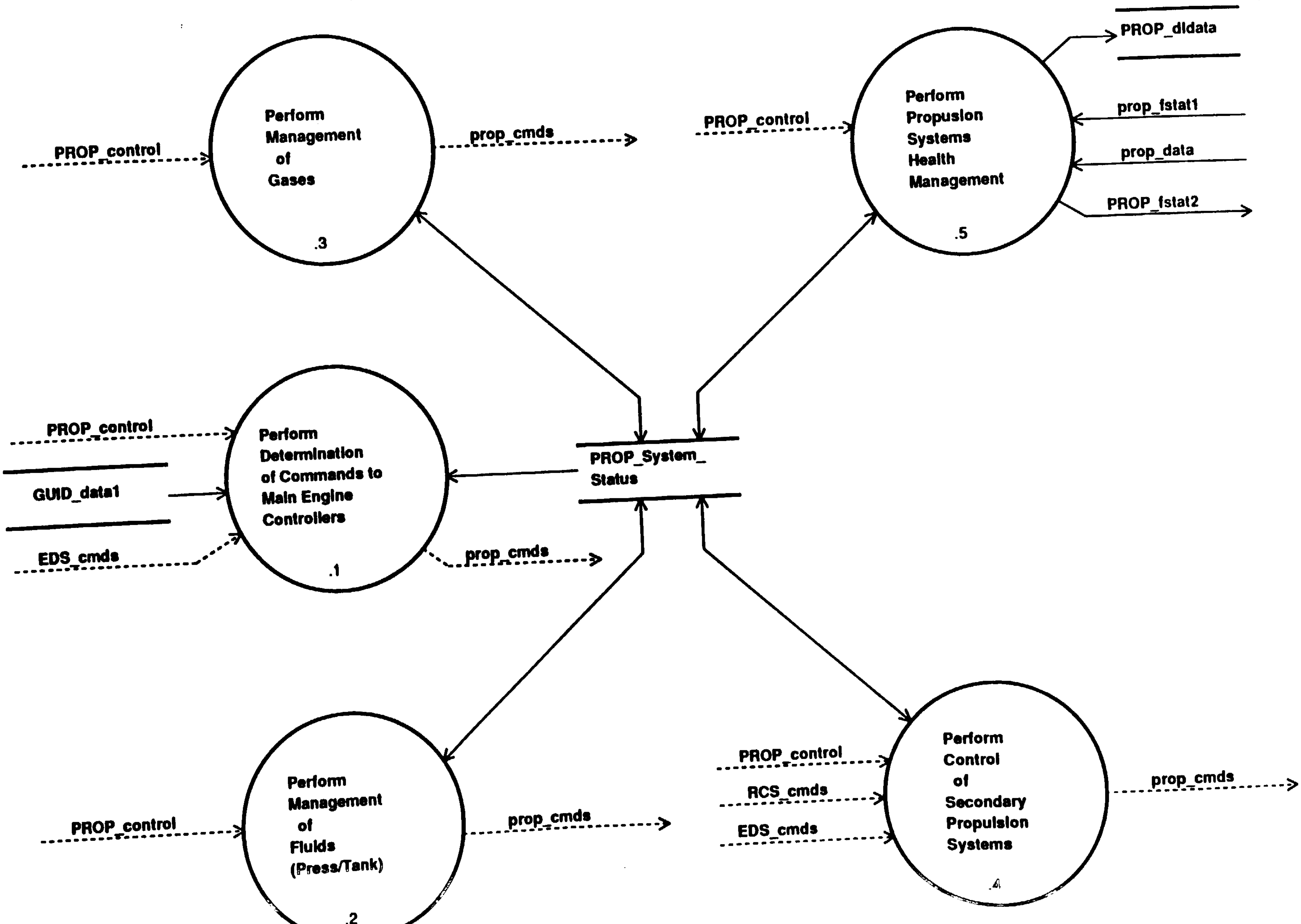
The Flight Control Health Management subfunction subfunction determines the health of the Flight Control system including any reconfiguration.


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



7;6
Perform Propulsion Sy- ..s 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 operat (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

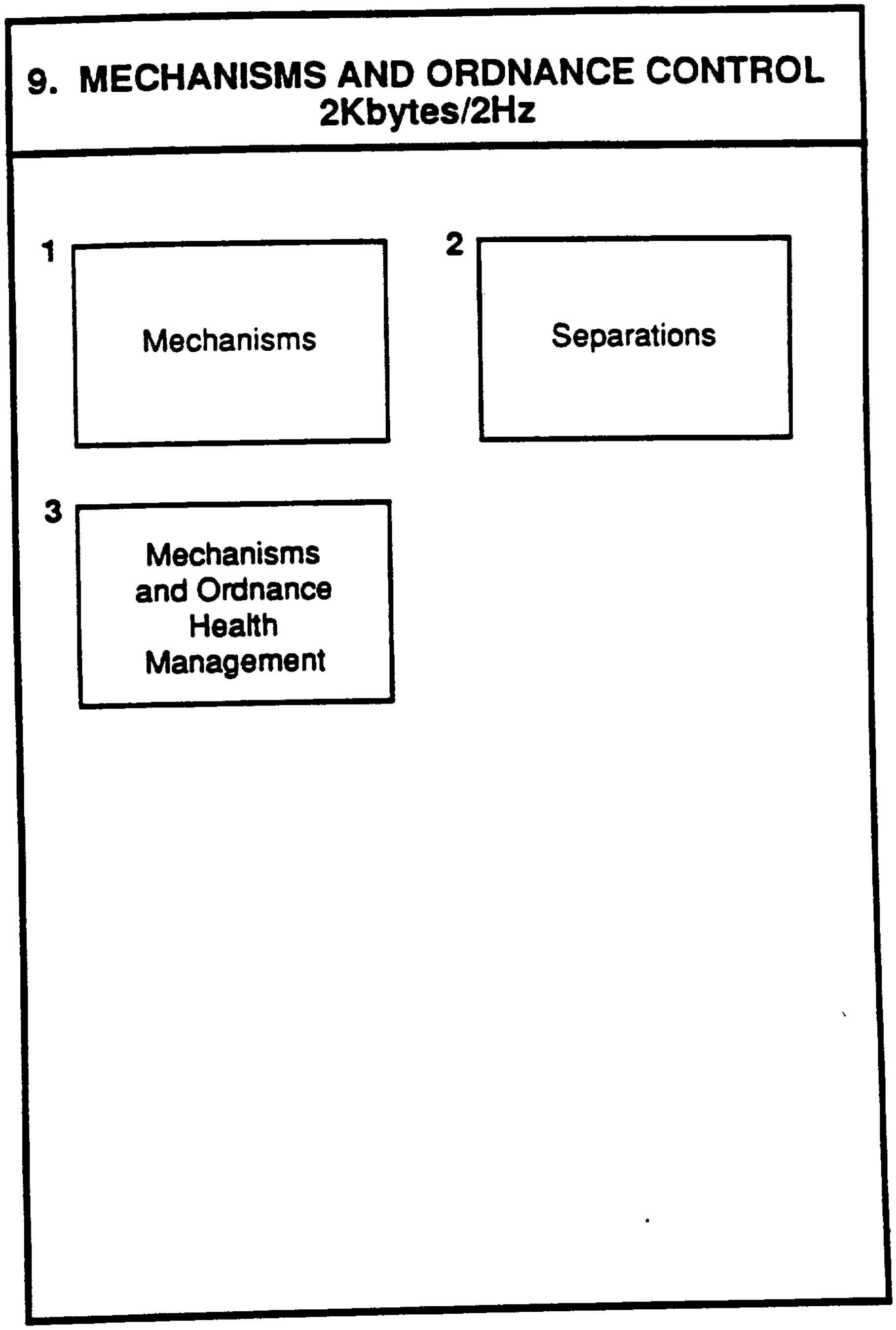
The Manage Gases subfunction receives commands to distribute helium for prelaunch purges during final launch countdown. This subfunction also manages the distribution of valve actuation gas for the main propulsion system as required during mission operations.

#### 3.1.7.4 Secondary Propulsion Control

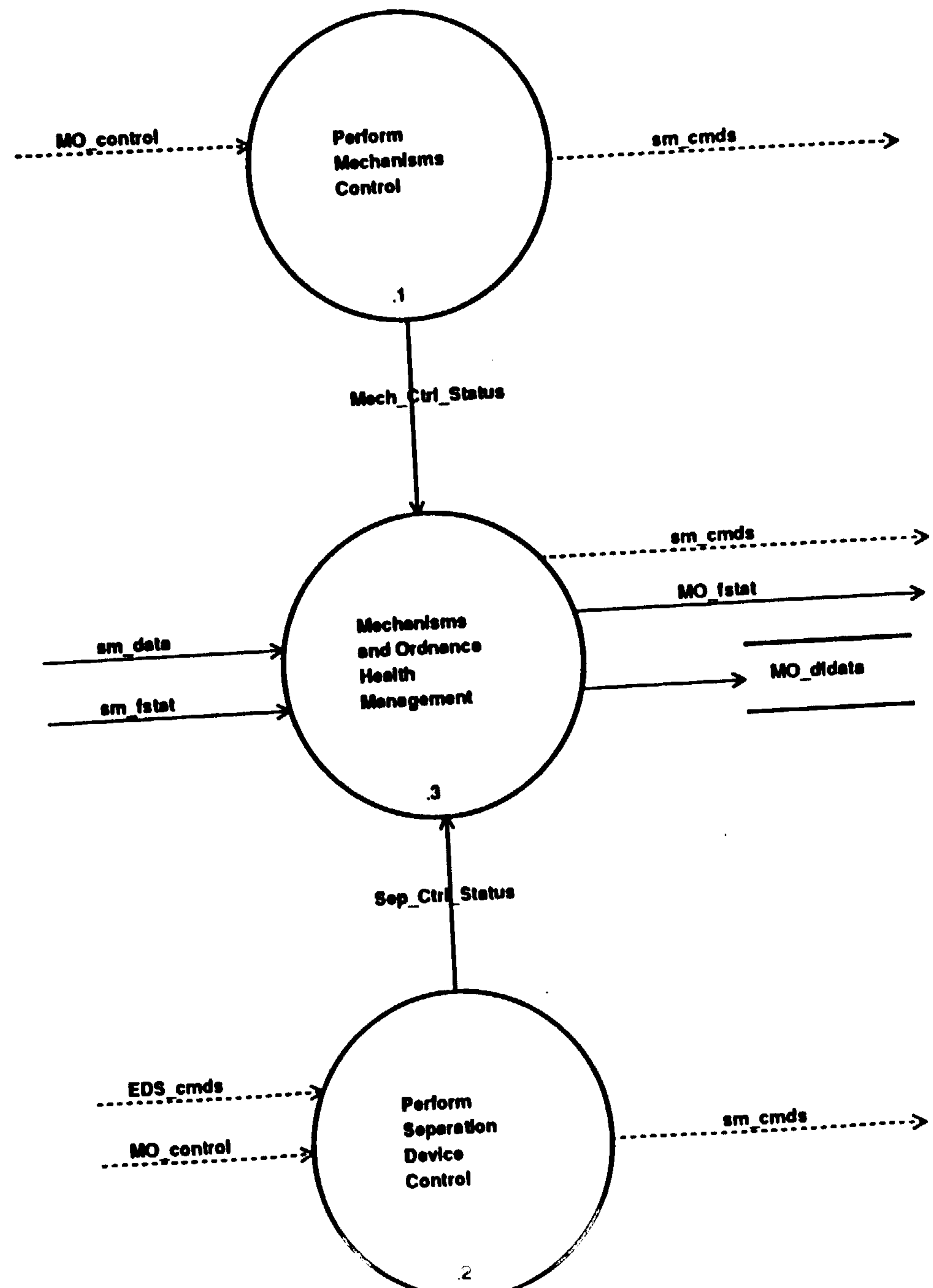
Upon command from the Flight Control function, the Secondary Propulsion Control subfunction arms/controls the secondary propulsion system. (Secondary propulsion consists of SSRBs, CTV engine(s) and controller(s), Upper Stage engine(s) and controller(s), RCS and deorbit engines.) Thruster, valve, pressure,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

9.4
Perform Mechanism and Ordnance C



## 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.

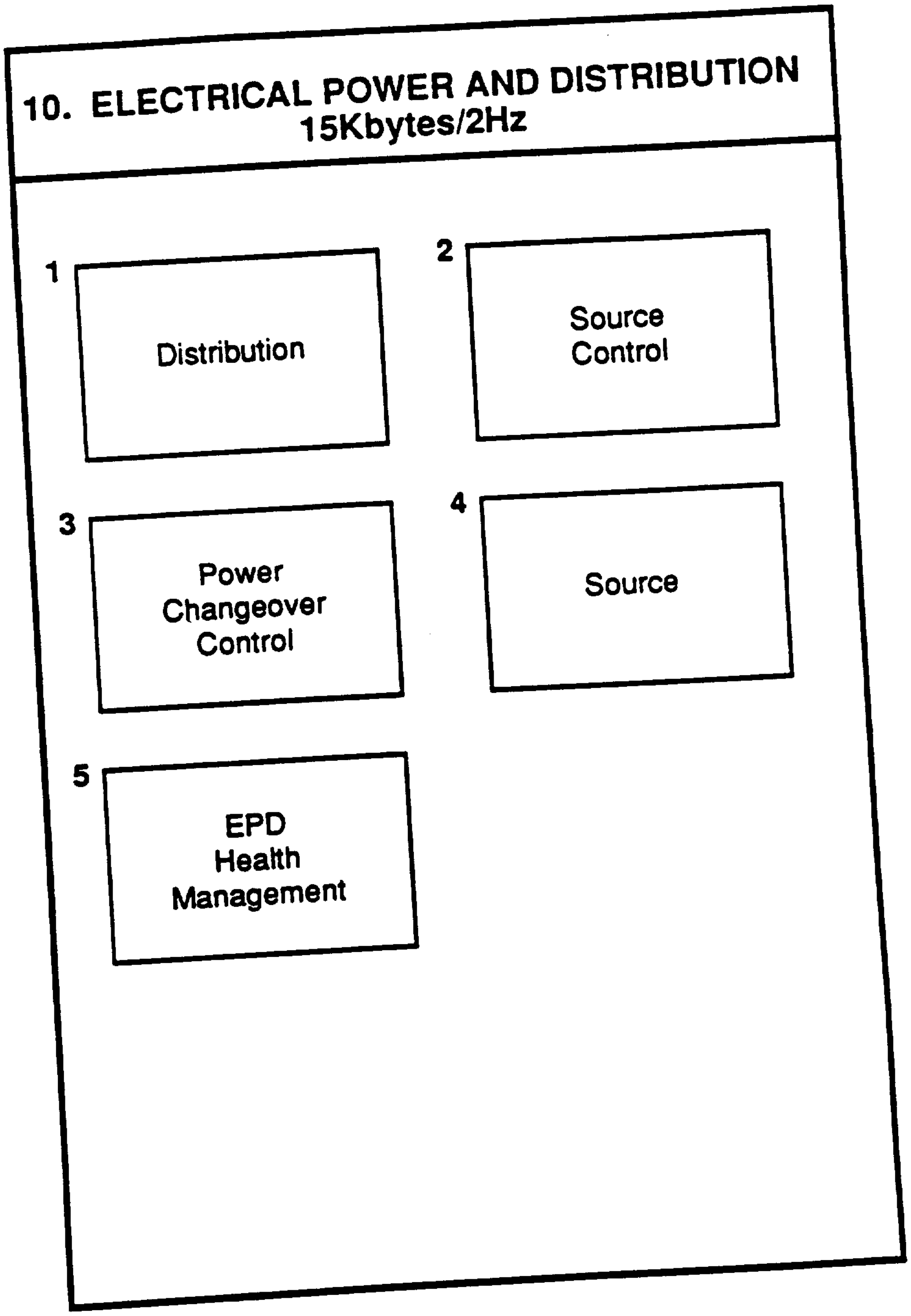
### 3.1.9.2 Separations

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:

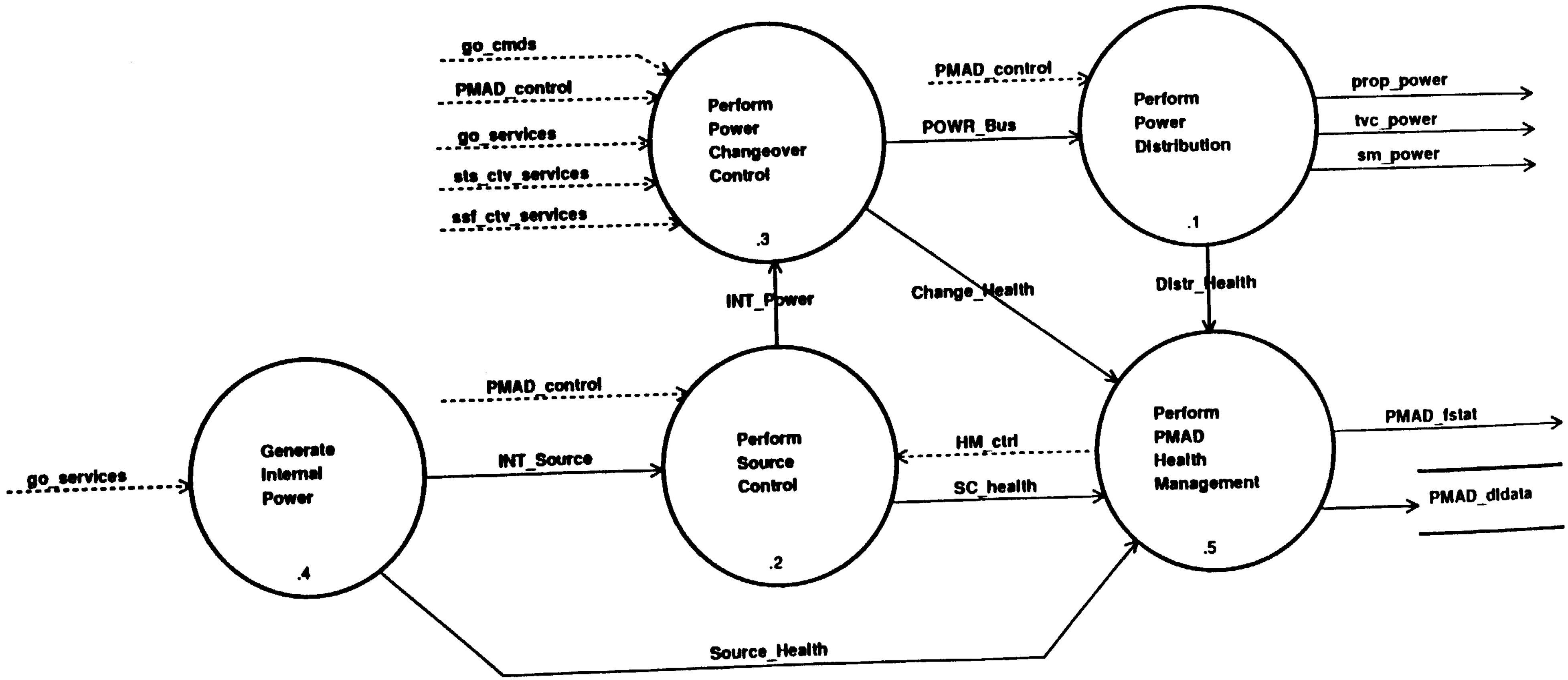
(a) T0 umbilical and holddown release
(b) Booster separation
(c) Shroud separation
(d) Payload separation
(e) CTV antenna deployment
(f) Strongback deployment.

### 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

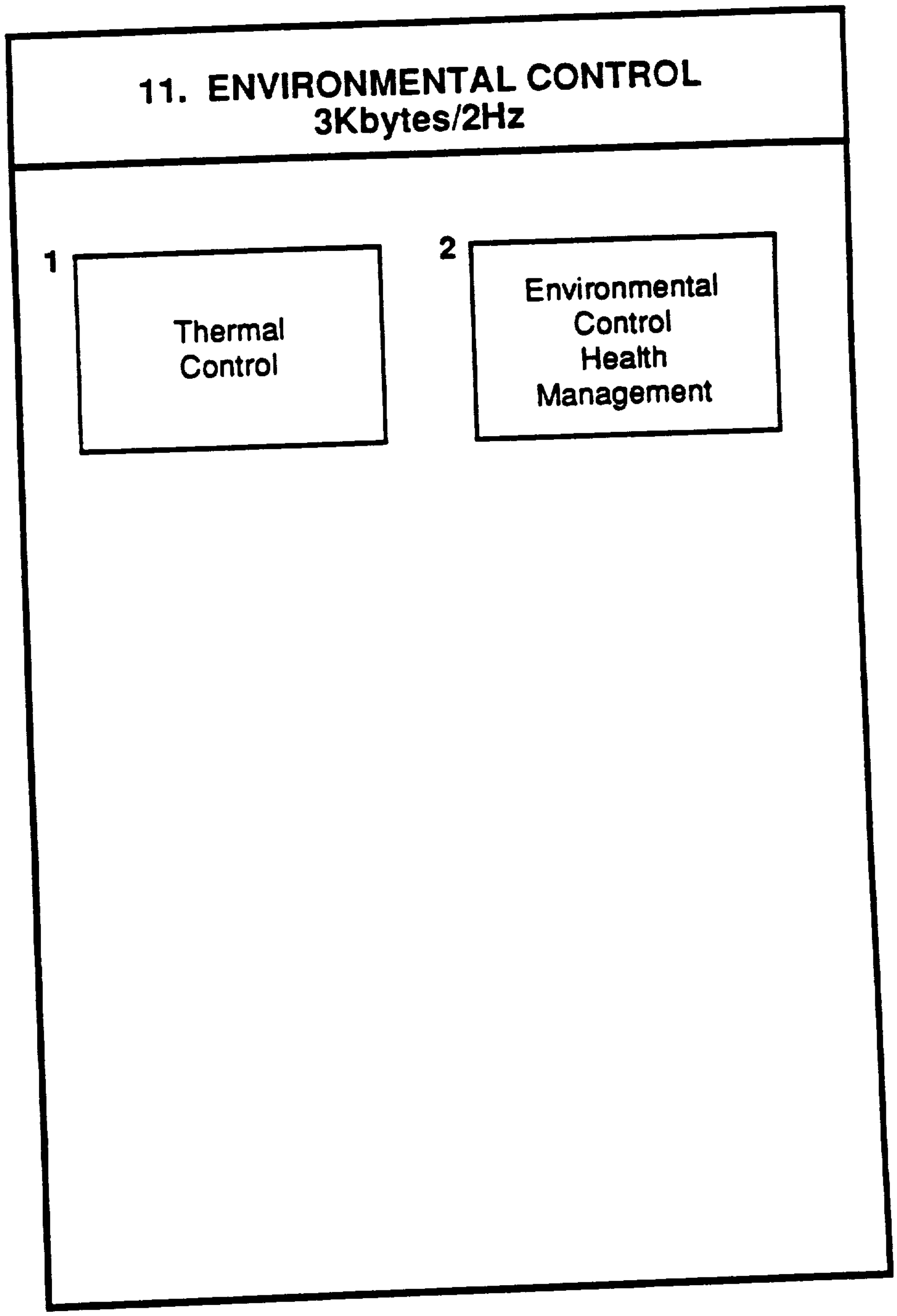
The Power Changeover Control subfunction shall initiate and complete power transfer between individual sources such as ground power to vehicle power or CTV power to SSF power. It shall also provide any necessary sequencing.

### 3.1.10.4 Source

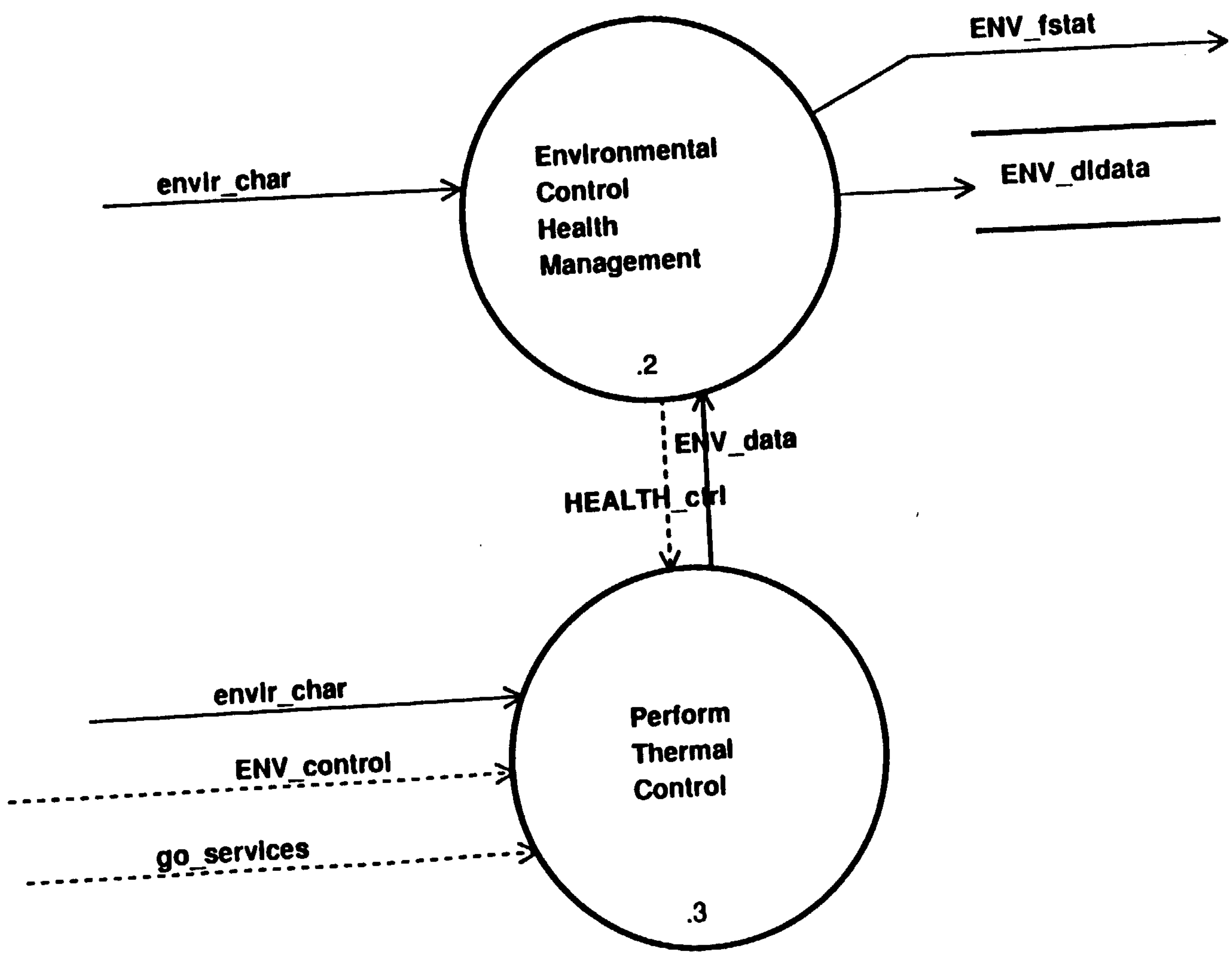
The Source subfunction provides the main power point of origin, i.e. batteries, ground power, fuel cells, etc.

### 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 Environental Control



### 3.1.11 Environmental Control

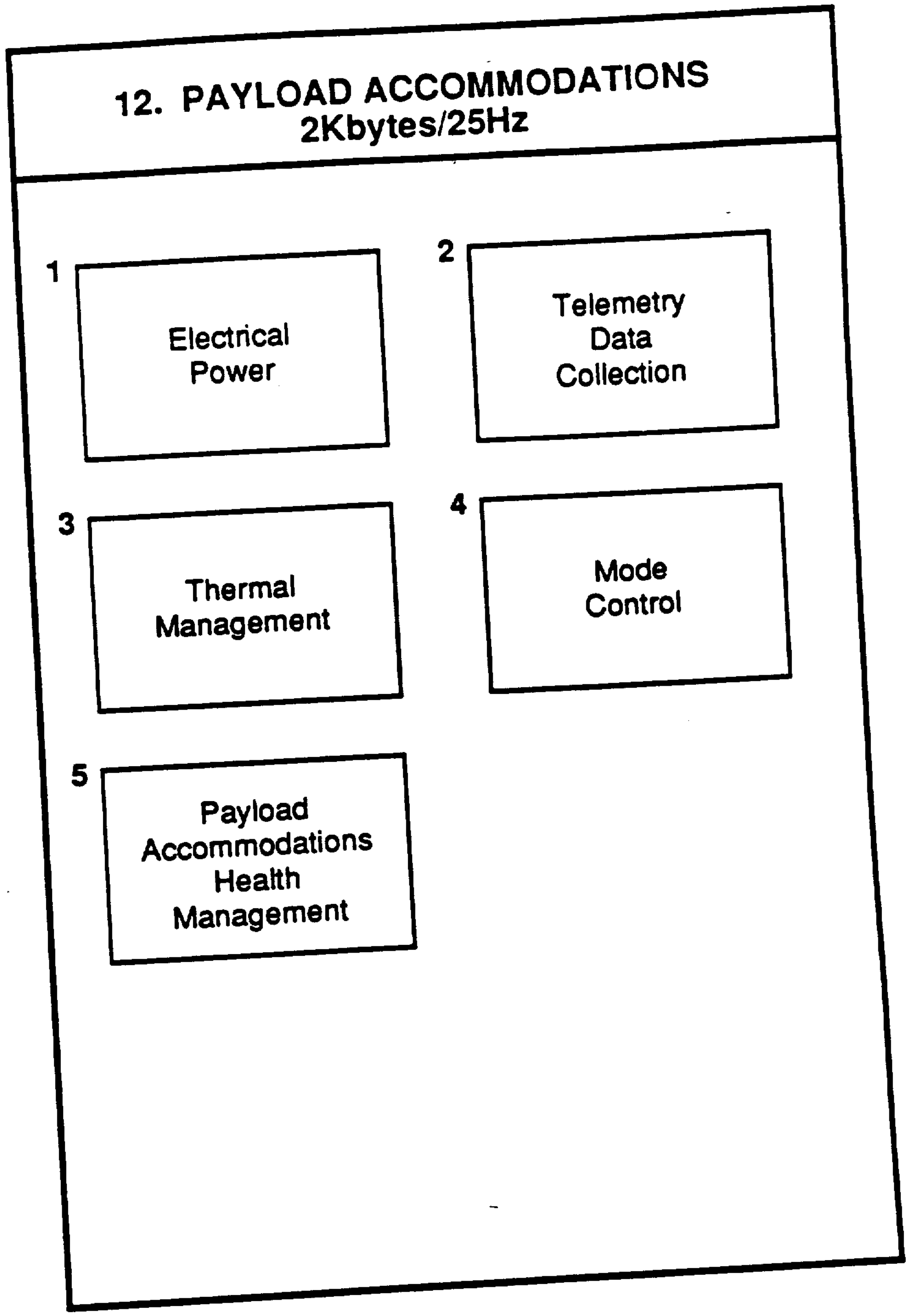
The Environmental Control function shall respond to environmental conditions in order to ensure that the avionics is maintained within acceptable thermal limits. Environmental Control Shall perform its own health monitoring, self-test and related subsystems health monitoring.

#### 3.1.11.1 Thermal Control

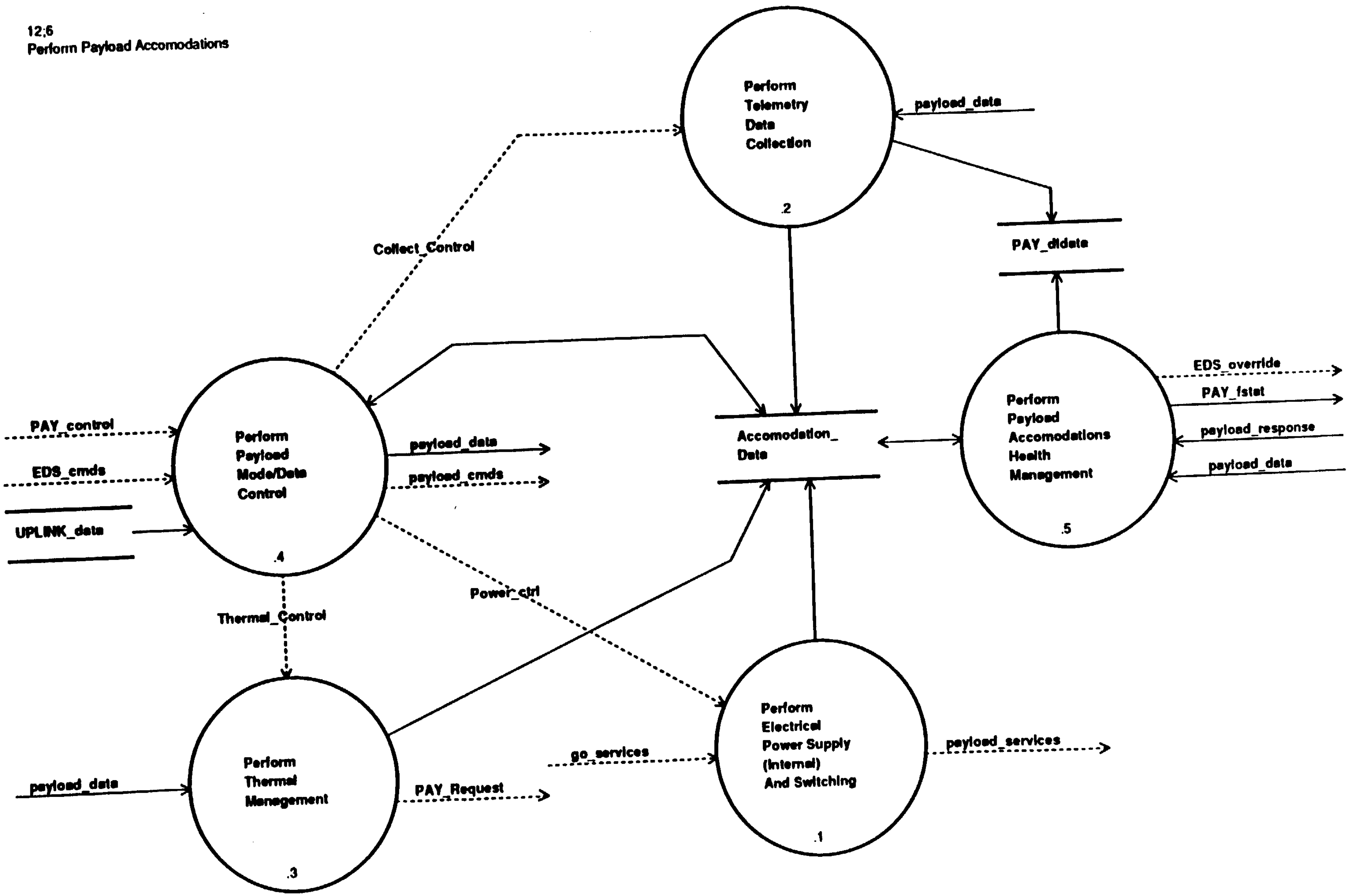
The Thermal Control subfunction monitors and provides control of avionics temperature during the mission. This will include both heating and cooling of the avionics systems.

#### 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 Accomodations



### 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.

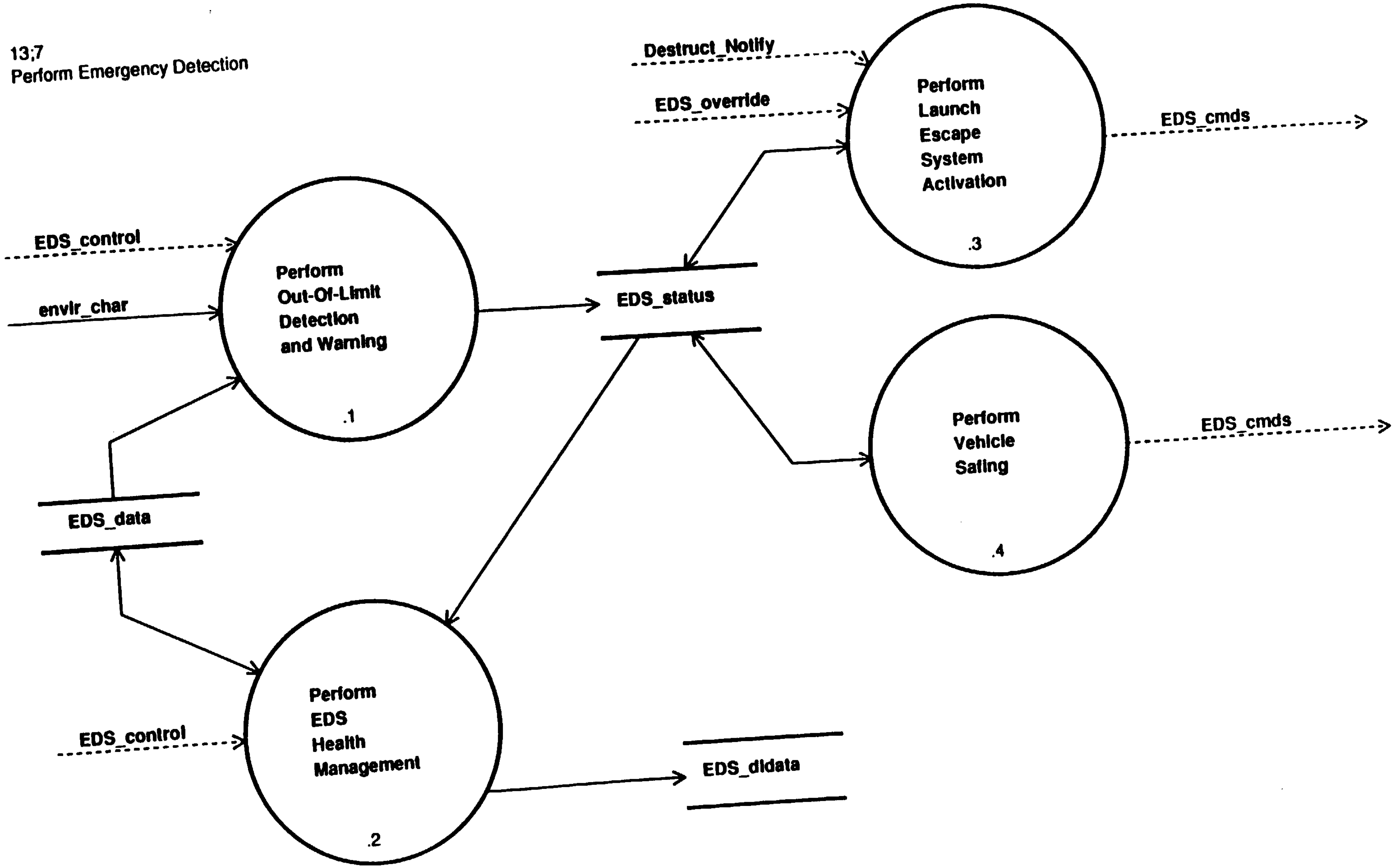
#### 3.1.12.5 Payload Accommodations Health Management

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

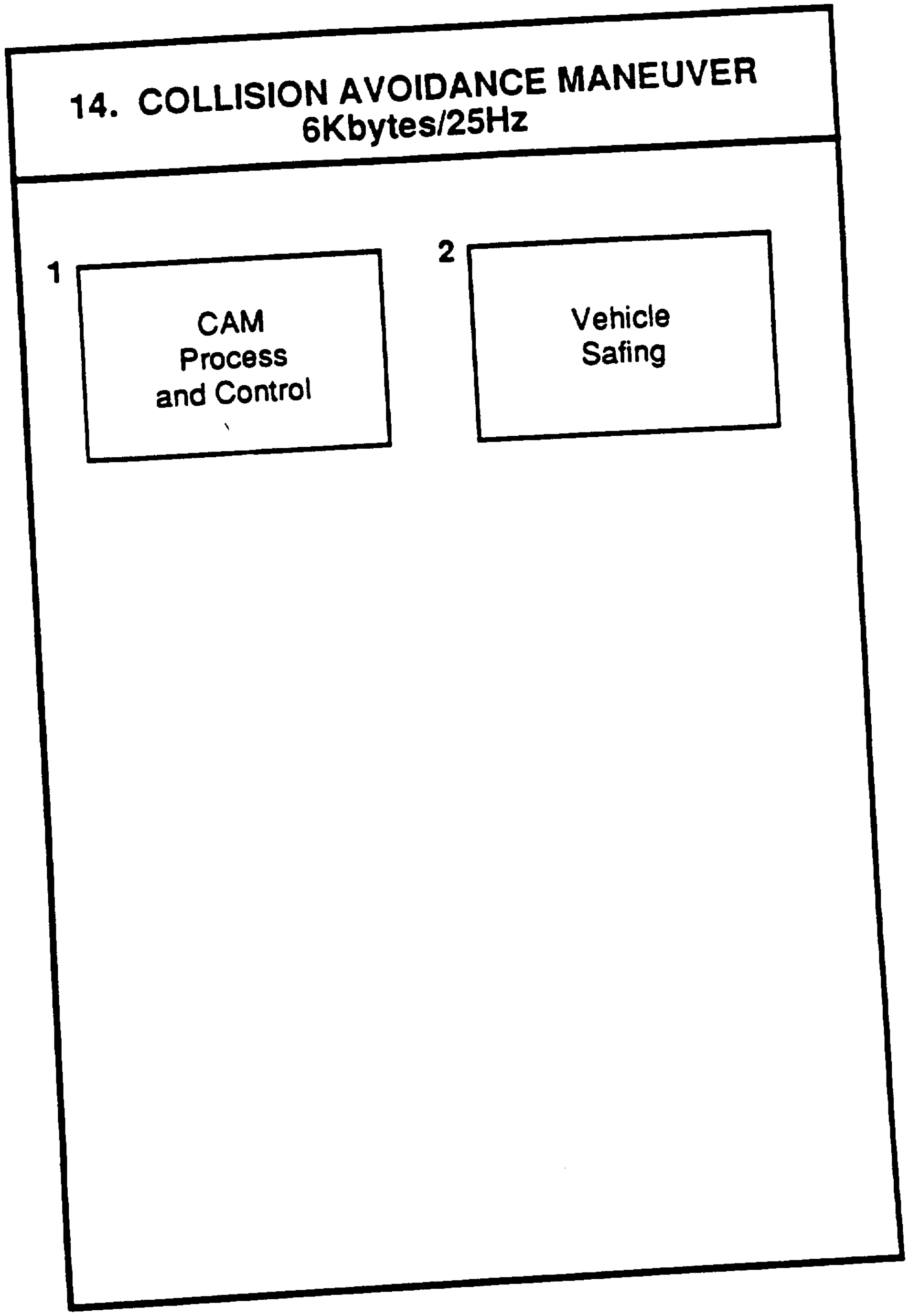
The Launch Escape System Activation subfunction automatically or by manual command initiates an onboard sequence of events that cause people to be safely removed from the launch vehicle, either before or afte. launch, if an uncorrectable hazardous condition is detected.

### 3.1.13.3 Vehicle Safing

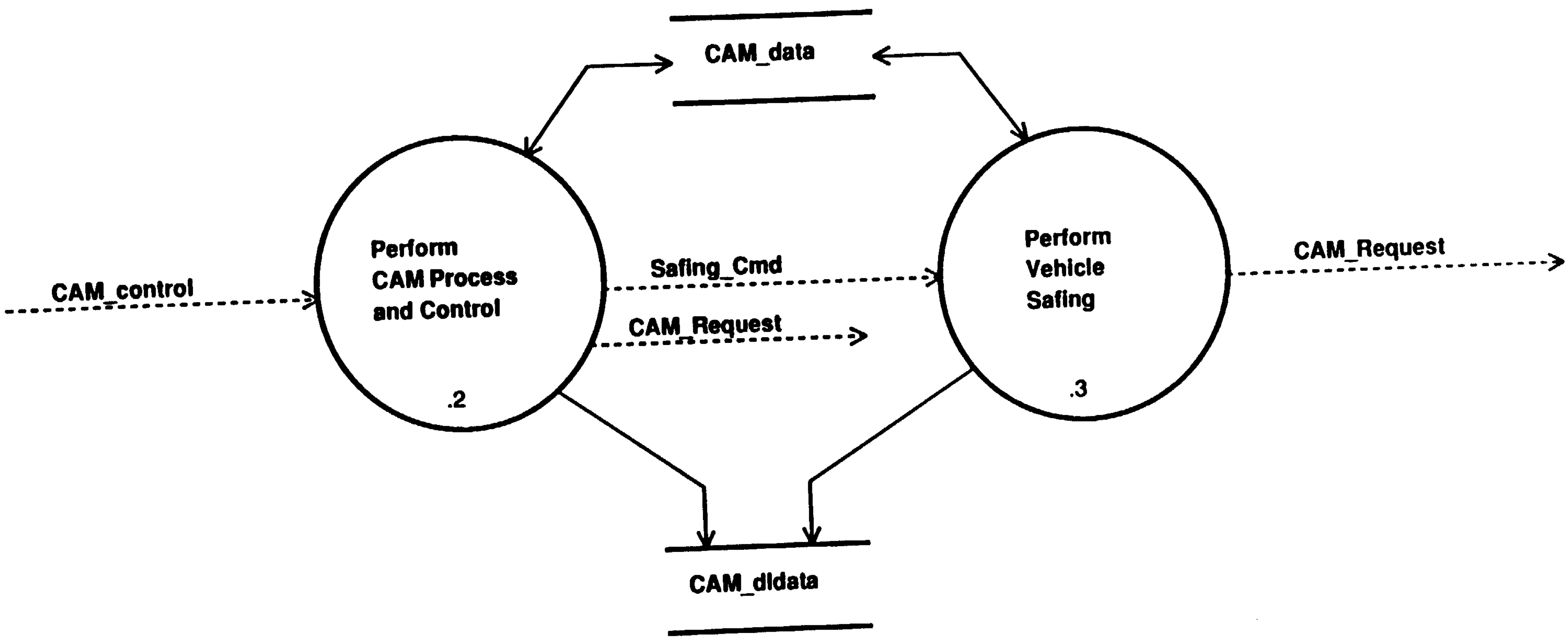
The Vehicle Safing subfunction inhibits all vehicle functions that may present any hazard to people. Hazardous functions may include the vehicle becoming propulsive or the performance of any ordnance event.

### 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

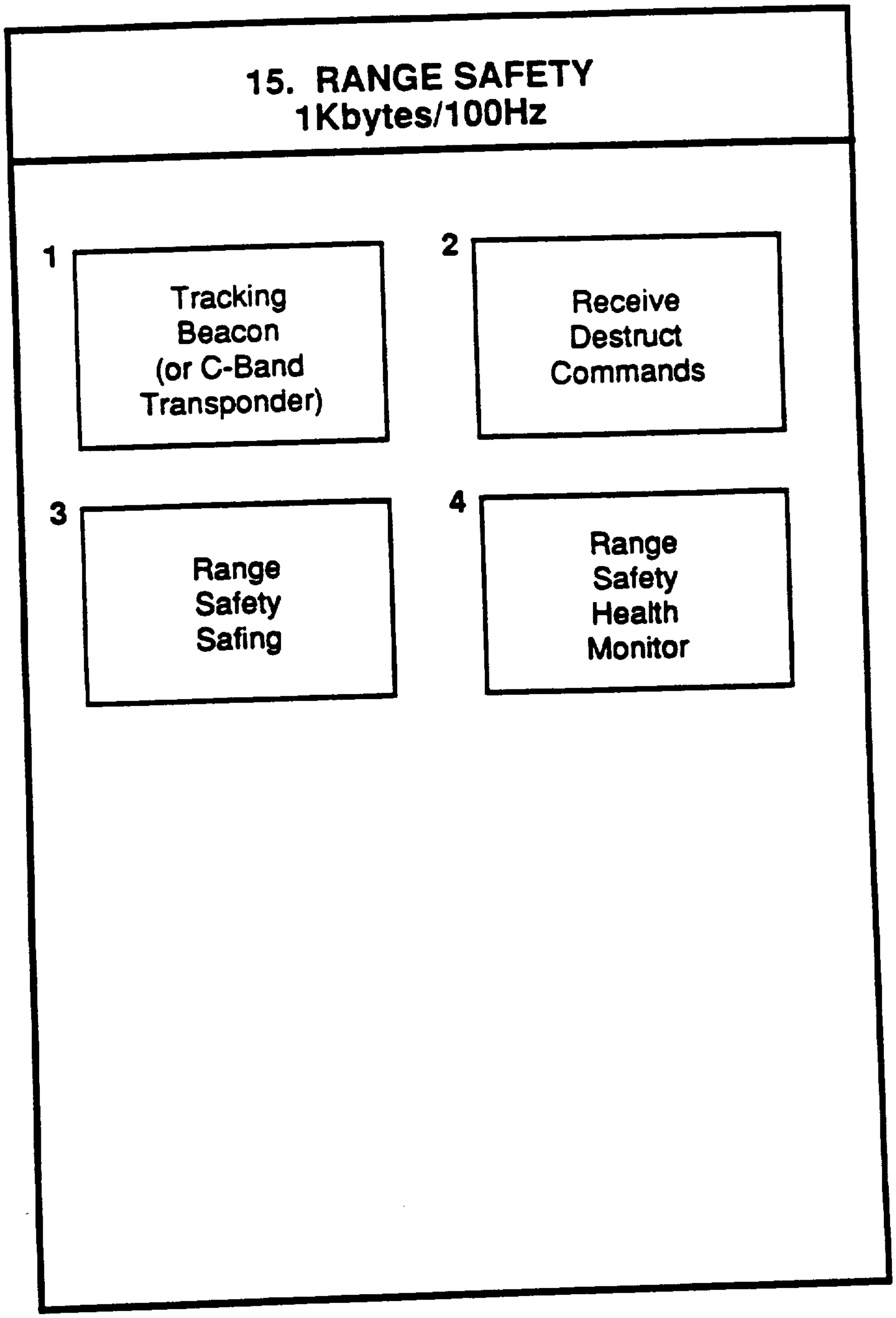
The CAM function shall monitor operation of the CTV when activated. When a hazardous condition is detected, or on command, the CAM function will intervene and maneuver the CTV to a safe position. The CAM function shall be an intervention level function.

#### 3.1.14.1 CAM Process and Control

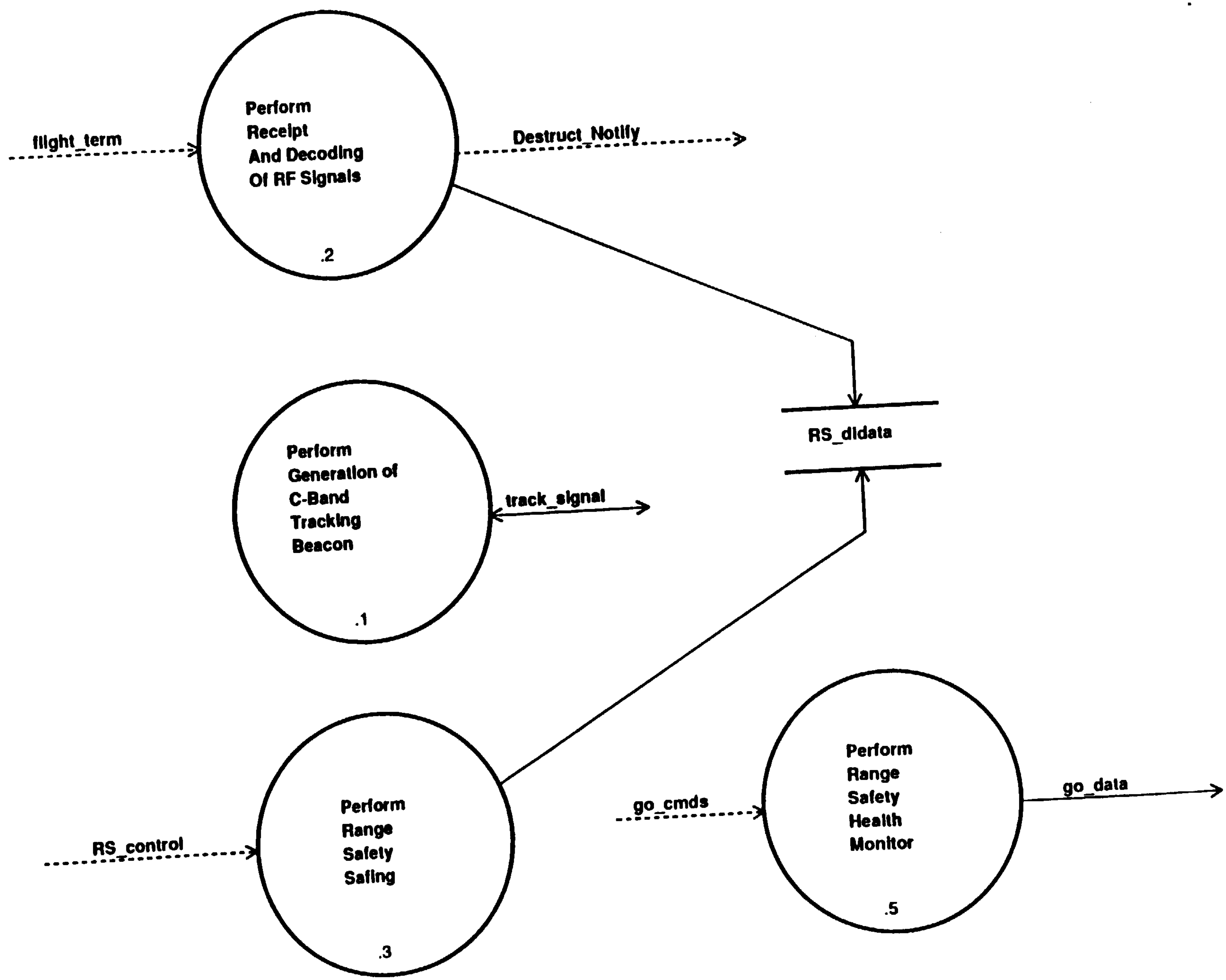
The CAM Process and Control subfunction will maneuver the CTV to a predetermined hold point which is at a safe distance from the target vehicle. The CTV will remain at the hold point sufficiently long for the ground/SSF controllers to decide if another proximity operation attempt is advisable. The CAM 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_Uplnk_Cmd | TC_Mode].

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

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

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

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

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

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

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

PROP_control (control flow) =
[PROP_Uplnk_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_Uplnk_Cmd | GUID_Mode].

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

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

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

CAM_control (control flow) =
[CAM_Uplnk_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_Uplnk_Cmd].

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

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

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

FCTL_control (control flow) =
[FCTL_Uplnk_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** | | | | | | 150 | 50 | |
| • 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** | | | | | | 29 | 50, 2 | |
| • Formatting Telemetry | √ | CDHU | √ | | | 10 | 50 | |
| • Storage | √ | CDHU | √ | | | 8 | 50 | |
| • Receive | | | √ | | | | | |
| • Transmit | | | √ | | | | | |
| • Decode | √ | CDHU | √ | | | 1 | 50 | |
| • RF Link Control | √ | CDHU | √ | | | 1 | 2 | |
| • Instrumentation | √ | CDHU | √ | √ | √ | 5 | 50 | |
| • T&C Health Mgmt. | √ | CDHU | √ | | | 4 | 50 | |

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

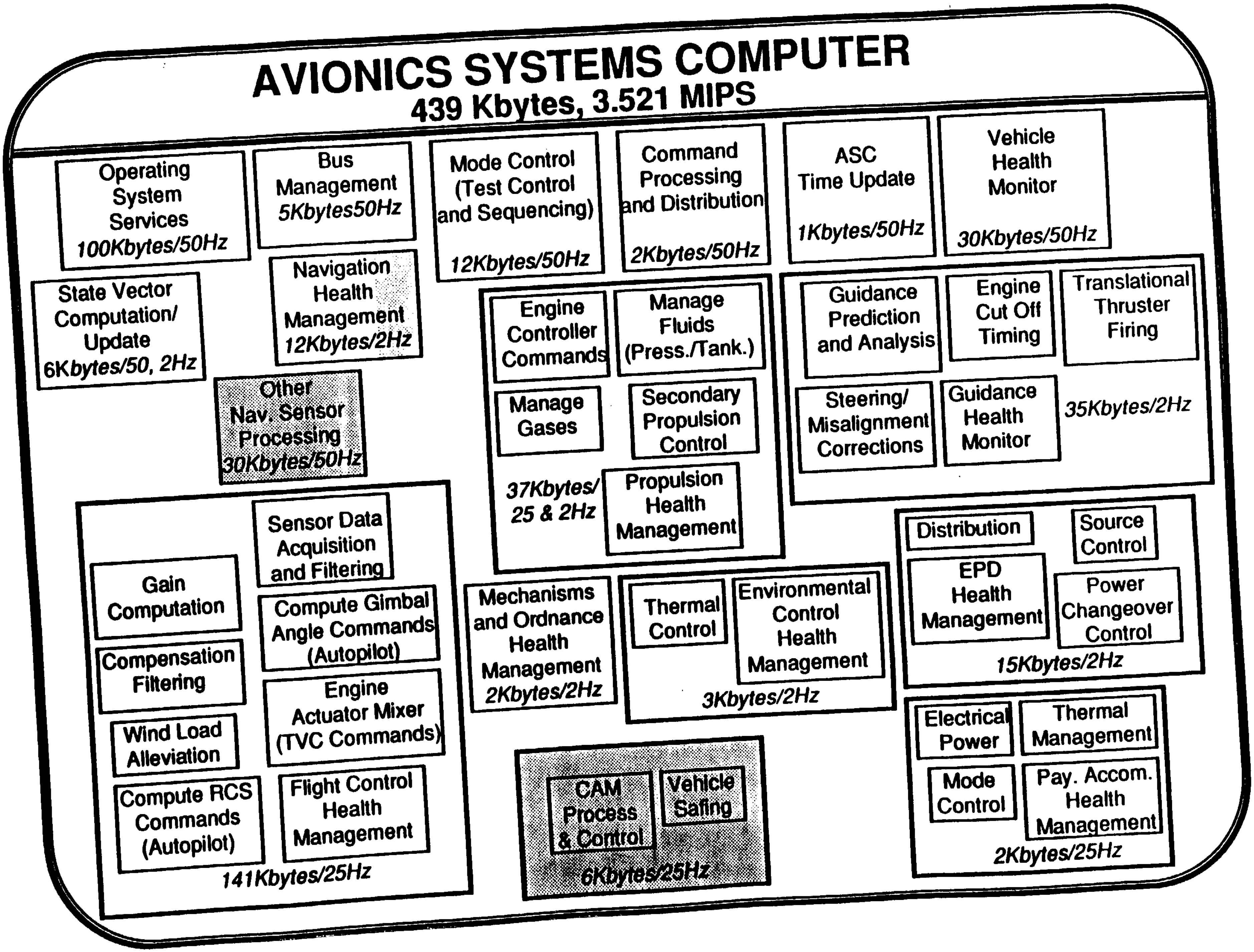
| | Proces. & S/W | Proces. Name | H/W | Common S/W | Common H/W | Sizing Kbytes | Timing Hz | Notes |
|---|---|---|---|---|---|---|---|---|
| **Navigation** | | | | | | 100 | 100, 50, 2 | |
| • Inertial Measurement | | | √ | | √ | | | |
| • Sensor Compensation | √ | IMU | | √ | | 6 | 50 | |
| • State 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** | | | | | | 141 | 25 | |
| • Gain Computation | √ | ASC | | √ | | | 25 | |
| • Sensor Data Acquisition & Filtering | √ | ASC | √ | √ | | | 25 | |
| • Compensation Filtering | √ | ASC | | √ | | | 25 | Could be designed as a common package. |
| • Compute Gimbal Angle Commands (Autopilot) | √ | ASC | | ? | | | 25 | |
| • Wind Load Alleviation | √ | ASC | | | | | 25 | Could be designed as a common package. |
| • Engine Actuator Mixer (TVC Commands) | √ | ASC | | ? | | | 25 | Could be designed as a common package. |
| • Compute RCS Commands (Autopilot) | √ | ASC | | √ | | | 25 | |
| • Flight Control Health Mgmt. | √ | ASC | √ | ? | | | 25 | |
| **Propulsion Control** | | | | | | 37 | 25, 2 | |
| • 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.** | | | | | | 2 | 2 | |
| • Mechanisms | | | √ | Not pertinent | | | | |
| • Separations | | | √ | | | | | |
| • M&O Health Management | √ | ASC | √ | | | | | |
| | | | | | | | | |
| **Electrical Power & Distrib.** | | | | | | 15 | 2 | |
| • Distribution | √ | ASC | √ | √ | | | | |
| • Source Control | √ | ASC | √ | √ | | | | |
| • Power Changeover Control | √ | ASC | √ | √ | | | | |
| • Source | | | √ | | | | | |
| • EPS Health Management | √ | ASC | √ | √ | | 4 | | |

| | Proces. & S/W | Proces. Name | H/W | Common S/W | Common H/W | Sizing Kbytes | Timing Hz | Notes |
|---|---|---|---|---|---|---|---|---|
| **Environmental Control** | | | | | | 3 | 2 | |
| • Thermal Control | √ | ASC | √ | | | | | |
| • Environ. Ctrl. Health Mgmt. | √ | ASC | √ | | | | | |
| | | | | | | | | |
| **Payload Accommodations** | | | | | | 2 | 25 | |
| • Electrical Power | √ | ASC | √ | √ | | | | |
| • 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.** | | | | | | 5 | 100 | |
| • Out of Limit Detection and Warning | √ | EDP | √ | | | | | |
| • Launch Escape System Activation | √ | EDP | √ | | | | | |
| • Vehicle Safing | √ | EDP | √ | | | | | |
| • EDS Health Management | √ | EDP | √ | | | | | |
| **Collision Avoidance Maneuv.** | | | | | | 6 | 25 | |
| • CAM Process & Control | √ | ASC | √ | | | | | |
| • Vehicle Safing | √ | ASC | √ | | | | | |
| | | | | | | | | |
| **Range Safety** | | | | | | 1 | 100 | |
| • Tracking Beacon (C-band Transponder | | | √ | | | | | |
| • 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
Bus Management 5Kbytes50Hz
Mode Control (Test Control and Sequencing) 12Kbytes/50Hz
Command Processing and Distribution 2Kbytes/50Hz
ASC Time Update 1Kbytes/50Hz
Vehicle Health Monitor 30Kbytes/50Hz
State Vector Computation/ Update 6Kbytes/50, 2Hz
Navigation Health Management 12Kbytes/2Hz
Other Nav. Sensor Processing 30Kbytes/50Hz
Engine Controller Commands
Manage Fluids (Press./Tank.)
Manage Gases
Secondary Propulsion Control
Propulsion Health Management
37Kbytes/ 25 & 2Hz
Guidance Prediction and Analysis
Engine Cut Off Timing
Translational Thruster Firing
Steering/ Misalignment Corrections
Guidance Health Monitor
35Kbytes/2Hz
Sensor Data Acquisition and Filtering
Gain Computation
Compute Gimbal Angle Commands (Autopilot)
Compensation Filtering
Engine Actuator Mixer (TVC Commands)
Wind Load Alleviation
Compute RCS Commands (Autopilot)
Flight Control Health Management
141Kbytes/25Hz
Mechanisms and Ordnance Health Management 2Kbytes/2Hz
Thermal Control
Environmental Control Health Management
3Kbytes/2Hz
Distribution
Source Control
EPD Health Management
Power Changeover Control
15Kbytes/2Hz
Electrical Power
Thermal Management
Mode Control
Pay. Accom. Health Management
2Kbytes/25Hz
CAM Process & Control
Vehicle Safing
6Kbytes/25Hz

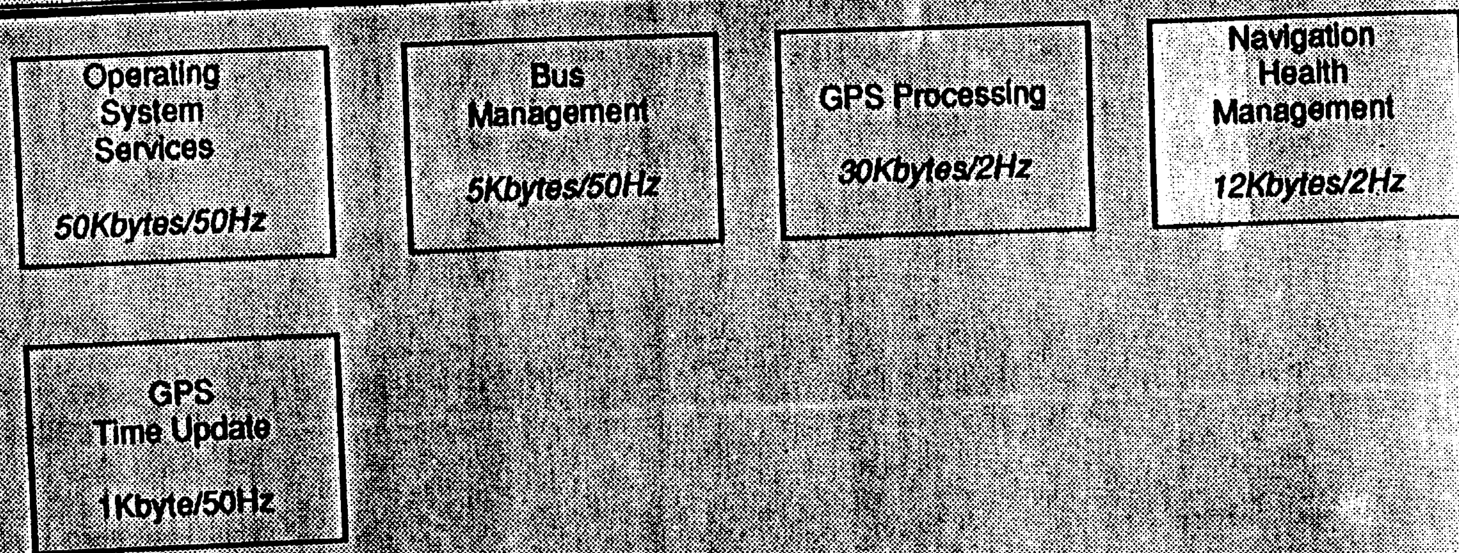
# COMMAND & DATA HANDLING UNIT

## 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



# INERTIAL MEASUREMENT UNIT

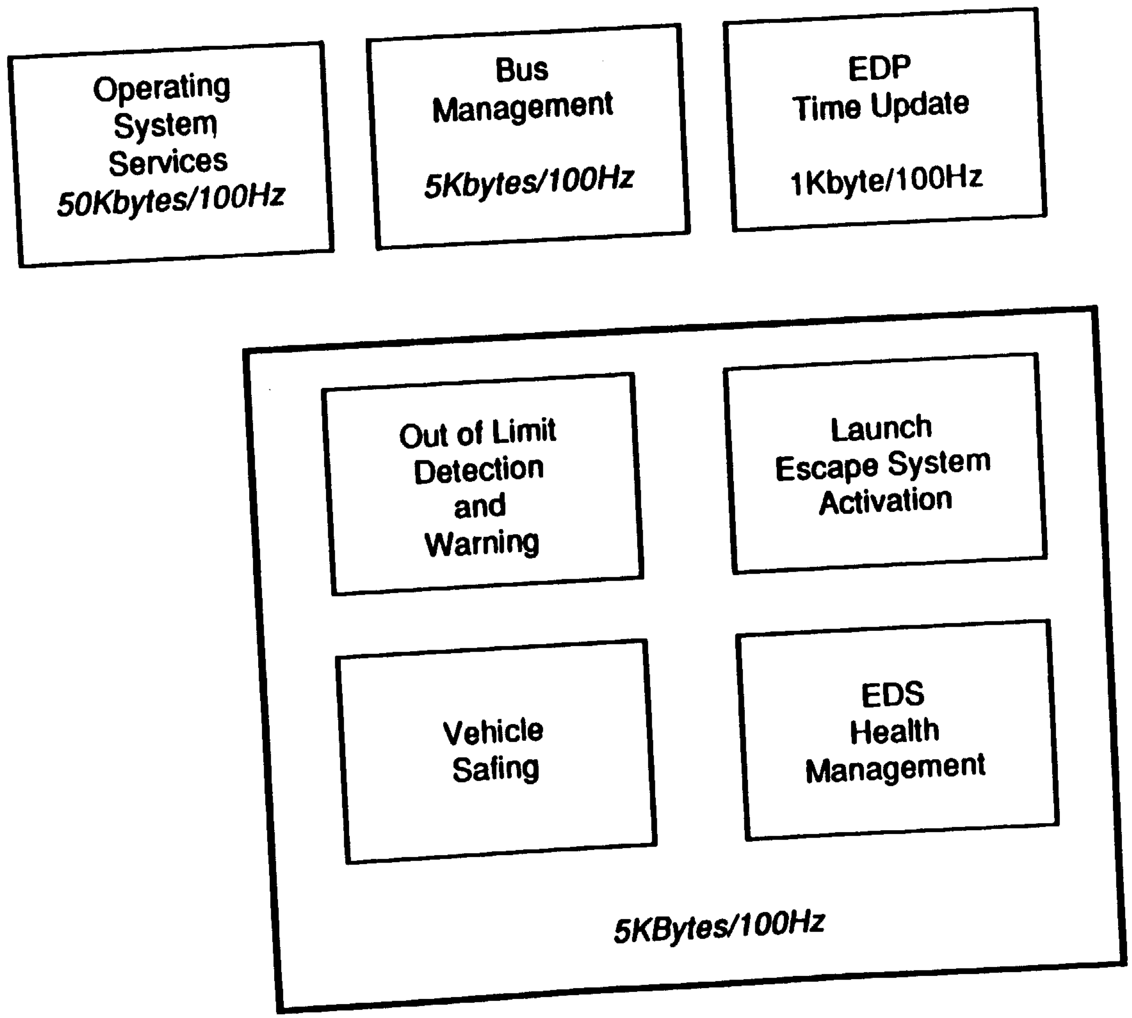
## 90 Kbytes, 2.25 MIPS

| Operating System Services | Bus Management | Sensor Compensation | On-Pad Alignment and Sensor Bias Estimation | Navigation Health Management |
|---|---|---|---|---|
| *50Kbytes/100Hz* | *5Kbytes/100Hz* | *6Kbytes/50Hz* | *16Kbytes/100Hz* | *12Kbytes/2Hz* |

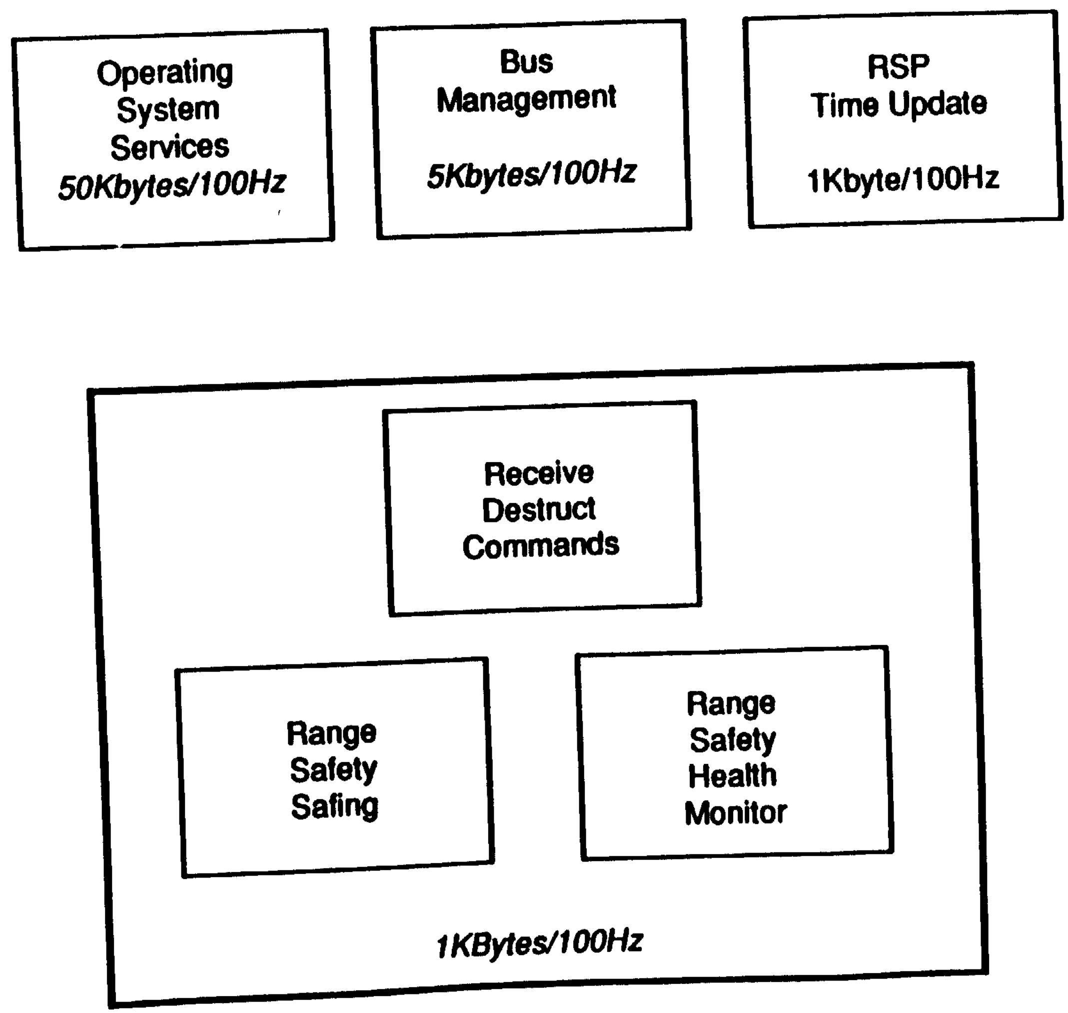
| IMU Time Update |
|---|
| 1Kbyte/100Hz |

# EMERGENCY DETECTION PROCESSOR

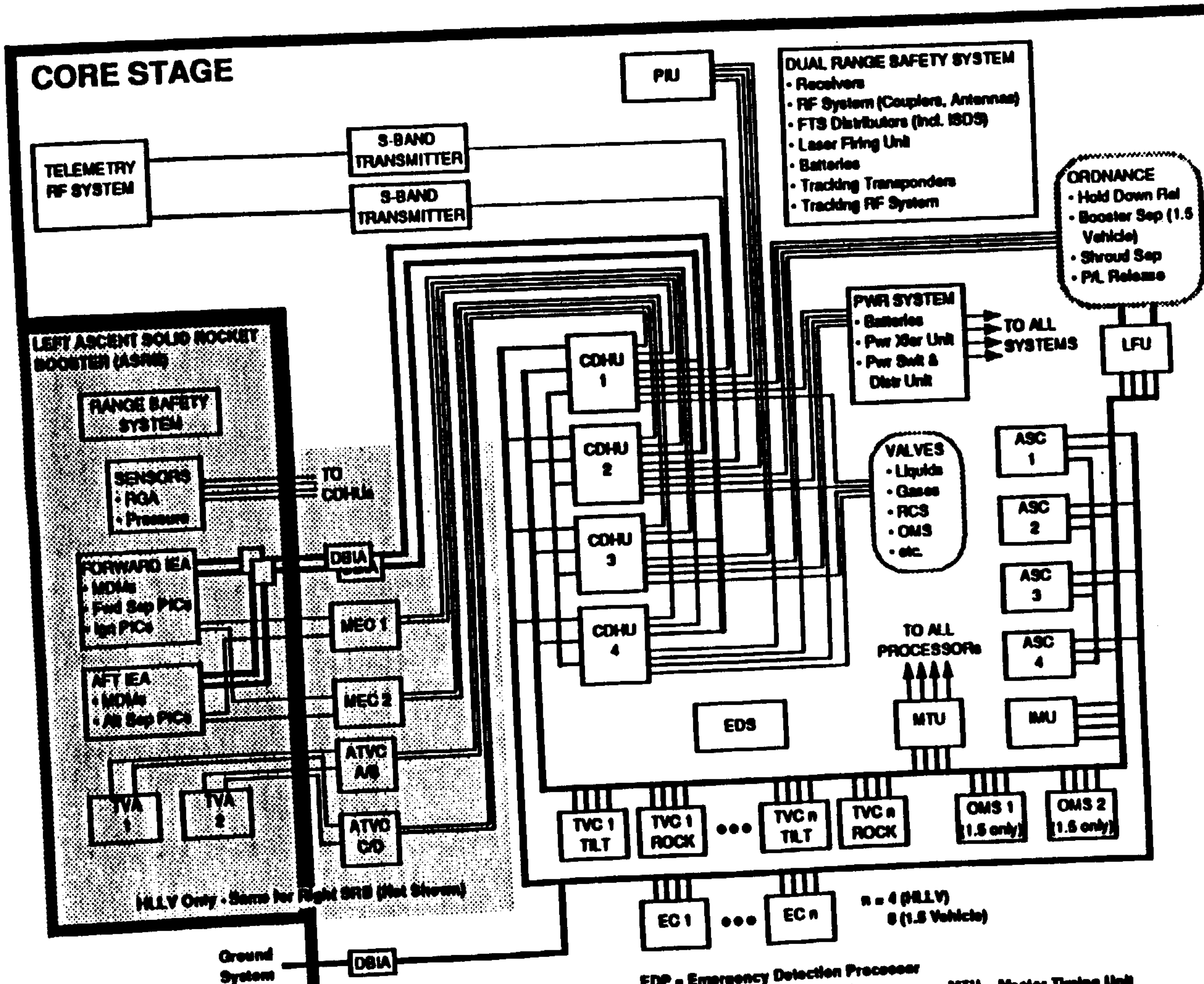
## 61 Kbytes, 1.5 MIPS



# RANGE SAFETY PROCESSOR
## 57 Kbytes, 1.43 MIPS



# NLS Avionics Block Diagram - Core Stage




**VEHICLE & DATA MANAGEMENT**
- Mode Control (ASC)
- Command Process & Distrib (ASC)
- Vehicle Timekeeping (MTU)
- Vehicle Health Monitor (ASC)
- Operating System Services (ASC)
- Bus Management (ASC)

**TELEMETRY & COMMAND**
- Formatting Telemetry (CDHU)
- Storage (CDHU)
- Transmit
- 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 Raw 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 Gimbal Angle Cmds
  - Autopilot (ASC)
- Wind Load Alleviation (ASC)
- Engine Actuator Mixer - TVC Commands (ASC)
- Compute RCS Cmds - Autopilot (ASC)
- Flight Control Health Mgmt (ASC)

**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
- 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 (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 Safing (EDP)
- EDS Health Management (EDP)

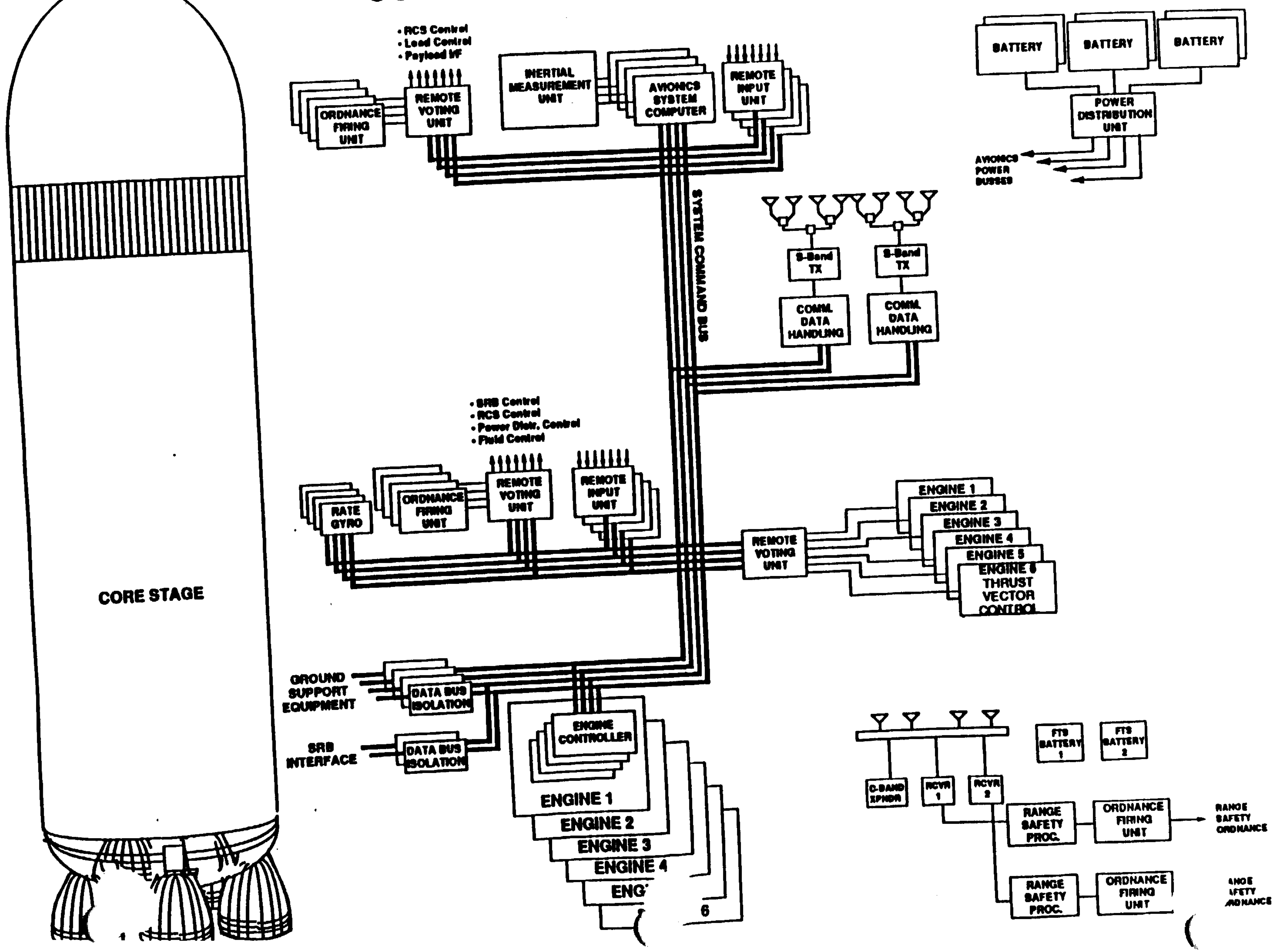
**RANGE SAFETY**
- Tracking Beacon
- Receive Destruct Commands (RSP)
- Range Safety Safing (RSP)
- Range Safety Health Mgmt (RSP)

ASC = Avionics System Computer
ATVC = Ascent Thrust Vector Controller
CDHU = Command & Data Handling Unit
DBIA = Data Bus Isolation Amp
EC = Engine Controller

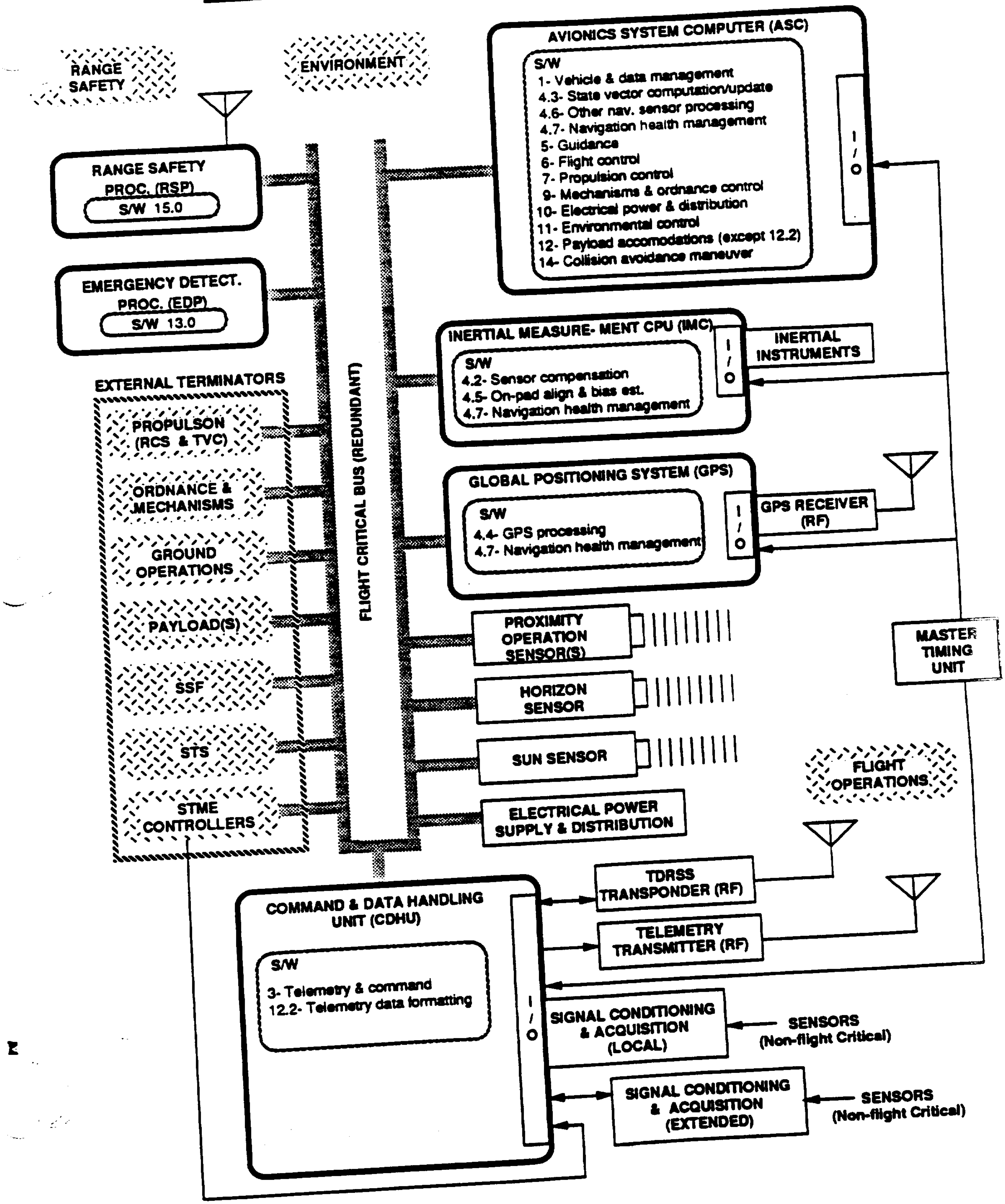
EDP = Emergency Detection Processor
EDS = Emergency Detection System
IEA = Integrated Electronics Assembly
IMU = Inertial Measurement Unit
LFU = Laser Firing Unit
MEC = Master Events Controller

MTU = Master Timing Unit
OMS = Orbital Maneuver System
PIU = Payload Interface Unit
RSP = Range Safety Processor
TVC = Thrust Vector Controller

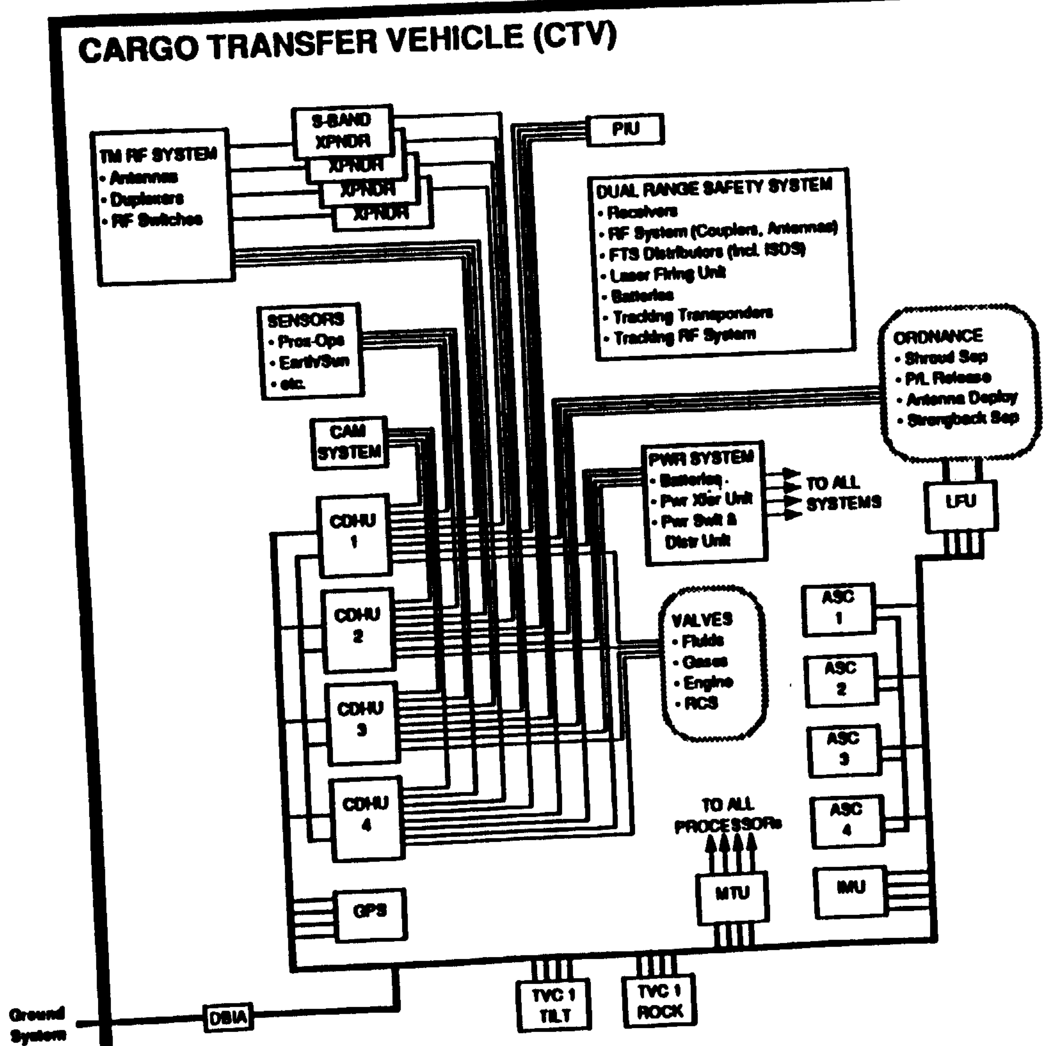
# CORE AVIONICS CONFIGURATION



# NLS AVIONICS FUNCTION ALLOCATION



# NLS Avionics Block Diagram - Cargo Transfer Vehicle (CTV)




**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/CDHU)

**TELEMETRY & COMMAND**
- Formatting Telemetry (CDHU)
- Storage (CDHU)
- Receive
- Transmit
- Decode (CDHU)
- RF Link Control (CDHU)
- Instrumentation (CDHU)
- T&C Health Management (CDHU)

**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)
- Nav Health Mgmt (ASC/IMU/GPS)

**GUIDANCE**
- Guidance Predict & Anal (ASC)
- Engine Cut-Off Timing (ASC)
- Translational Thruster Firing (ASC)
- Steer/Misalign 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 Alleviation (ASC)
- Engine Actuator Mixer - TVC Cmds (ASC)
- Compute RCS Cmds - Autopilot (ASC)
- Flight Control Health Mgmt (ASC)

**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
- 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 (CDHU)
- Thermal Management (ASC)
- Mode Control (ASC)
- Payload Accom Health Mgmt (ASC)

**COLLISION AVOID MANEUV - CTV**
- CAM Process & Control (ASC)
- Vehicle Safing (ASC)

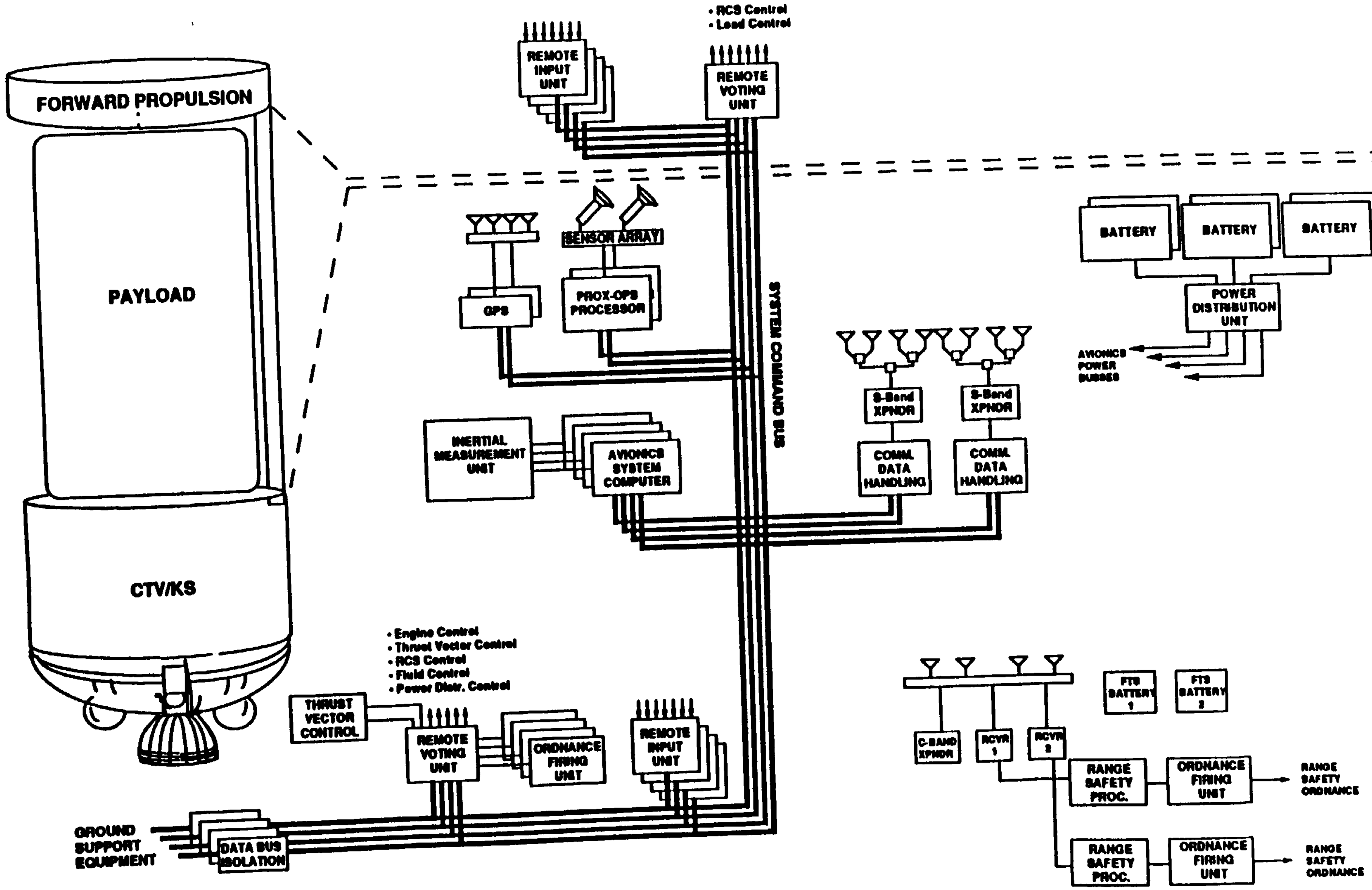
**RANGE SAFETY**
- Tracking Beacon
- Receive Destruct Commands (RSP)
- Range Safety Safing (RSP)
- Range Safety Health Mgmt (RSP)

ASC = Avionics System Computer
CAM = Collision Avoidance Maneuver
CDHU = Command & Data Handling Unit
...ta Bus Isolation Amp
...al Position System

IMU = Inertial Measurement Unit
LFU = Laser Firing Unit
MTU = Master Timing Unit
PIA = Payload Interface Unit

RSP = Range Safety Processor
TM = Telemetry
TVC = Thrust Vector Controller
XPNDR = Transponder

# CTV AVIONICS CONFIGURATION



# 3-FM-003

# NLS Cycle 1
# Acoustics Analysis

# January, 1992

Author: ______________________
Stan Barrett
MMAG, Denver

______________________
Richard Harris
Systems Analysis Manager

______________________
Zach Kirkland
Systems Engineering Director
NLS / Shuttle-C

**Distribution:**
NLS / Shuttle-C Contracts (1)

NLS Technical Library (1)

# 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 excedence 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

MARTIN MARIETTA
MANNED SPACE SYSTEMS

# 3-FM-003 NLS Acoustics

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

**Key Issues:**

- Liftoff Condition (Pad Configuration & H20 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

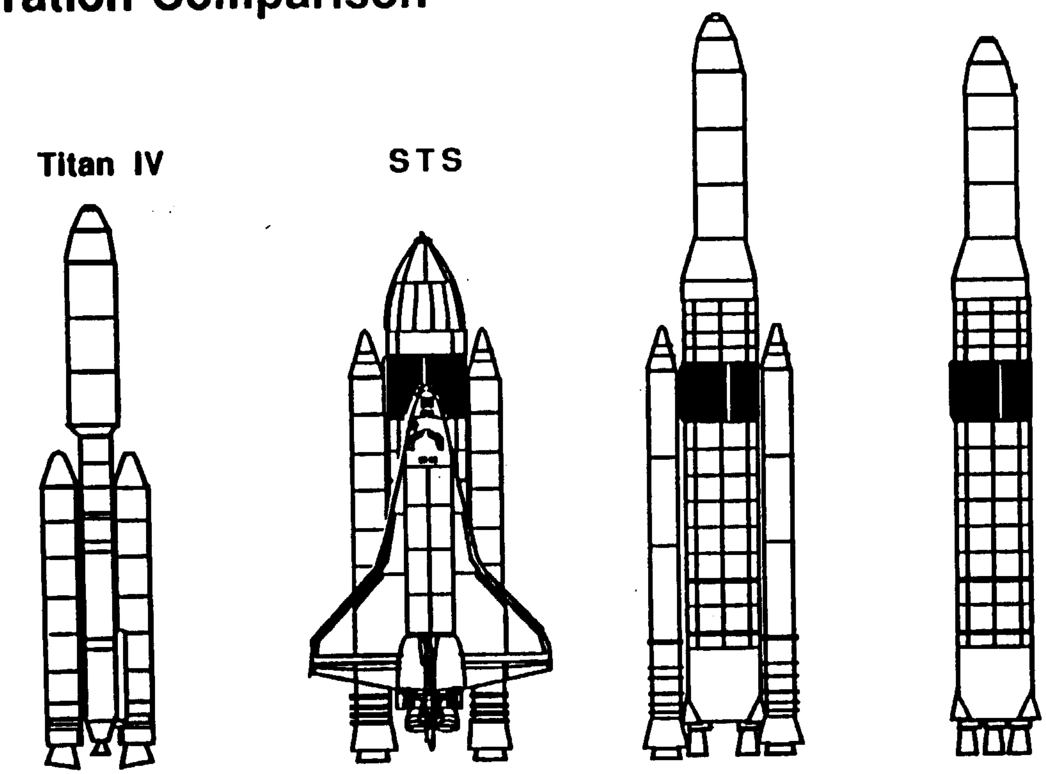
# 3-FM-003 NLS Acoustics

## 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 Charcteristics 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**

$$\Delta \text{ dB's} = 10 \log \frac{Ve_2 * Thrust_2}{Ve_1 * Thrust_1}$$

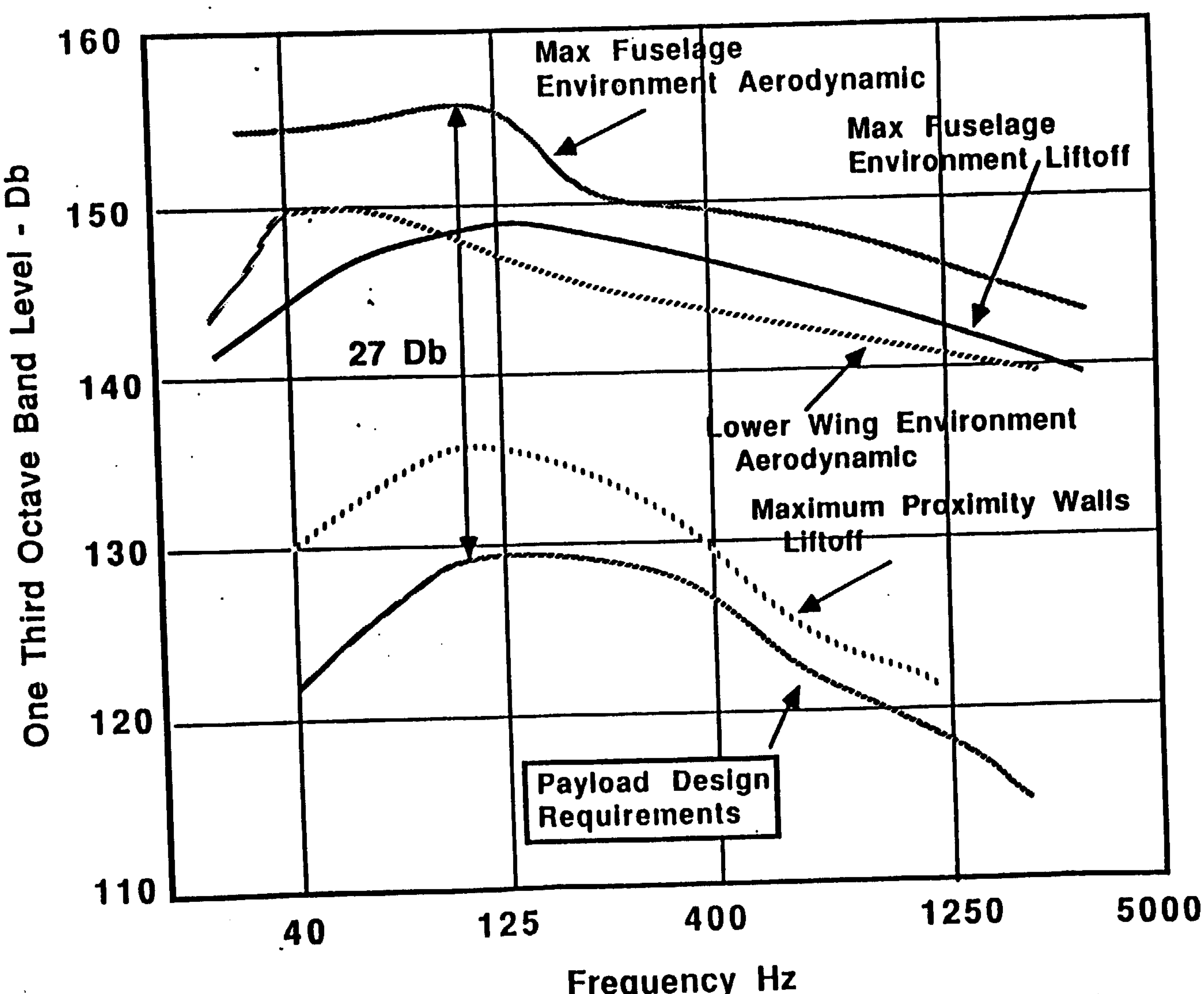
2 Times Increase in Power = 3 dB

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

2 Times Increase in Pressure = 6 dB

5

# Orbiter Acoustic Levels Measured

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7

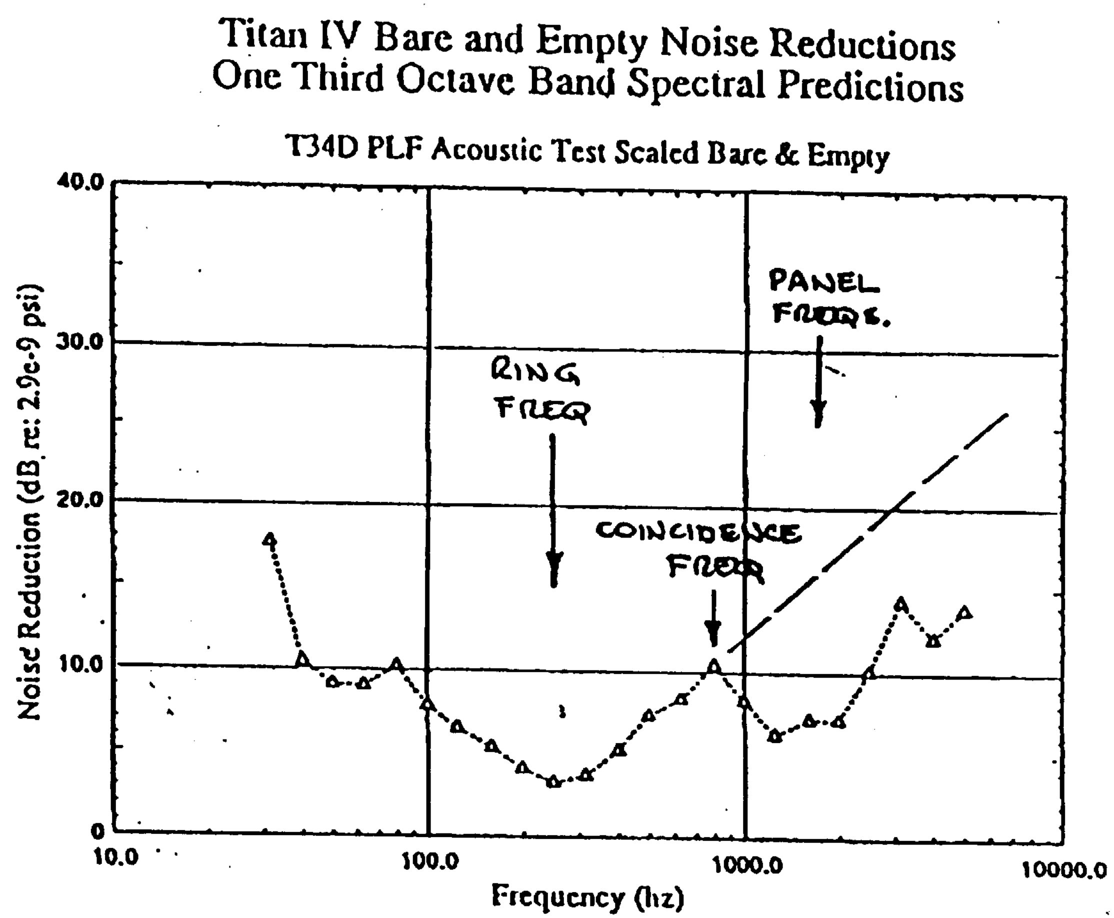
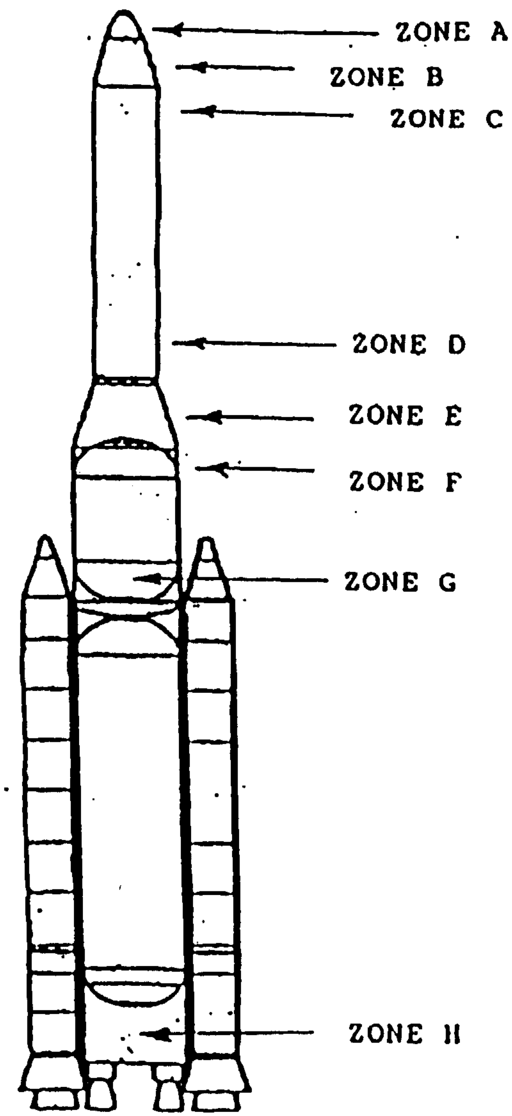



Fig. 22. TIV Predicted Bare and Empty PLF Noise Reductions.

# ACOUSTIC ANALYSIS FOR NLS

DEFINITION OF HLLV ZONES

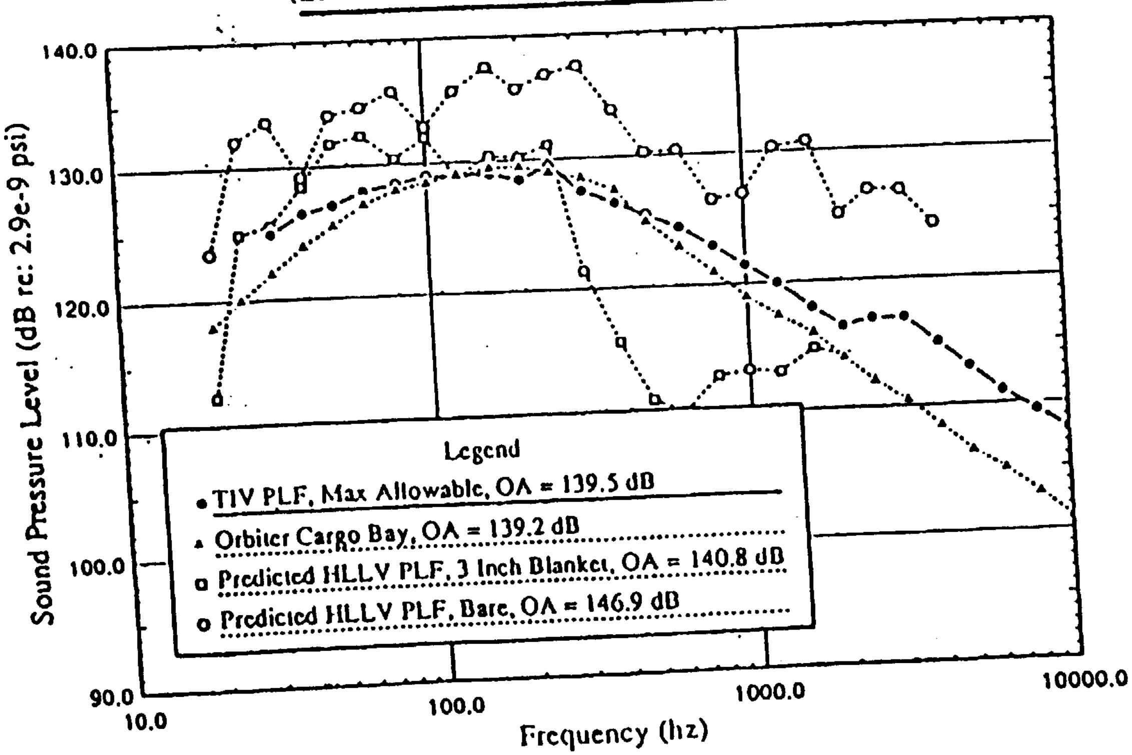



VG No. 8

# 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)

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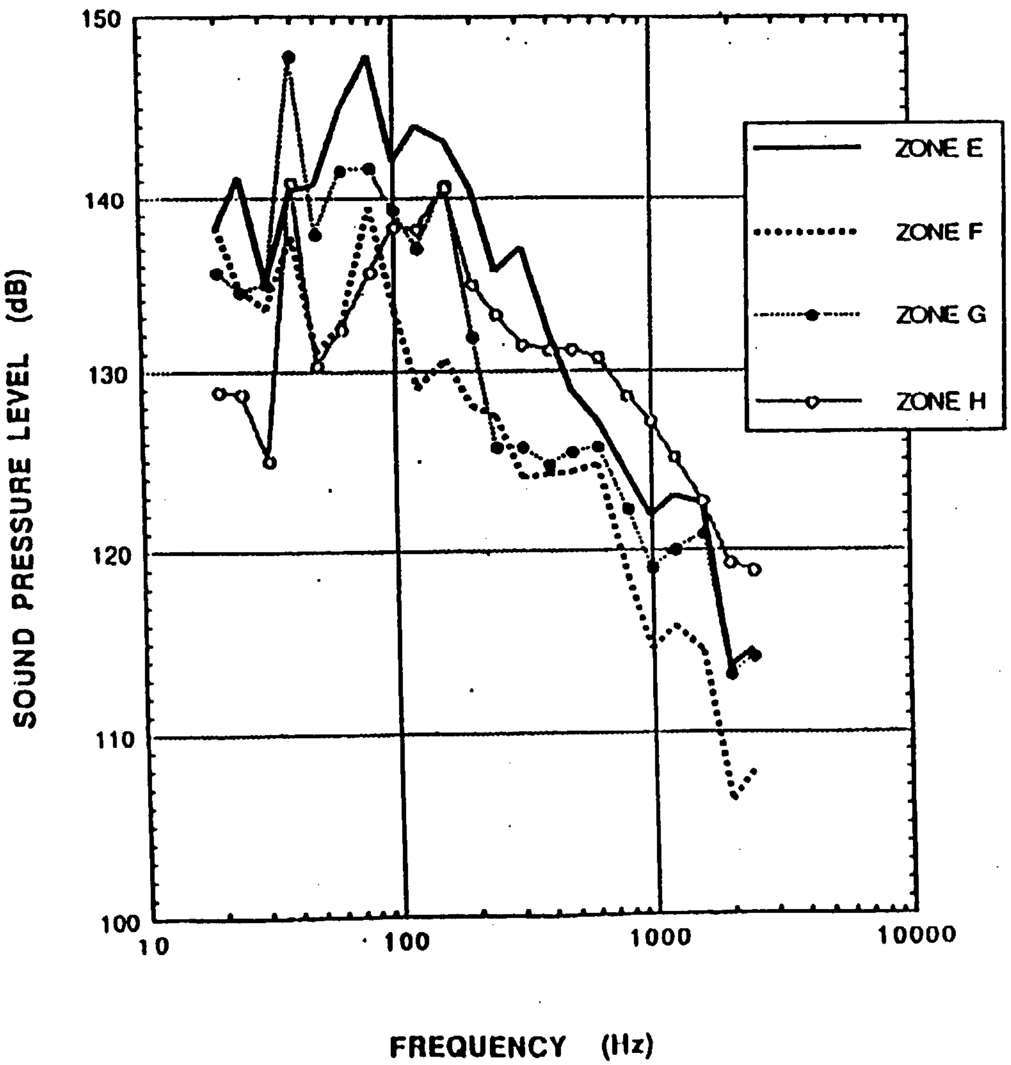
1D

# ACOUSTIC ANALYSIS FOR NLS

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




| ZONE | OASPL (dB) |
|---|---|
| E | 153.4 |
| F | 145.6 |
| G | 151.3 |
| H | 147.6 |

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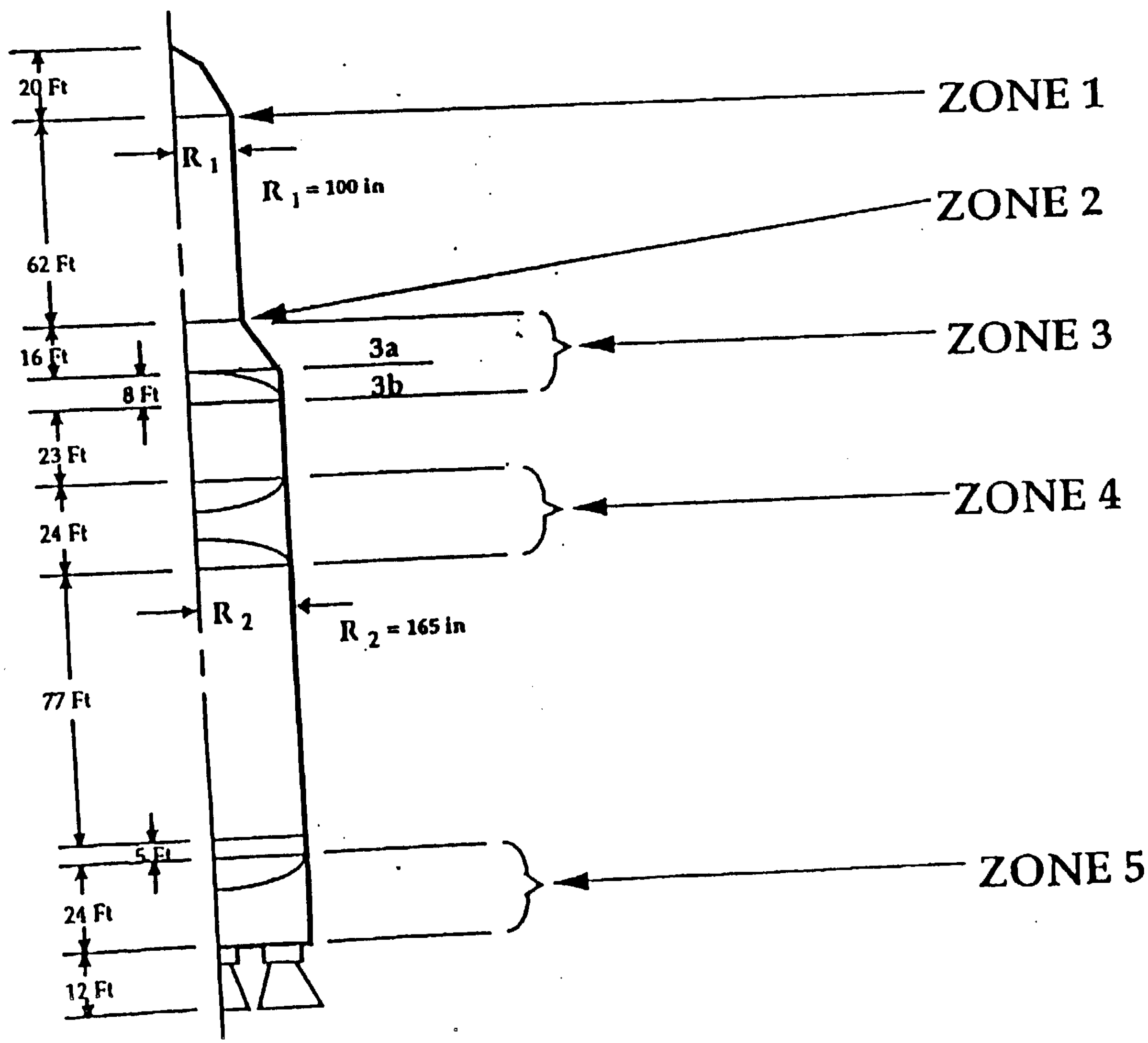
11
12

# ACOUSTIC ANALYSIS FOR NLS

## NLS 1.5-Stage Acoustic Prediction Zones

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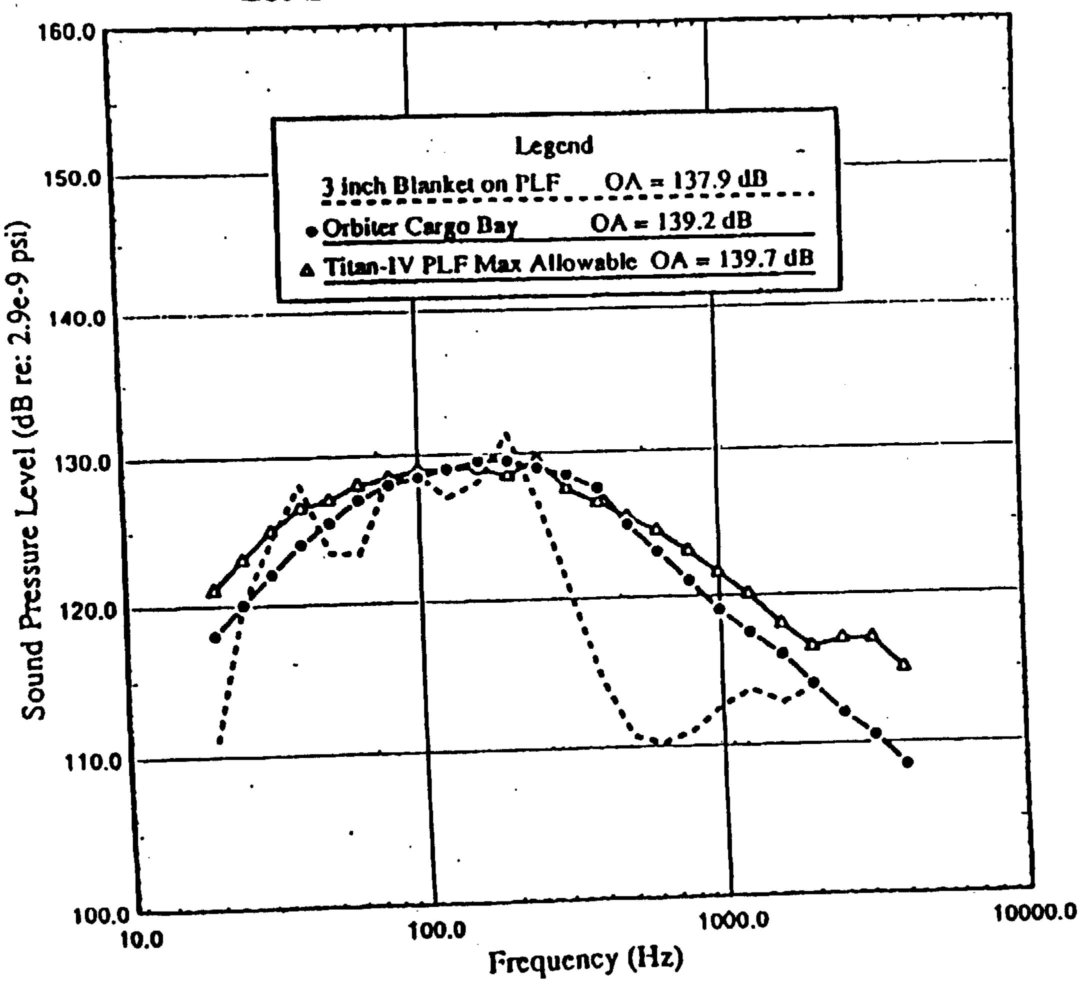
# REQUIREMENT COMPARISON FOR ZONE 2

ZONE 2 LIFTOFF AND ASCENT ENVELOPE

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# 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: SBarrett FOR

R. B. LOWE, STAFF ENGINEER

RFoss

R. L. FOSS, SENIOR ENGINEER

SBarrett

S. BARRETT, UNIT HEAD

ENVIRONMENTAL & SUBSYSTEM DYNAMICS
SPACE LAUNCH SYSTEMS

20 DECEMBER 1991

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

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

LIST OF FIGURES

## LIST OF TABLES

## 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 occurrance 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.

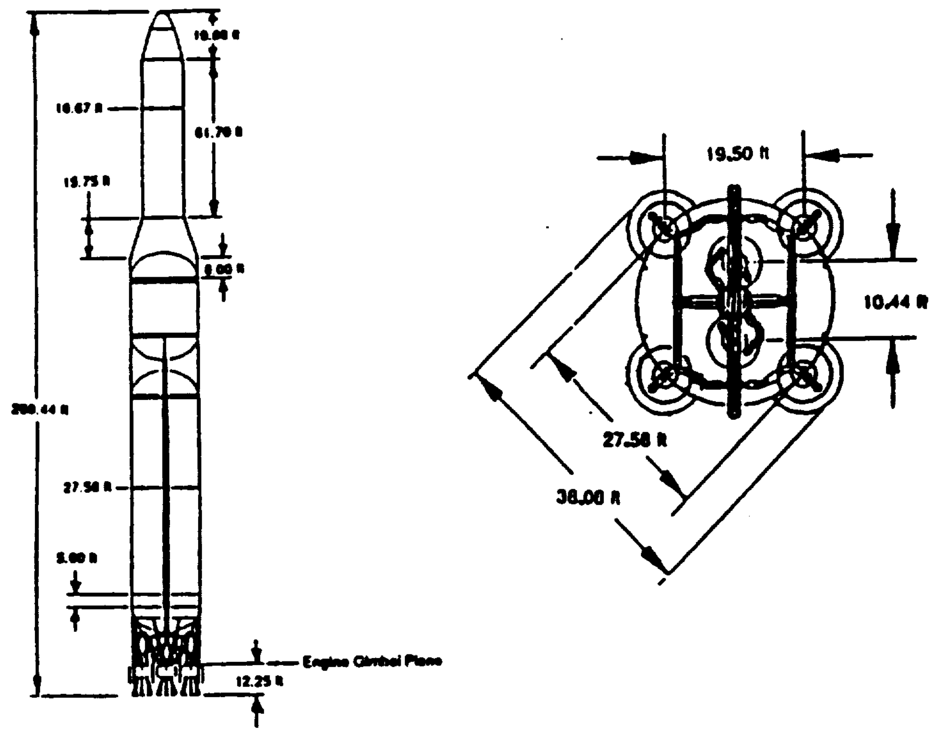
When the calculated PLF internal acoustic levels were compared with the specified allowable empty fairing levels for the Titan IV and the Space Shuttle, severe exceedances were found across wide frequency ranges, showing that steps would have to be taken to reduce the noise levels. As an example of a 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

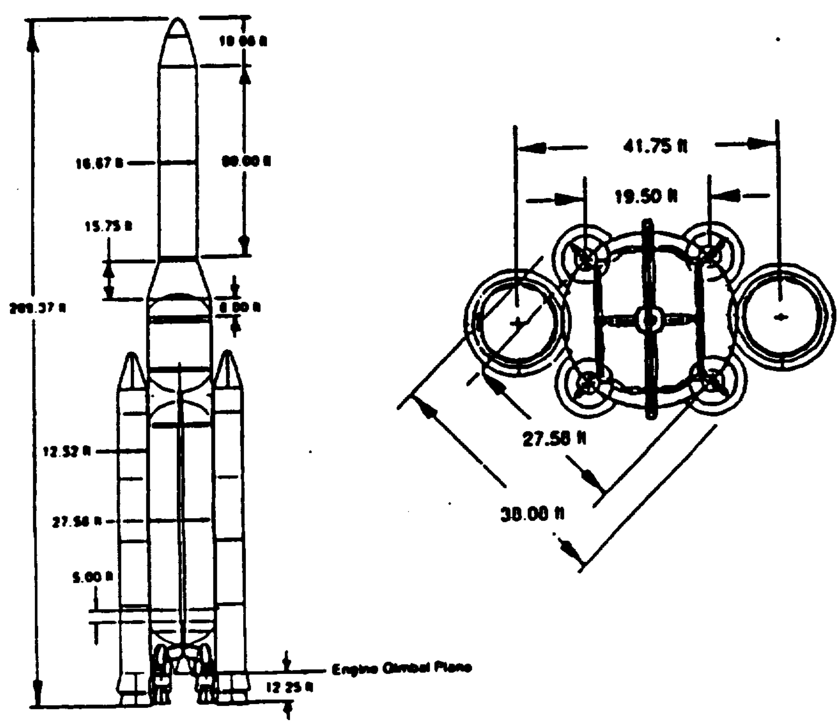
This study was performed by the Environmental & Subsystem Dynamics Group, which is part of the SLS Loads and Dynamics Department, in response to a request for technical support from Martin Marietta Manned Space Systems in New Orleans, Louisiana. The objectives of the study were to perform acoustic analyses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

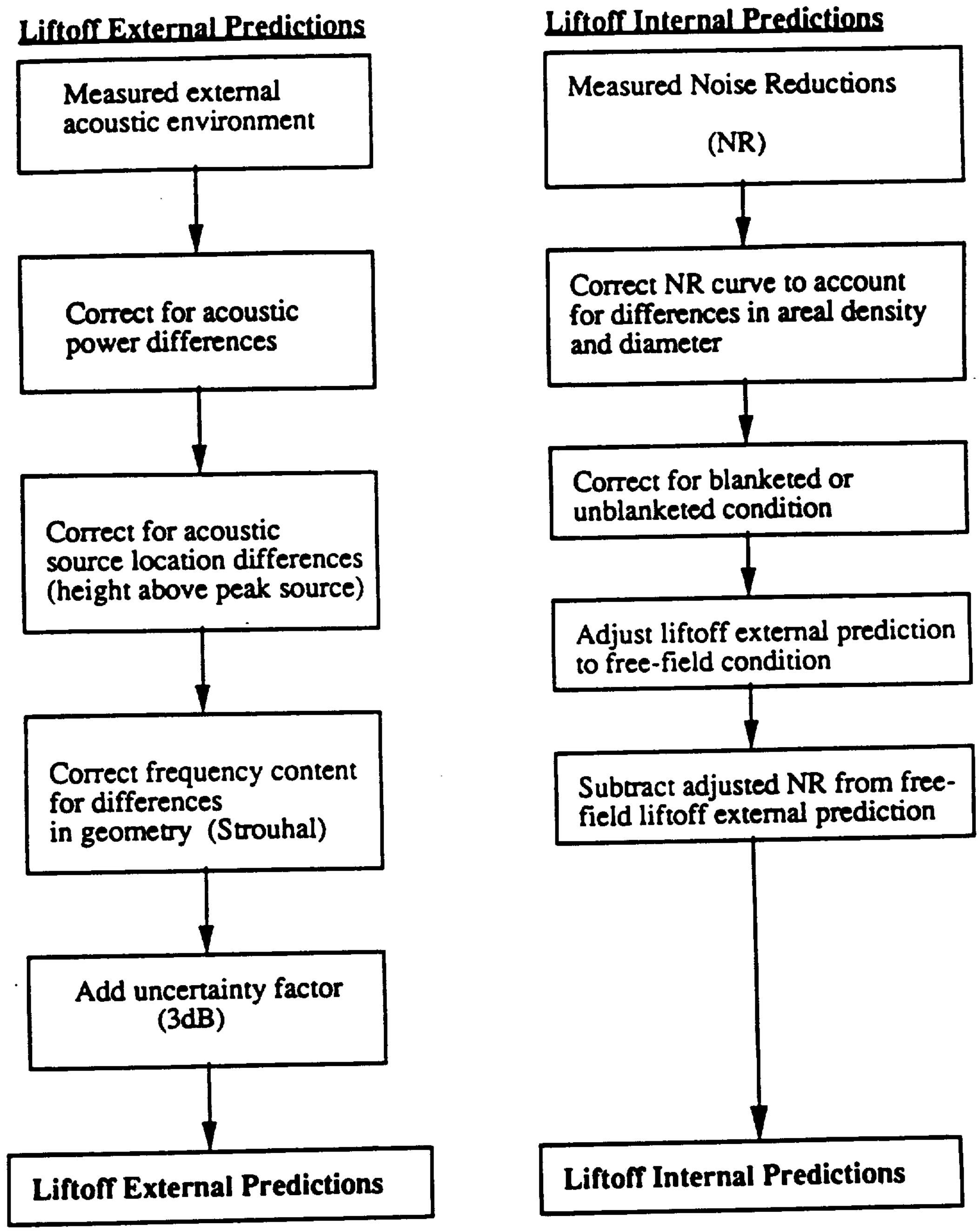



Figure 1.2

Liftoff Prediction Sequence

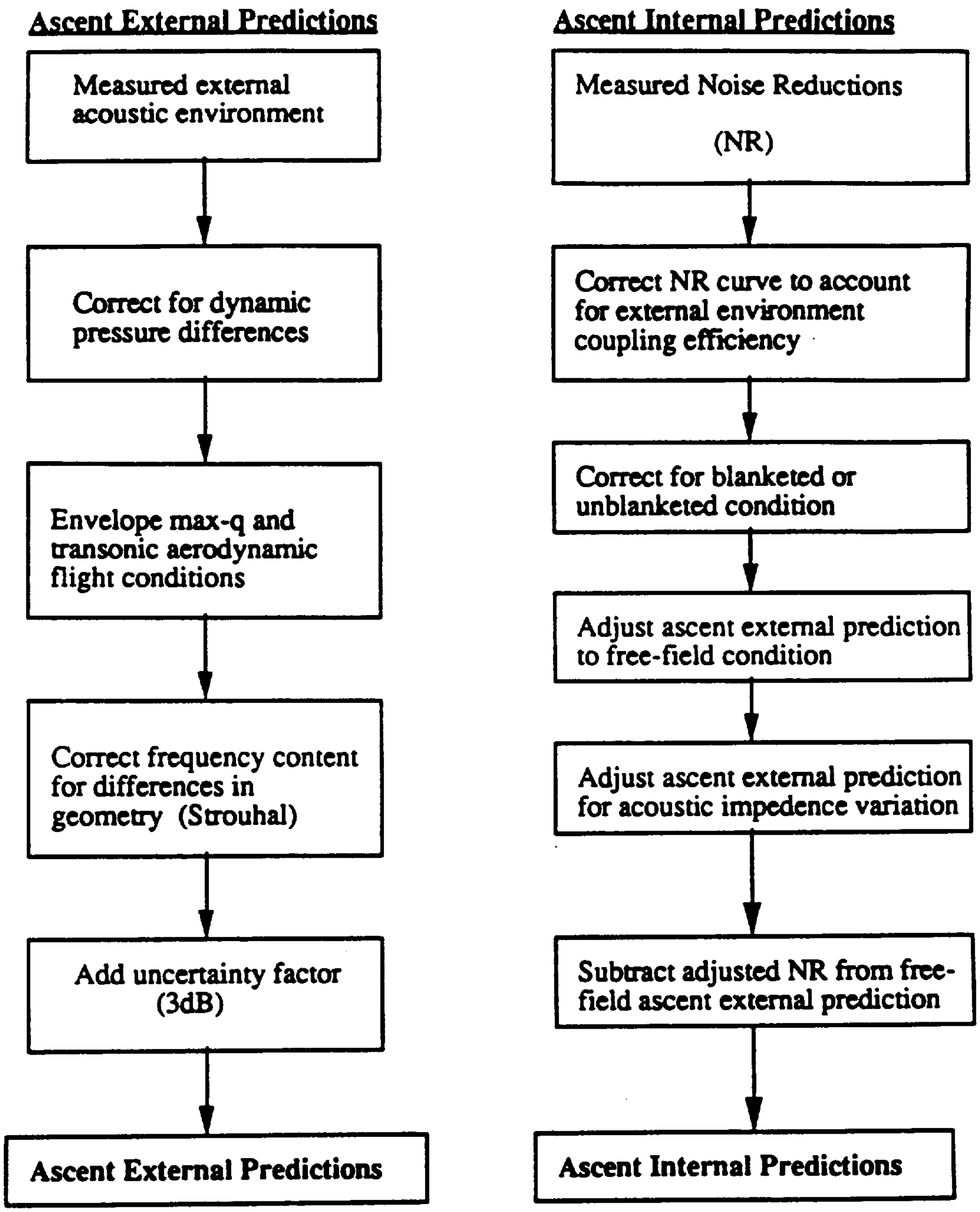



Figure 1.3

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:

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

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.

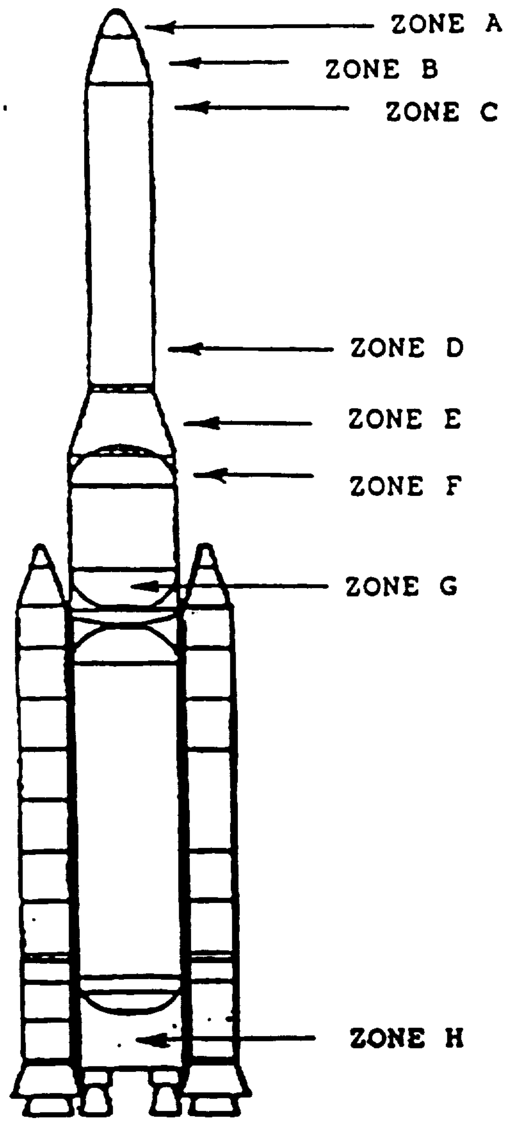



Figure 2.1 Definition of Acoustic Zones for HLLV

(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

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

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 x D/V:

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

--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:

$$APCF = 10 \ Log_{10} \frac{2 \times 14.68E06 \times 2763 \ + \ 4 \times 2.593E06 \times 4247}{2 \times 11.8E06 \times 2500 \ + \ 3 \times 1.78E06 \times 3250}$$

$= 2.1$ dB.

(ii) Calculation of Strouhal parameter:

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

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

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

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

(iii) Calculation of mechanical power ratio:

$P(ASRB)/P(TOT) = 3.9E10/6.1E10 = 0.64$

$P(SRB)/P(TOT) = 2.95E10/3.8E10 = 0.78$

(iv) Calculation of equivalent nozzle exit diameter:

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

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

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

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

(v) Calculation of Strouhal parameter:

$$SN(STS)/f = 3.85/2665 = 0.00145$$

$$SN(HLLV)/f = 4.02/3240 = 0.00124$$

(vi) Calculation of frequency shifts

Under the assumption that Strouhal number is constant,

$$SN(HLLV) = SN(STS)$$

--therefore

$$\frac{f(HLLV) \times D(HLLV)}{V(HLLV)} = \frac{f(STS) \times D(STS)}{V(STS)}$$

$$\frac{f(HLLV)}{f(STS)} = \frac{D(STS) \times V(HLLV)}{D(HLLV) \times V(STS)}$$

$$= 0.00145/0.00124$$

$$= 1.17$$

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.

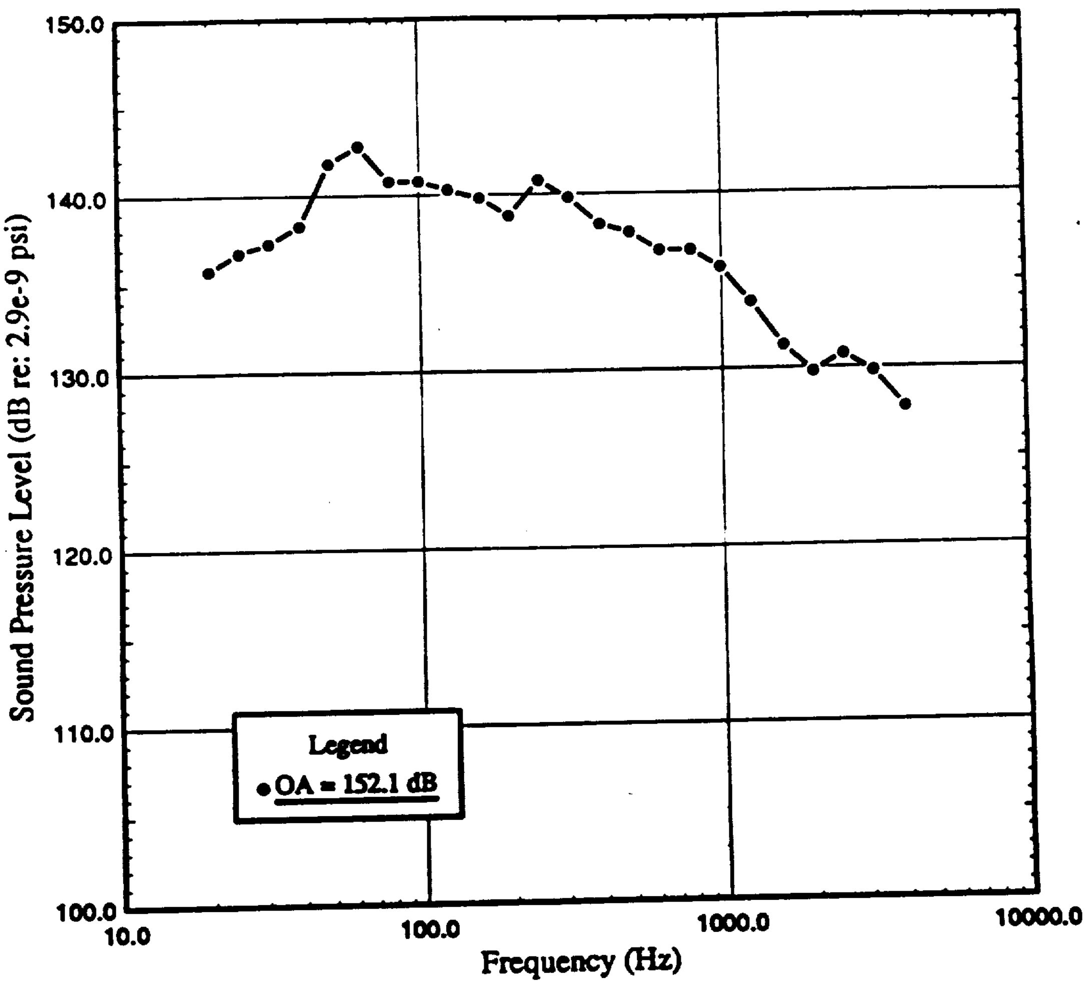



Figure 2.2

HLLV Liftoff Zone C External Acoustic Levels

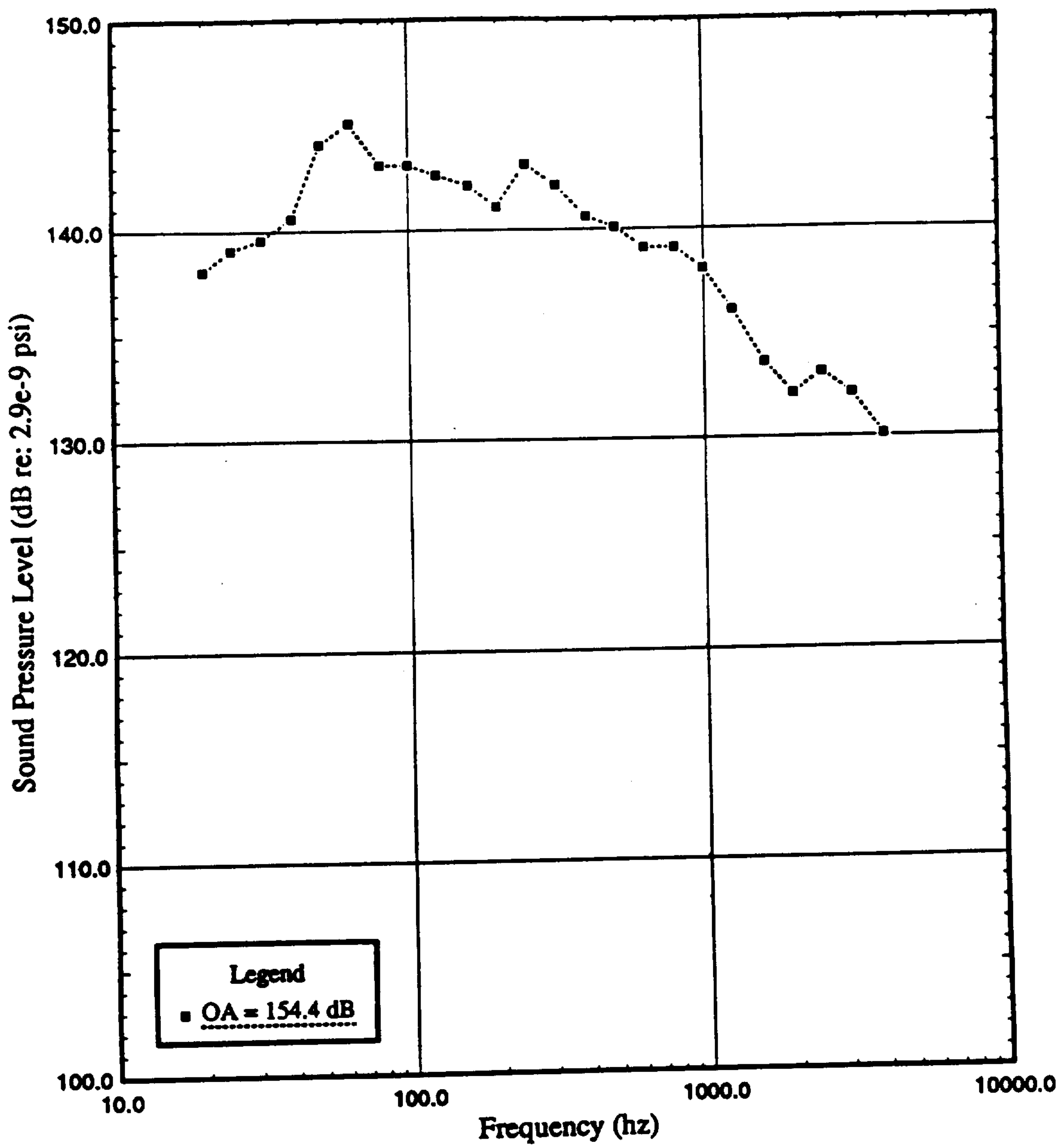



Figure 2.3

HLLV Liftoff Zone D External Surface Acoustic Levels

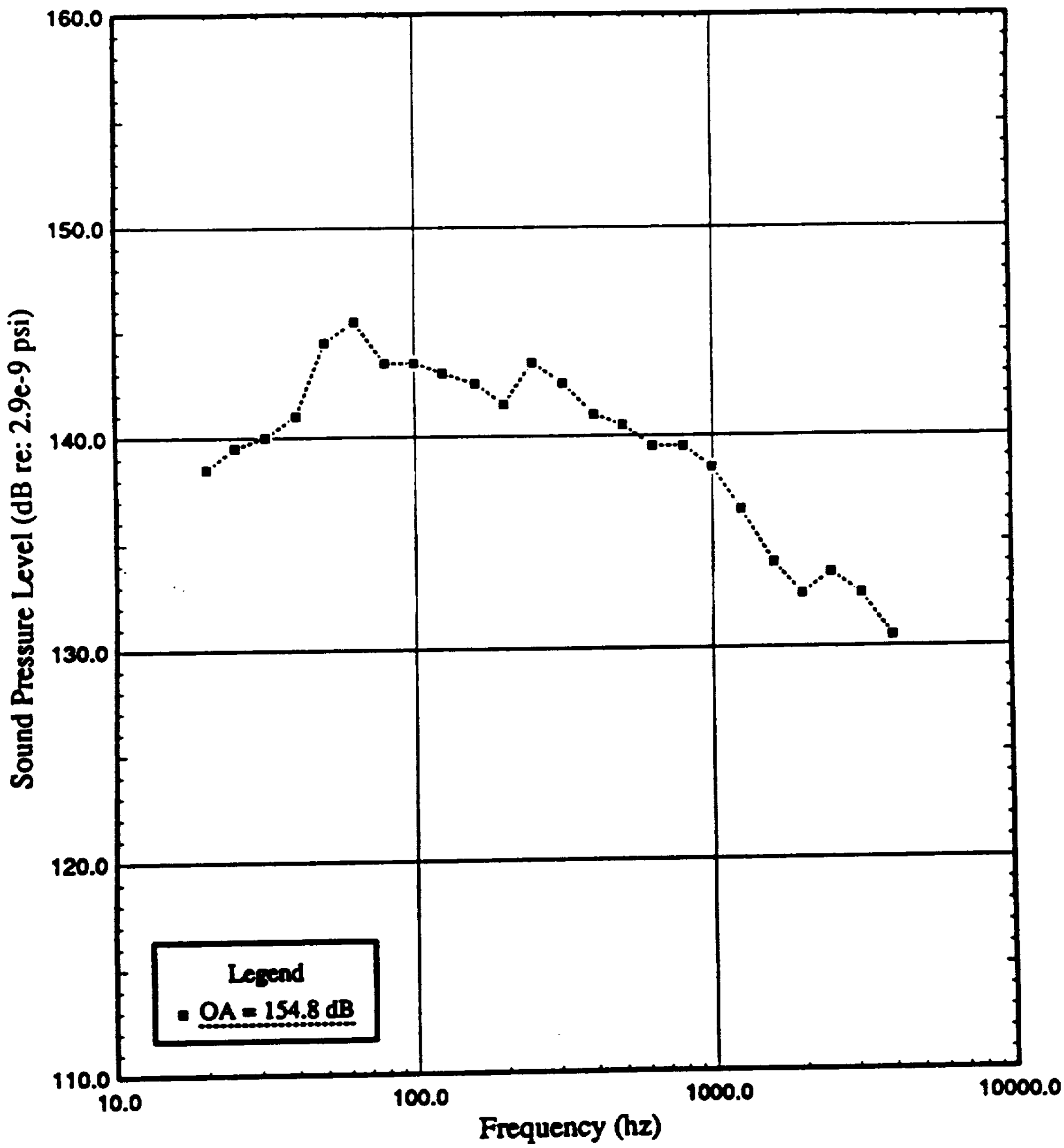



Figure 2.4

HLLV Liftoff Zone E External Surface Acoustic Levels

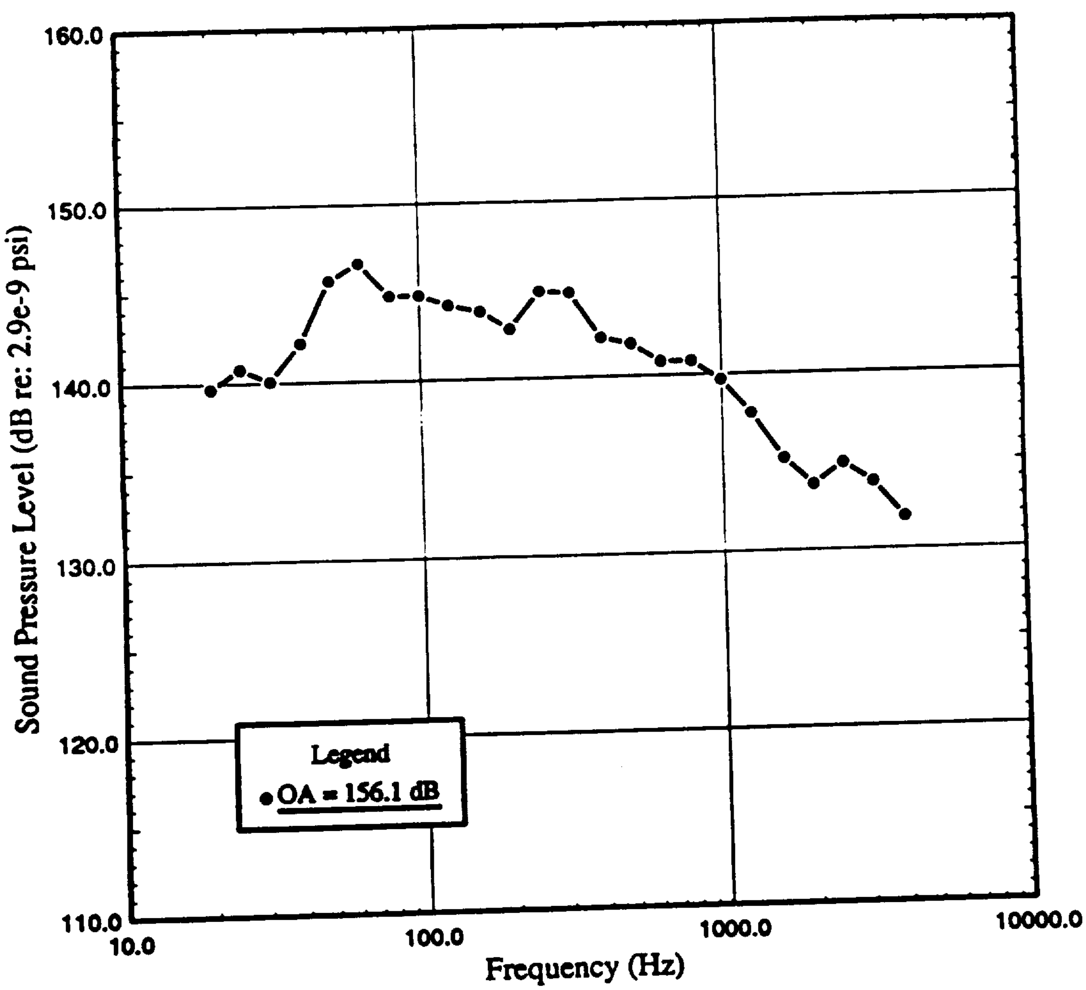



Figure 2.5

HLLV Liftoff Zone F External Acoustic Levels

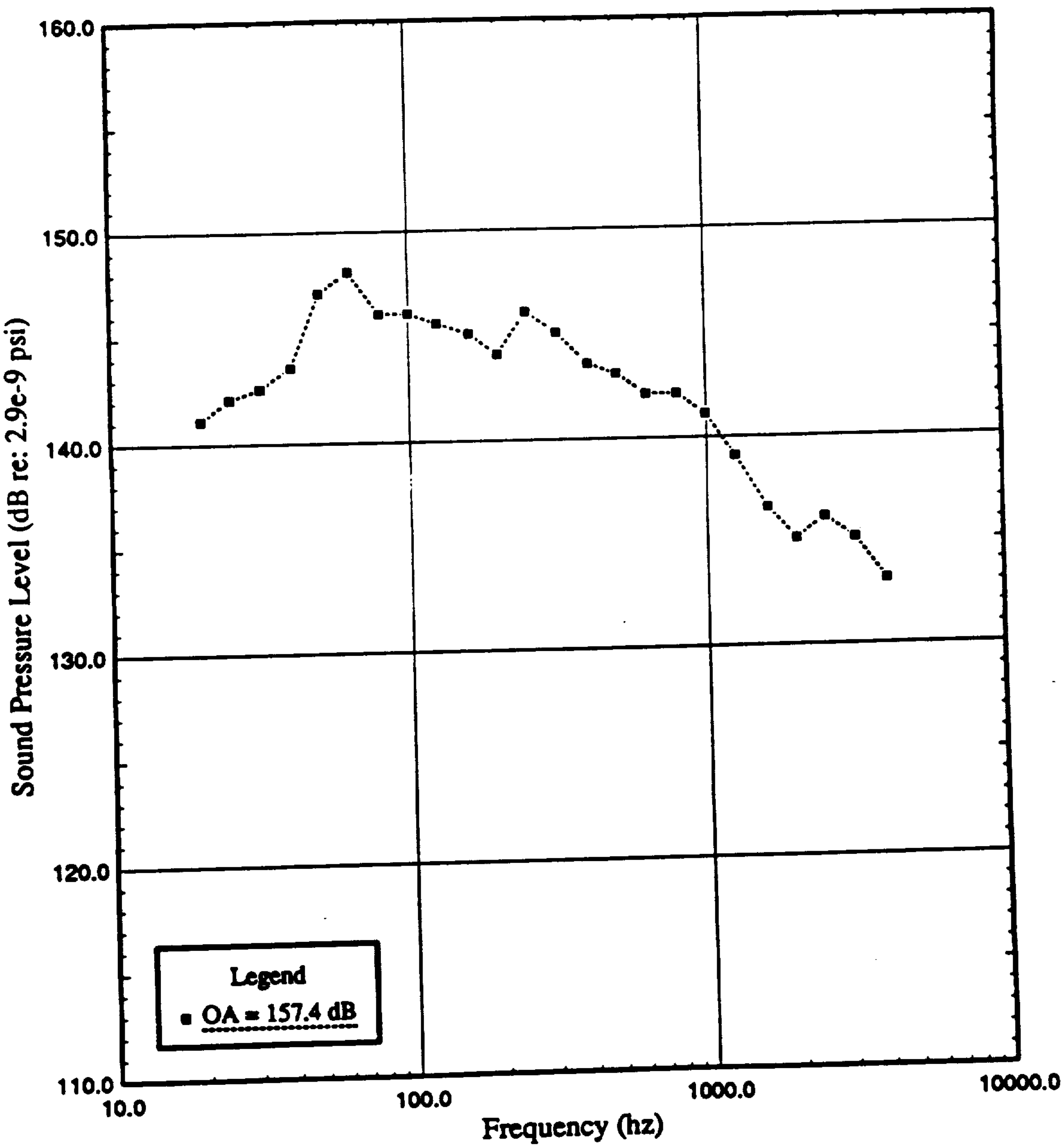



Figure 2.6

HLLV Liftoff Zone G External Surface Acoustic Levels

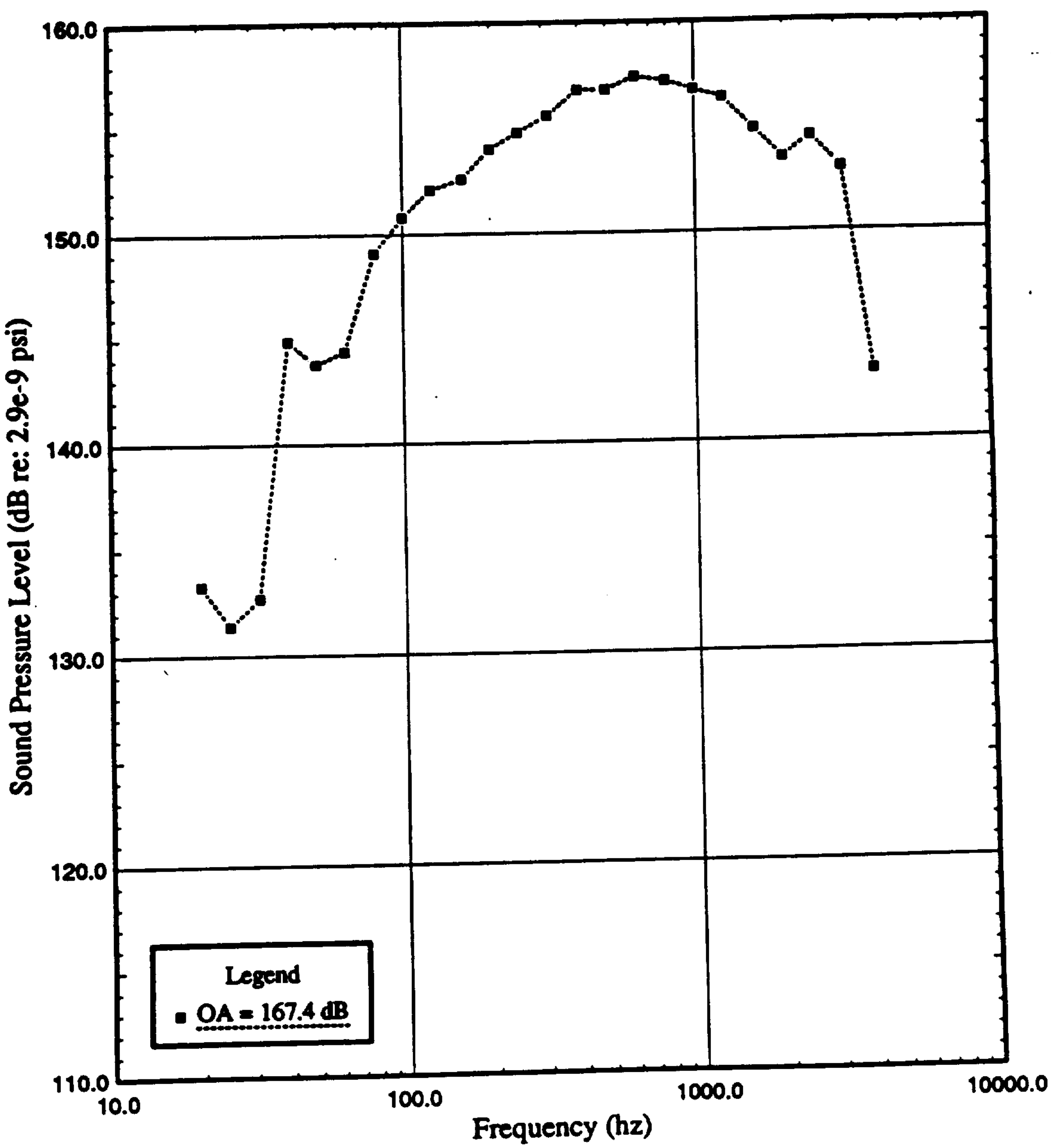
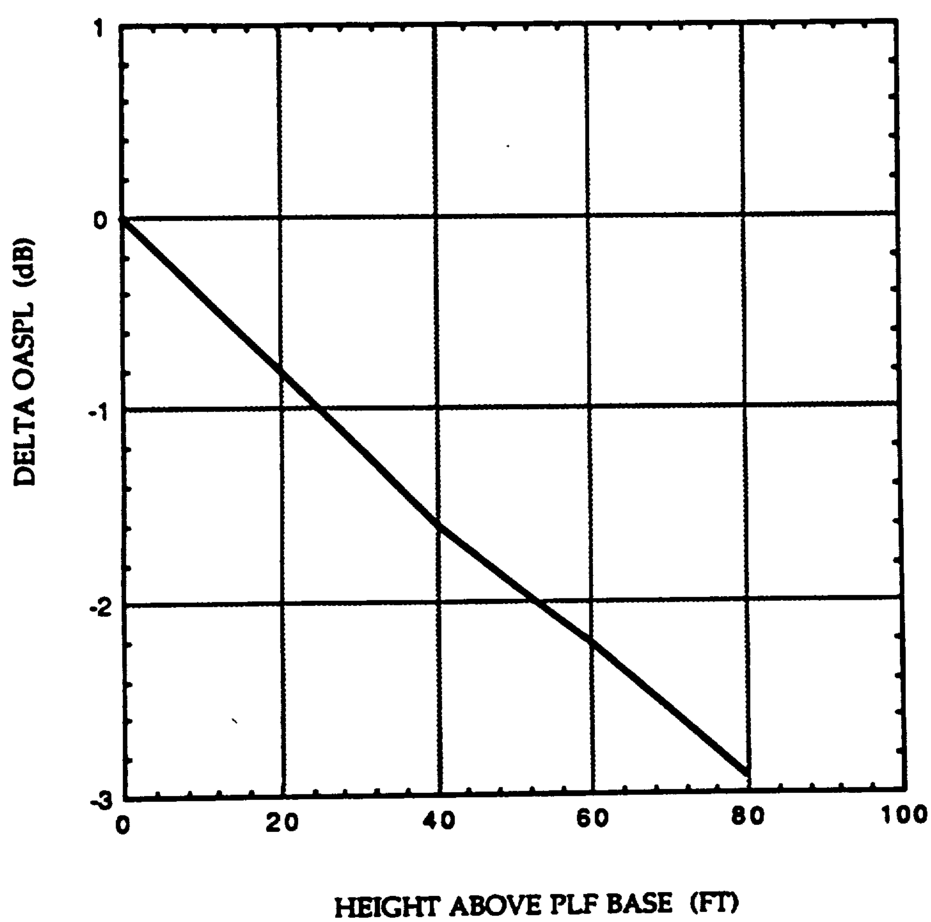



Figure 2.7

HLLV Liftoff Zone H External Surface Acoustic Levels

Figure 2.8

Variation of External Liftoff 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

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

### 2.2.2 Numerical Correction Factors

Correction factors were calculated having the following values:

Density scaling factor (DSF) for the PLF adapter:

$$DSF\ (dB) = 20\ Log\ (0.013773/0.013003) = +0.5\ dB$$

Density scaling factor (DSF) for forward skirt:

$$DSF\ (dB) = 20\ Log_{10}(\ [W/A]_{NLS}/[W/A]_{TEST}\ )$$

$$= 20\ Log\ (0.013624/0.013003)$$

$$= +0.4\ dB$$

Density scaling factor for intertank:

$$DSF\ (dB) = 20\ Log\ (0.023282/0.013003)$$

$$= +5.0\ dB$$

Density scaling factor for propulsion module aft skirt:

$$DSF\ (dB) = 20\ Log\ (0.02648/0.013003)$$

$$= +6.2\ dB$$

Ring frequency shift for PLF adapter:

$$r_{TEST}/r_{NLS} = 69''/143'' = 0.42$$

Frequency shift (in oct) = Log 0.42 / 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:

$$r_{TEST}/r_{NLS} = 60''/165'' = 0.36$$

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

$$DPCF\ (dB) = 20\ Log_{10}\ (\ q_{max}(HLLV)\ /\ q_{max}(T\text{-}IV))$$

$$= 20\ Log\ \ 806/936\ \ = -1.3\ dB.$$

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.

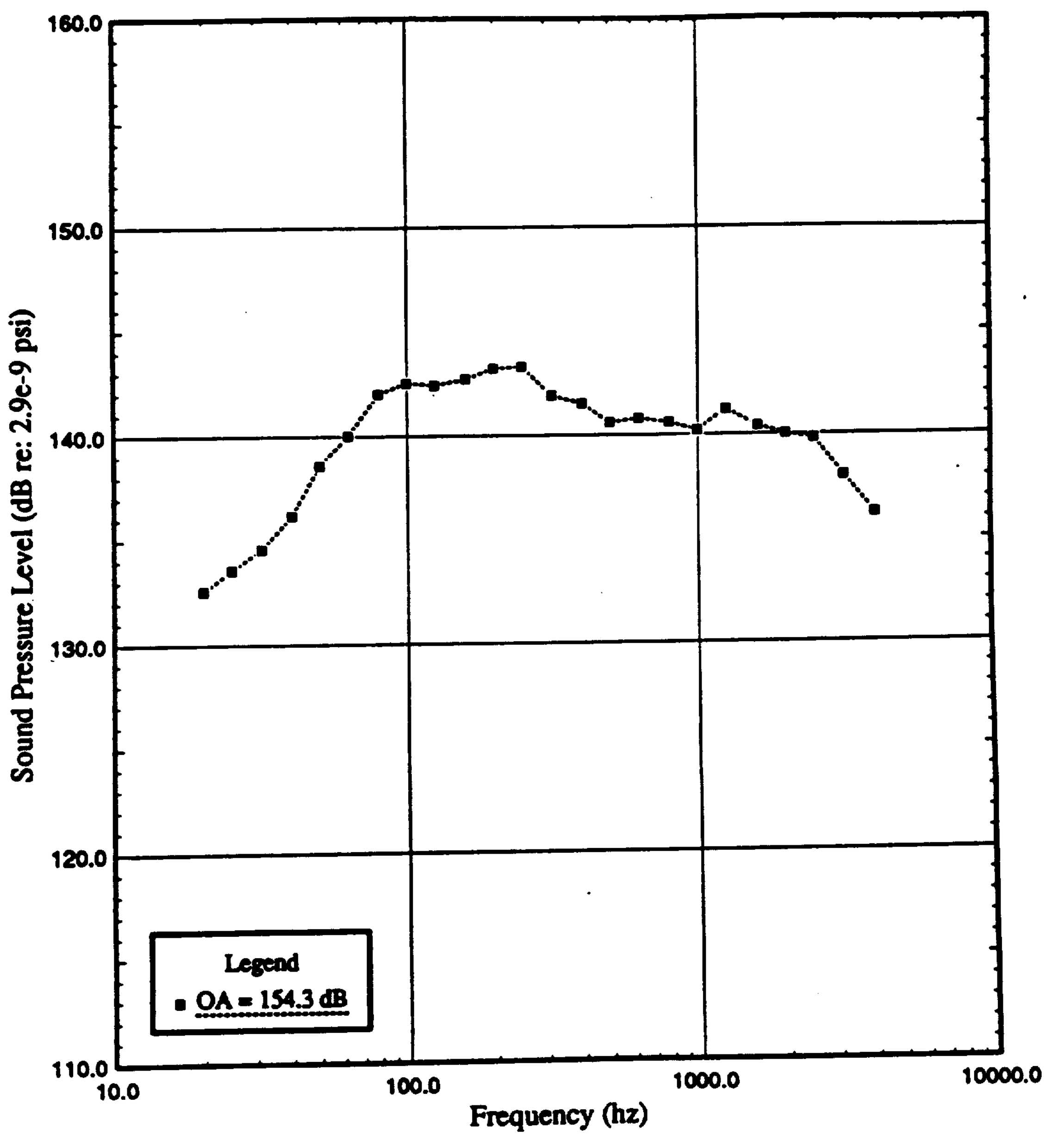



Figure 2.9

HLLV Zone A Max Aero Predicted External Surface Acoustic Levels

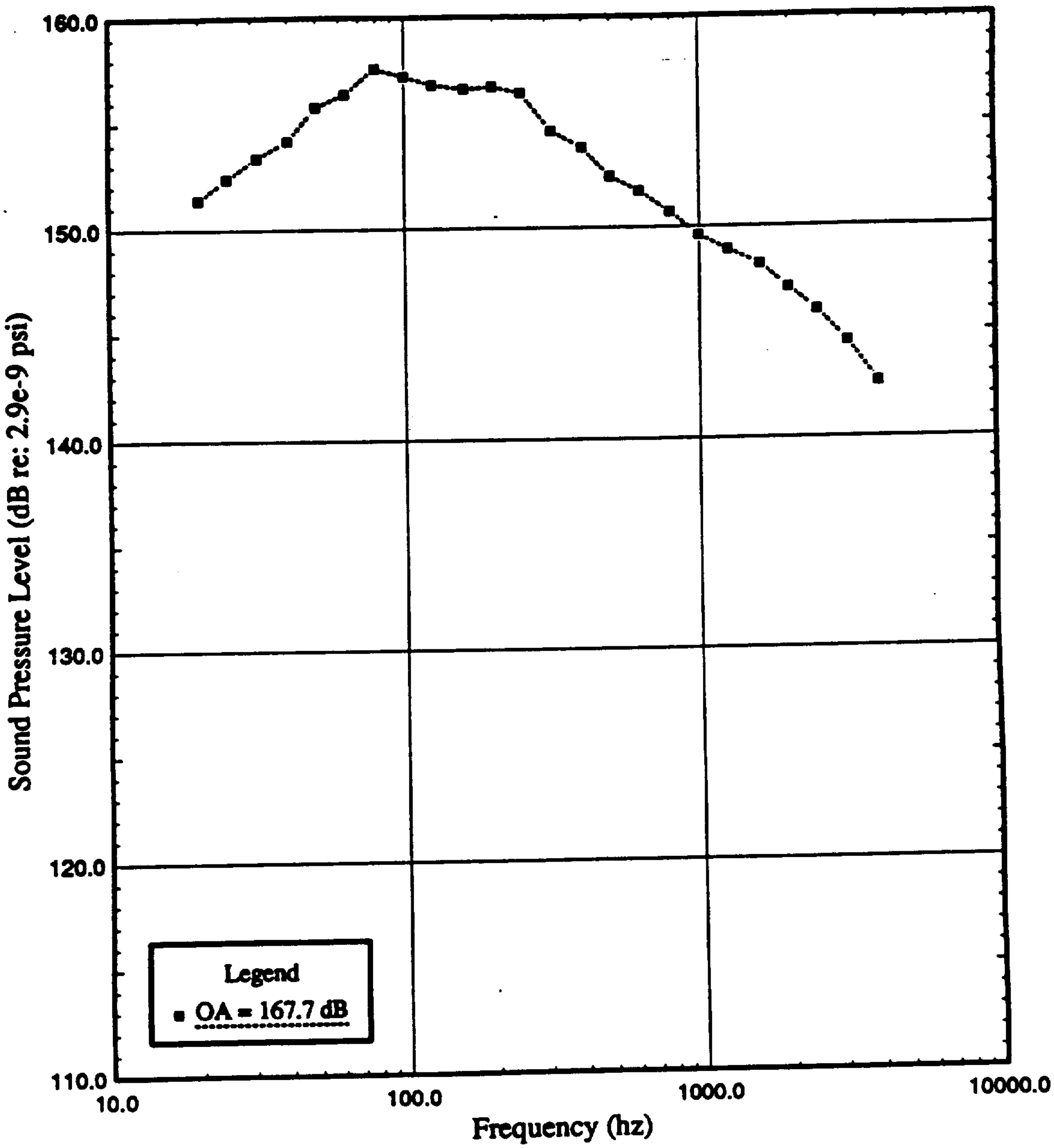



Figure 2.10

HLLV Zone B Max Aero Predicted External Surface Acoustic Levels

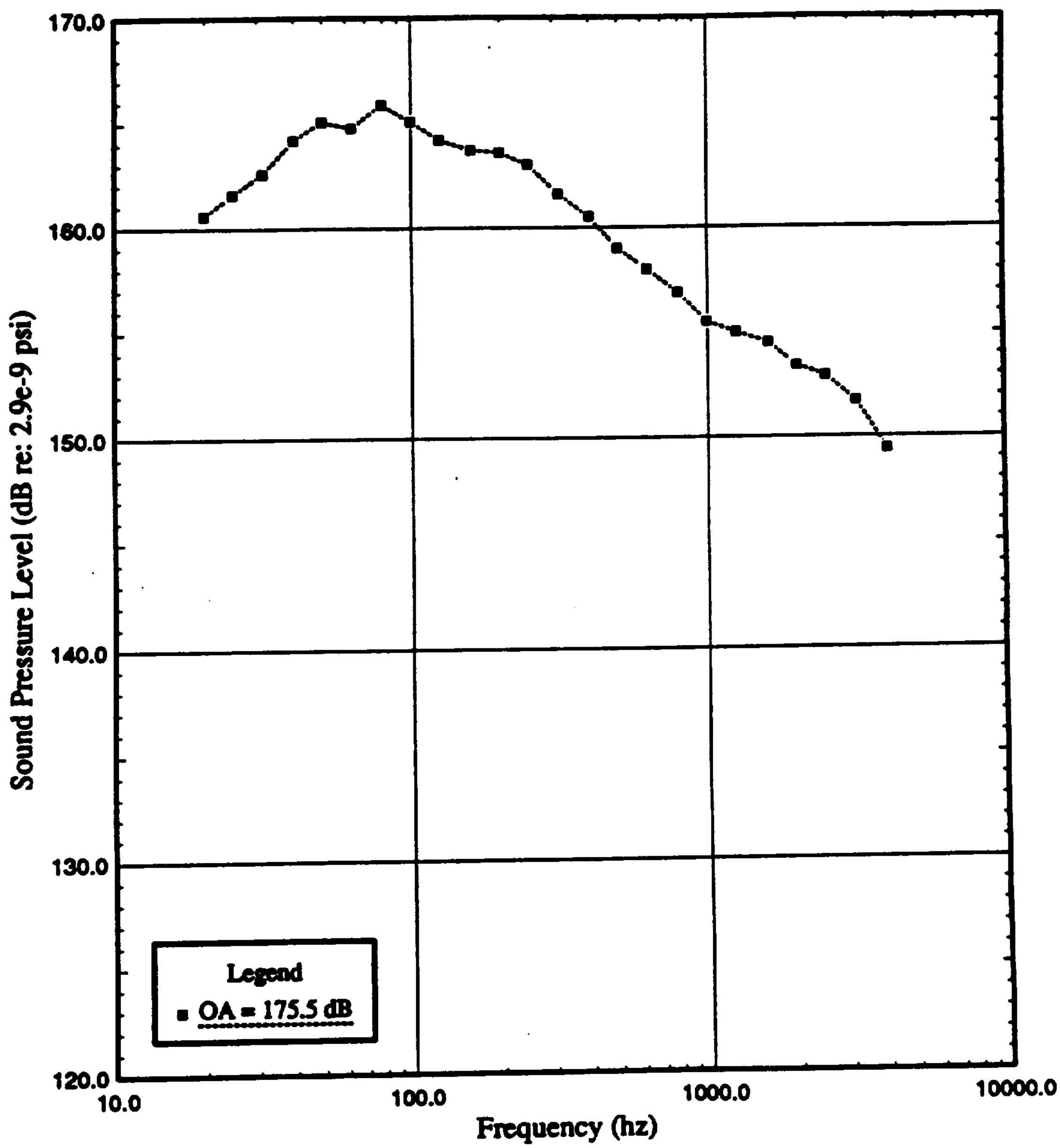



Figure 2.11

HLLV Zone C Max Aero Predicted External Surface Acoustic Levels

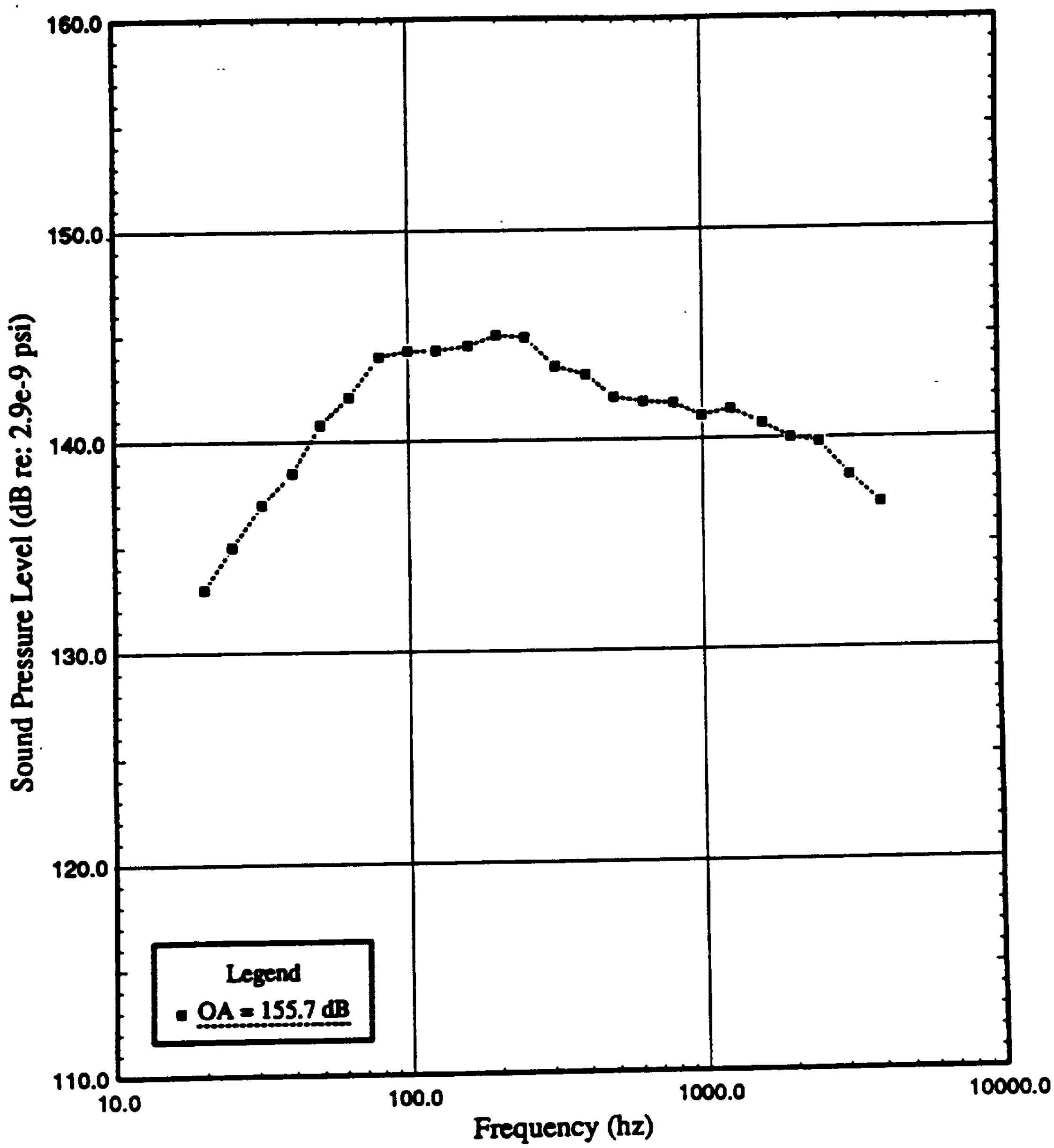



Figure 2.12

HLLV Zone D Max Aero Predicted External Surface Acoustic Levels



Aftermath v1.25 (orizaba) December 13, 1991

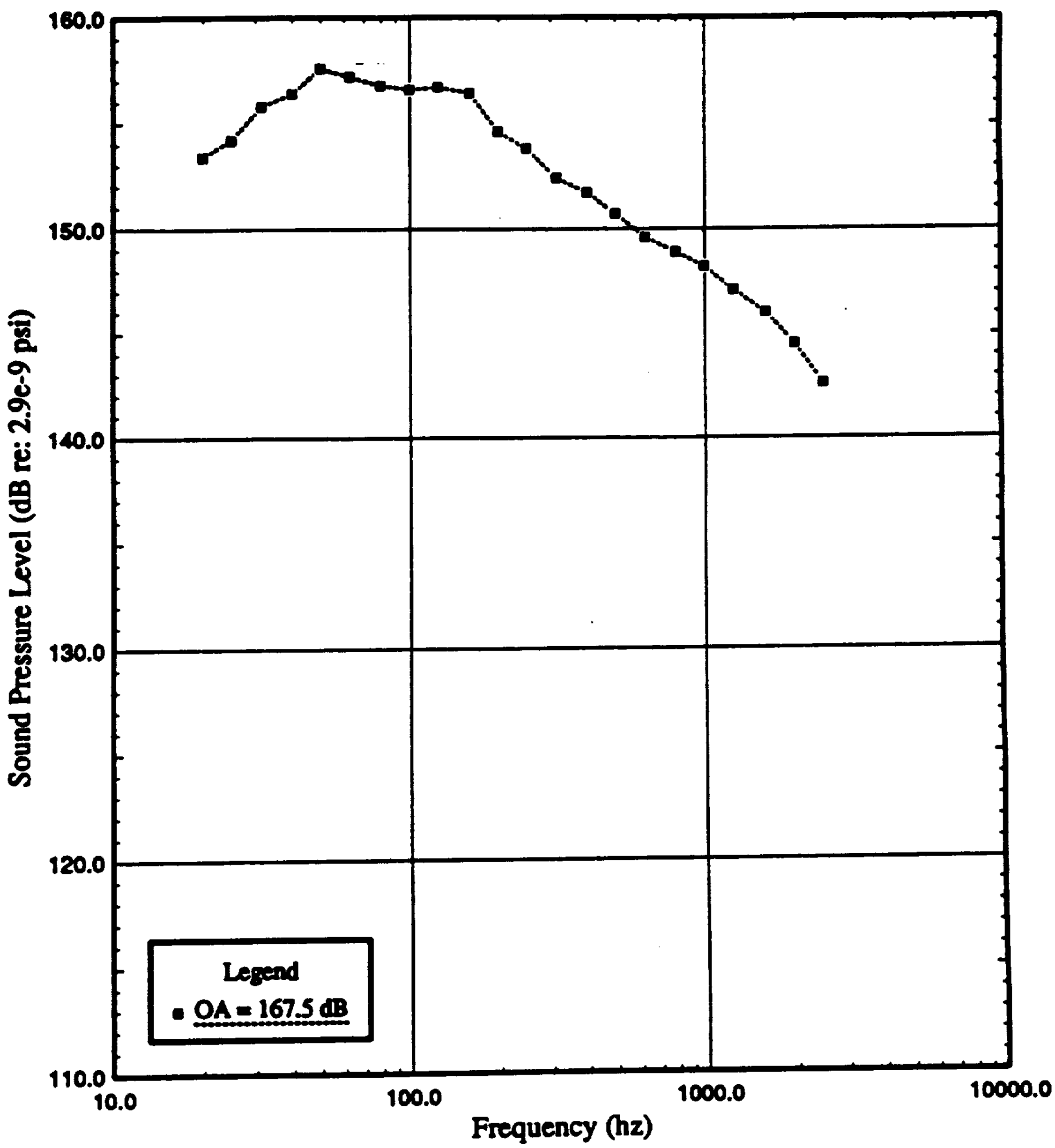



Figure 2.13

HLLV Zone E Max Aero Predicted External Surface Acoustic Levels

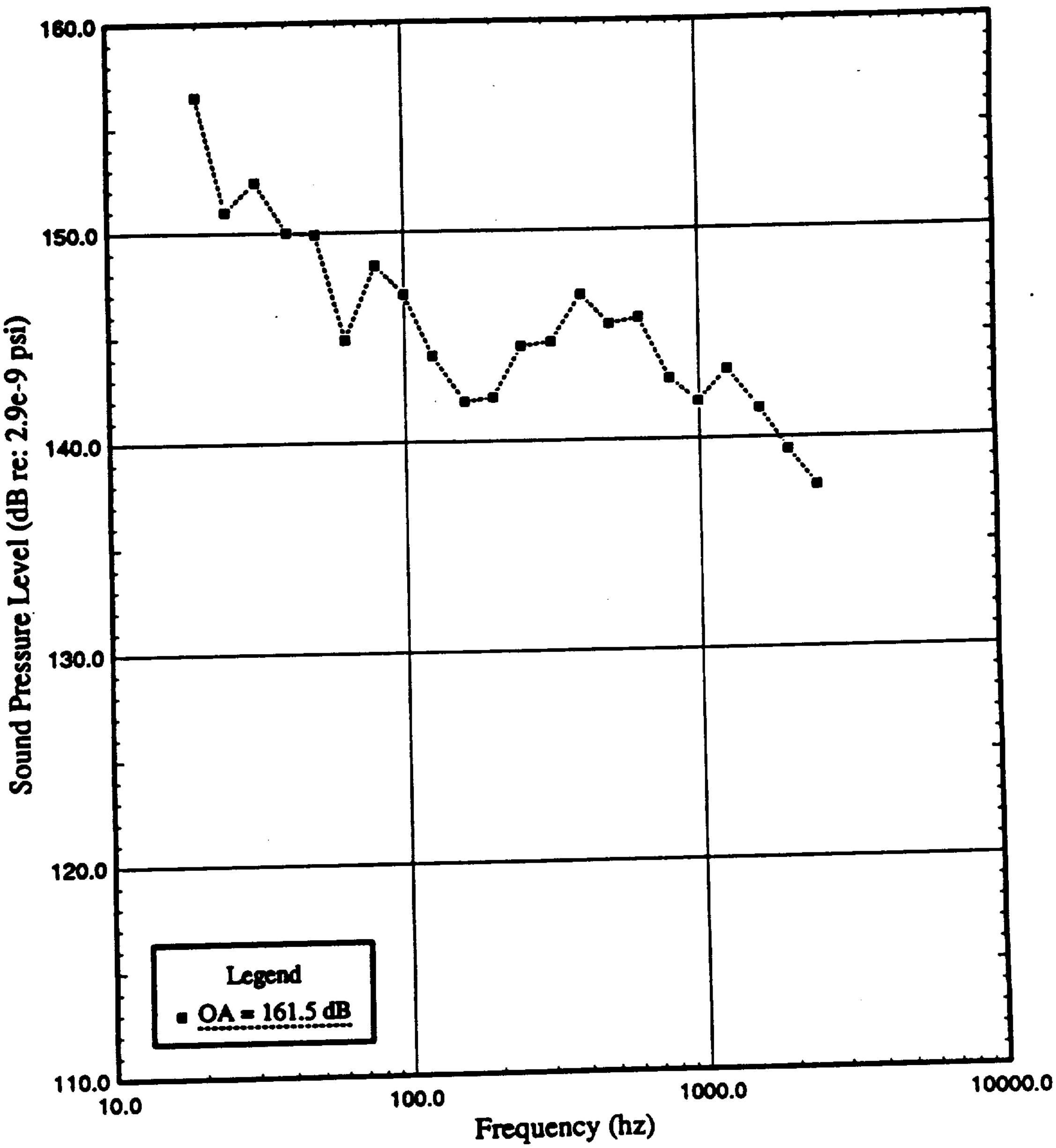



Figure 2.14

HLLV Zone F Max Aero Predicted External Surface Acoustic Levels

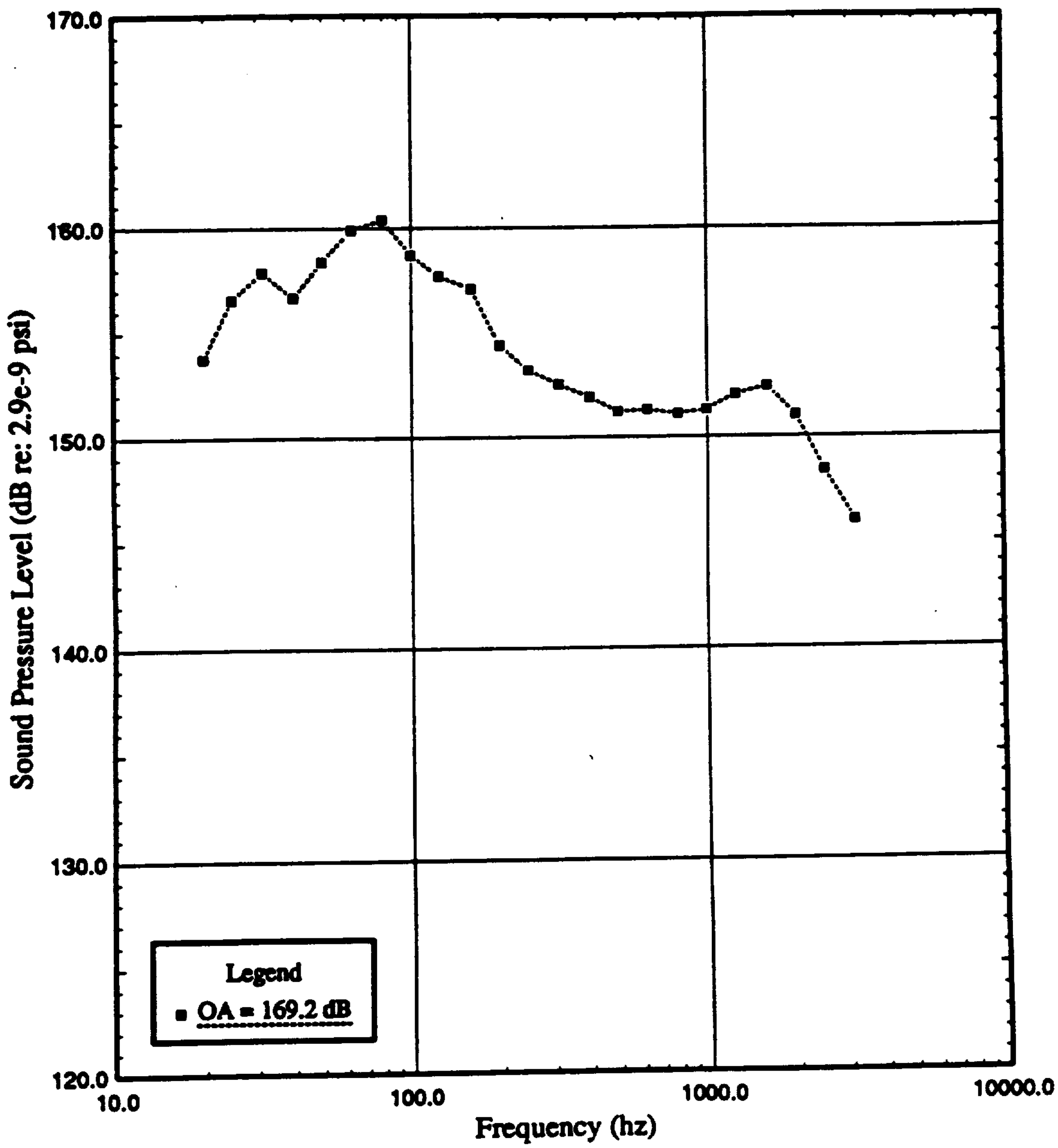



Figure 2.15

HLLV Zone G Max Aero Predicted External Surface Acoustic Levels

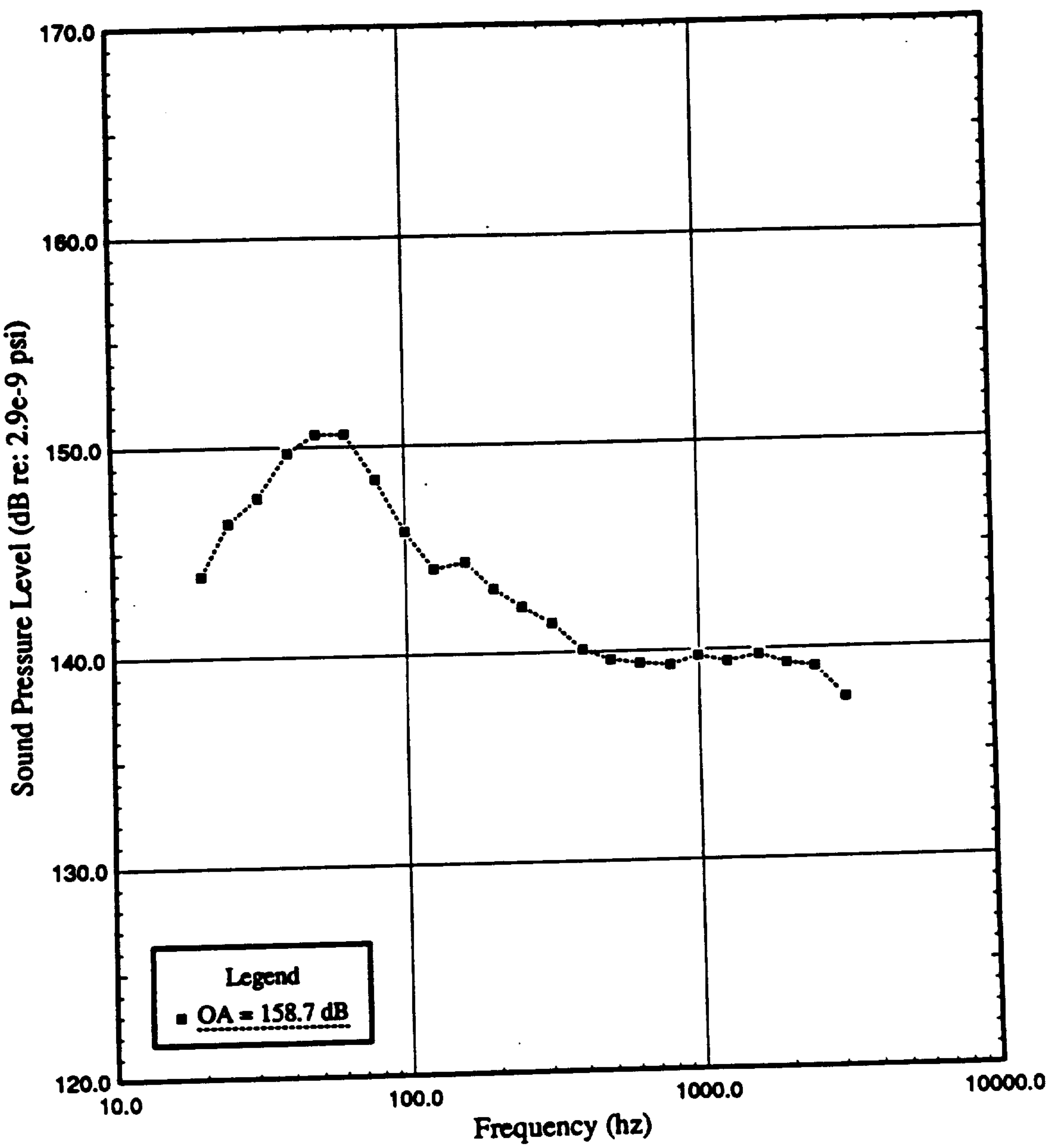



**Figure 2.16**

**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 evironments 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.

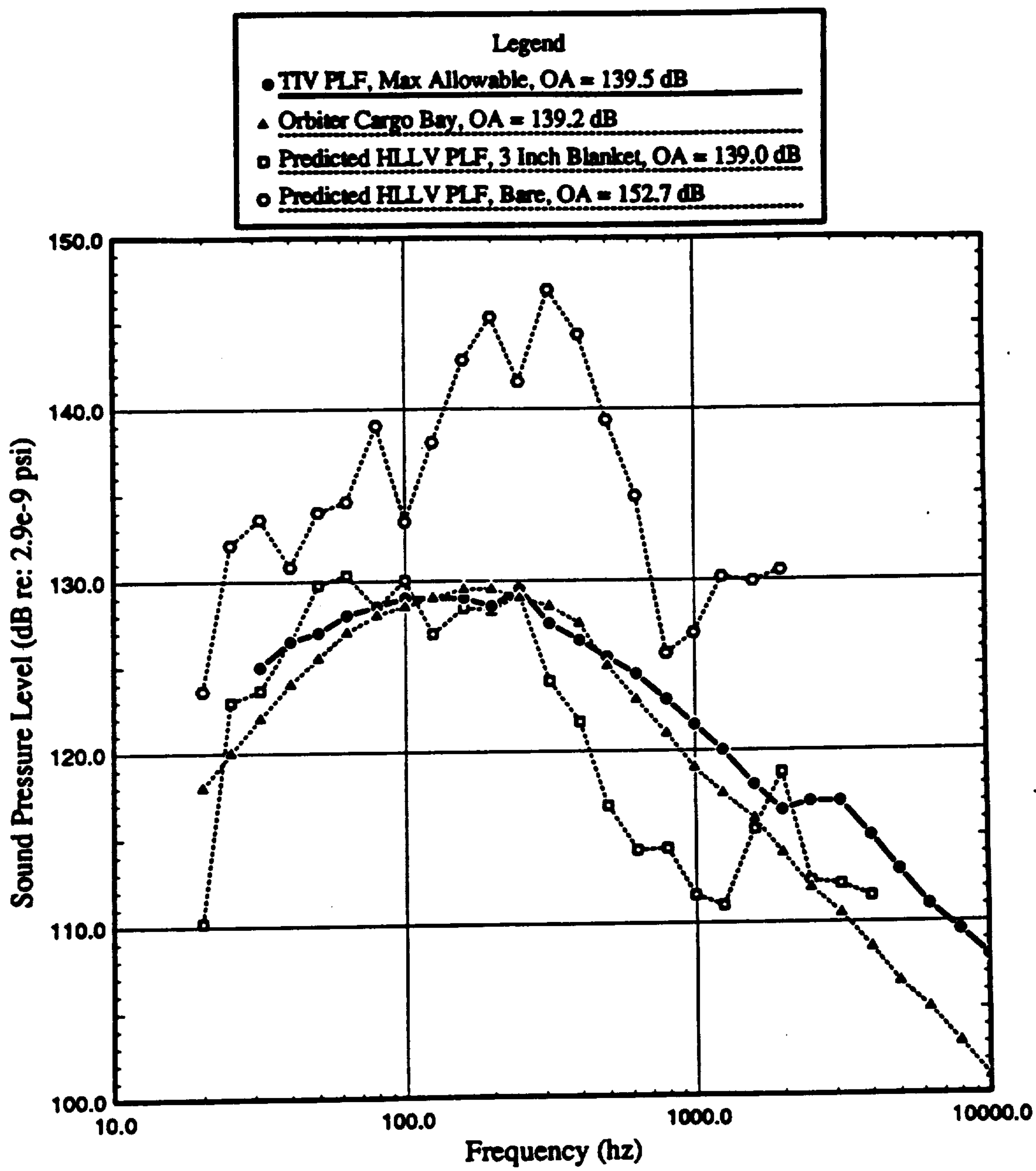



Figure 2.17

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

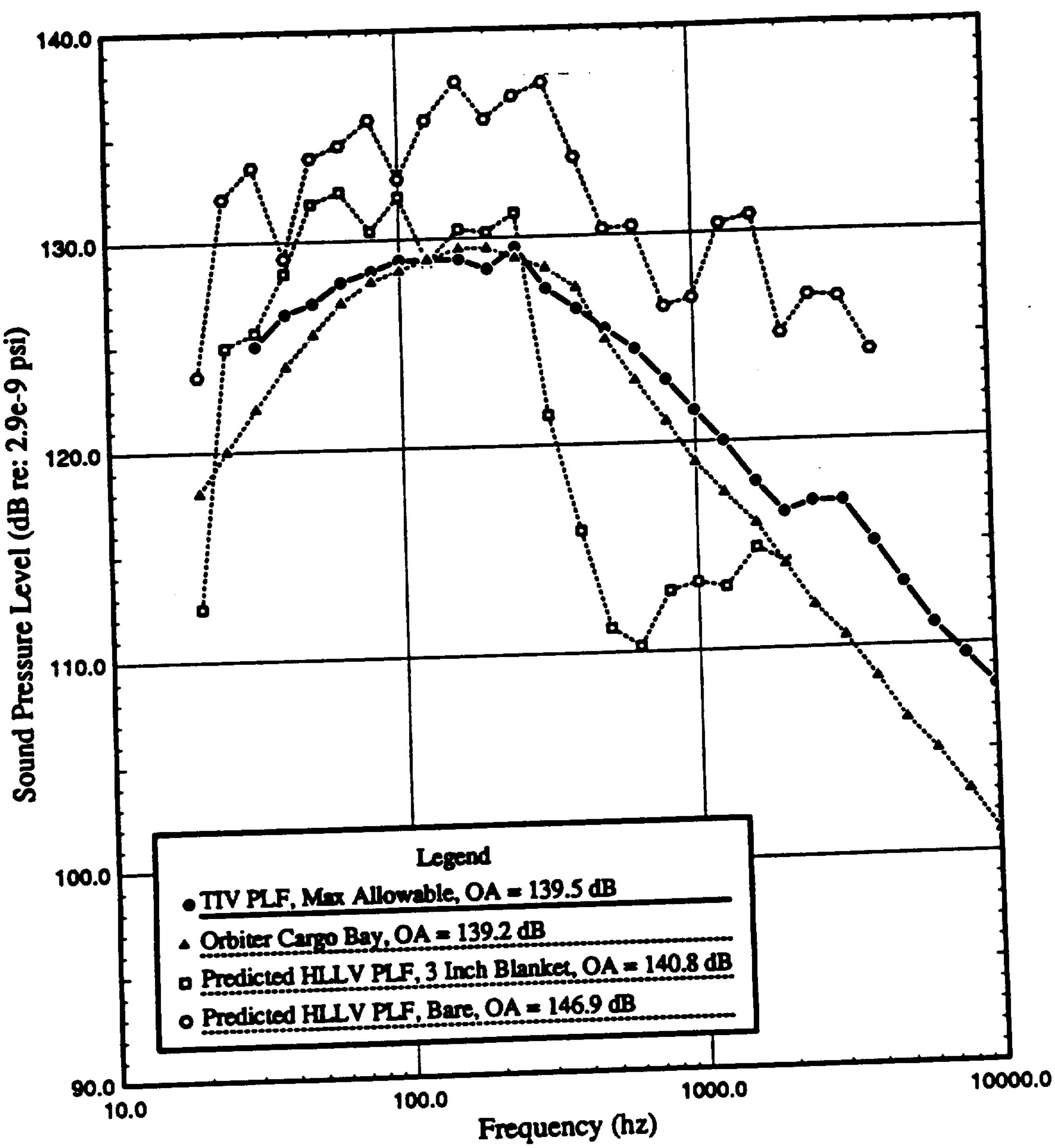



**Figure 2.18**

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

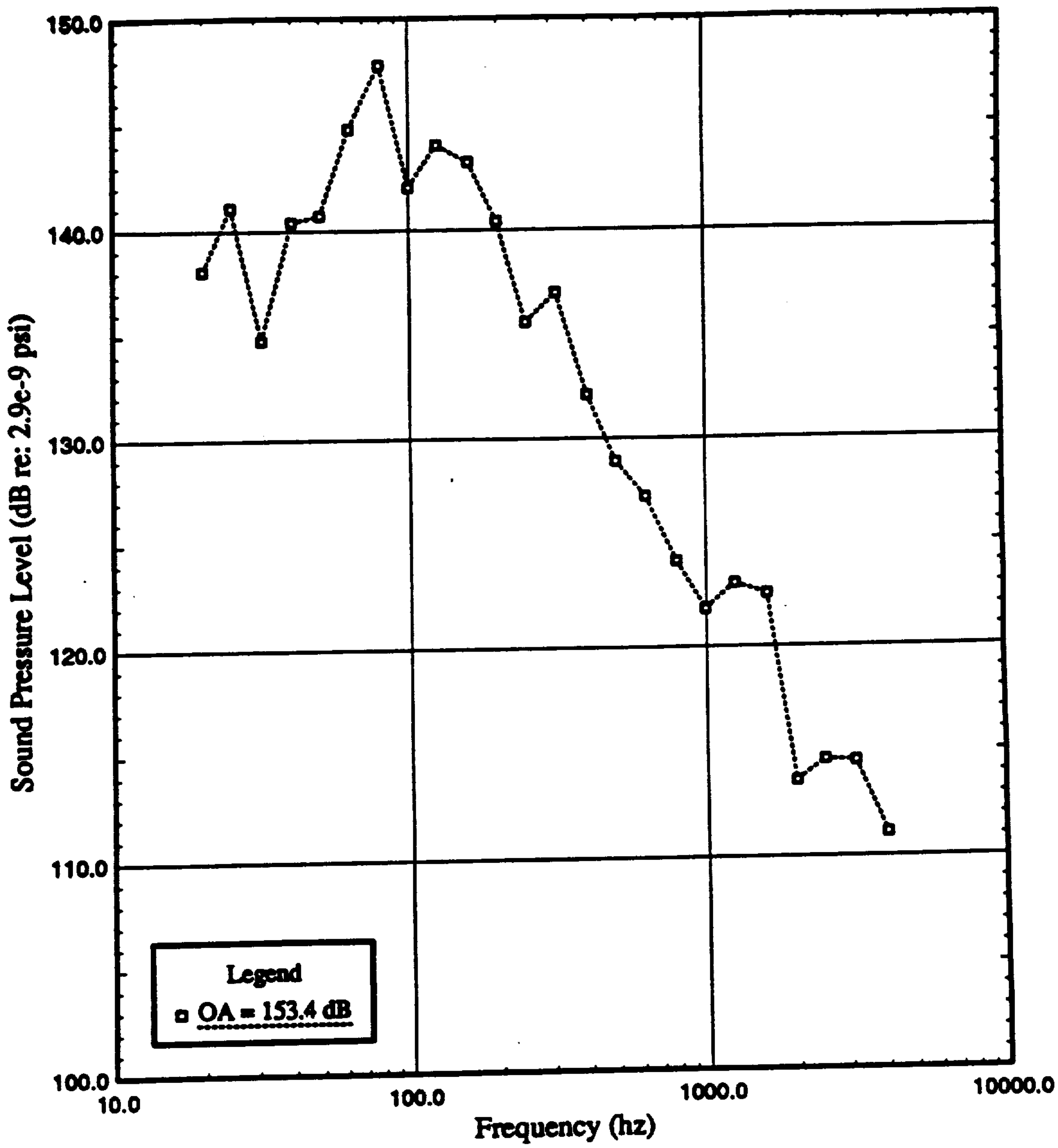



Figure 2.19

HLLV Zone E Internal Predicted Acoustic Levels

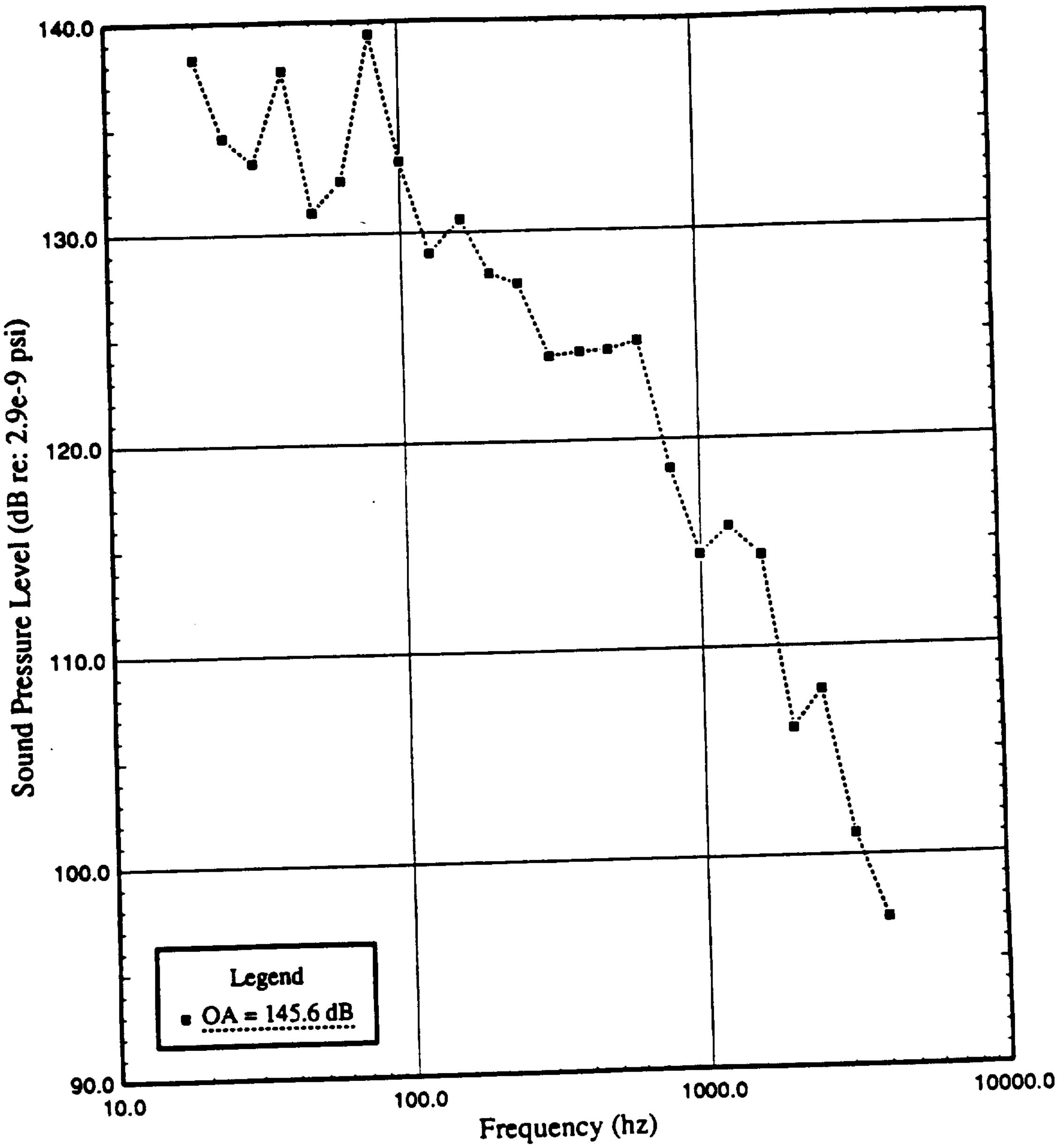



Figure 2.20
HLLV Zone F Internal Predicted Acoustic Levels

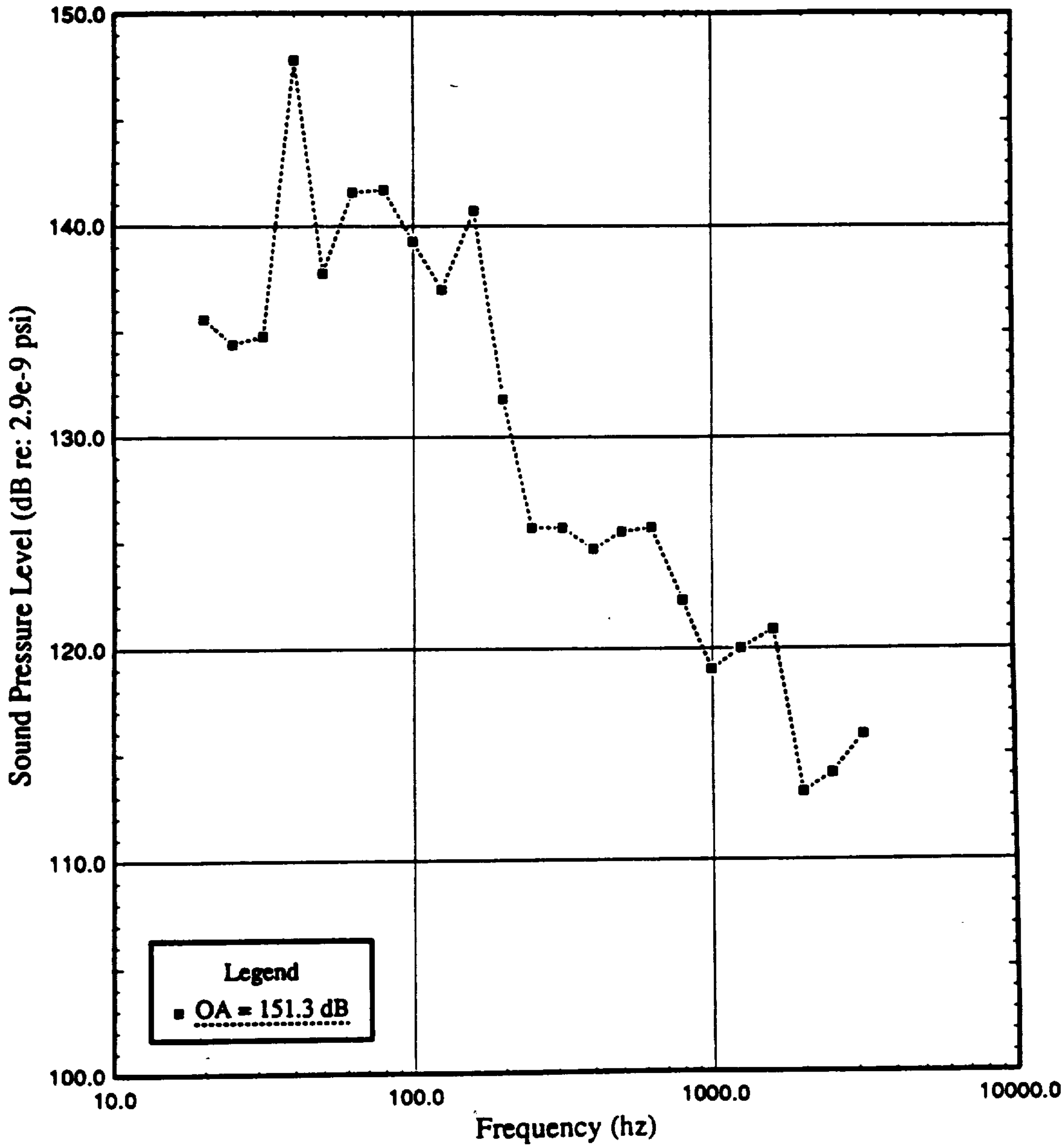



Figure 2.21

HLLV Zone G Internal Predicted Acoustic Levels

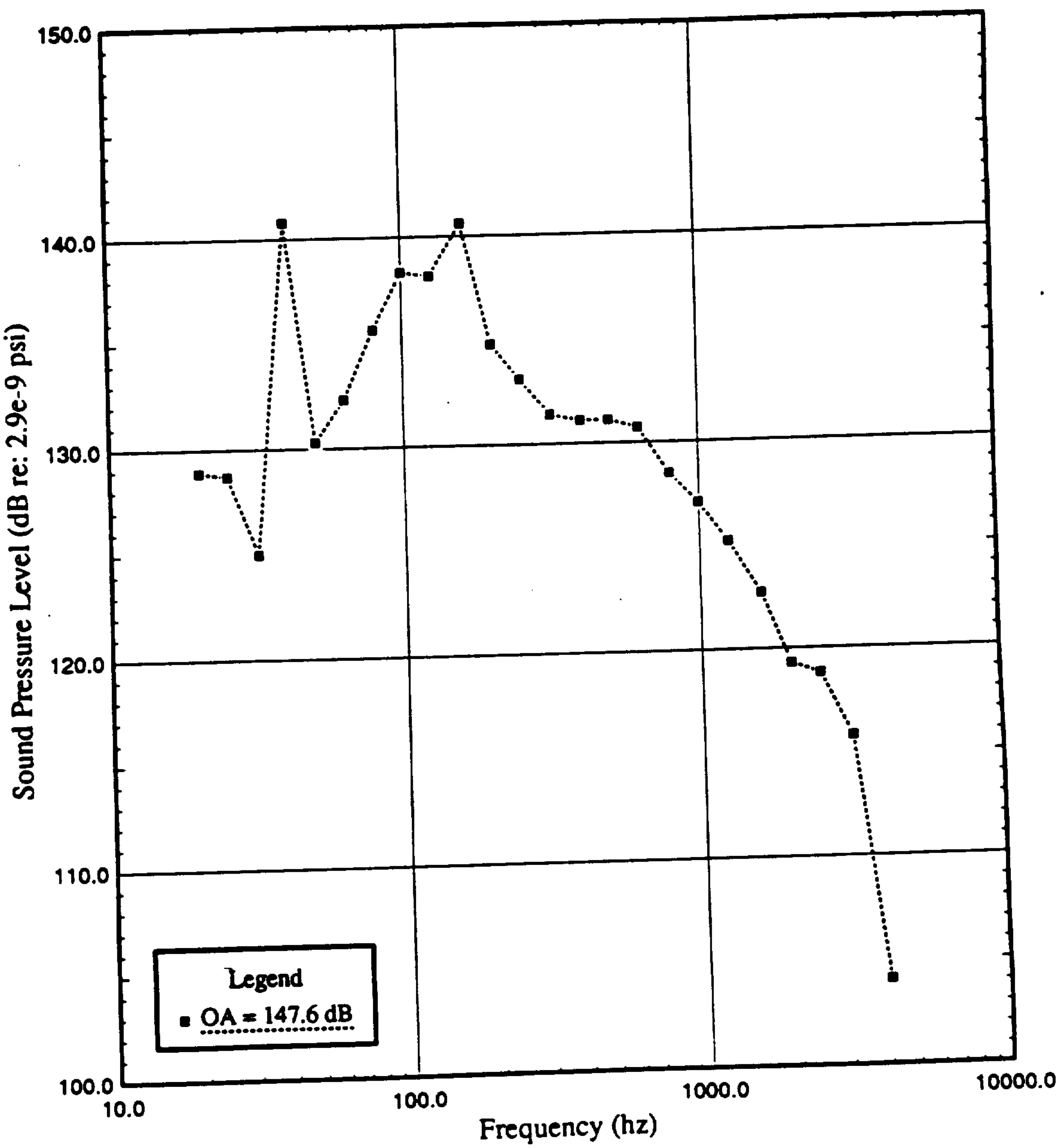



Figure 2.22

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:

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

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

$$APCF\ (dB) = 10\ Log_{10} \frac{6 \times 583{,}000 \times 13{,}934}{2 \times 2{,}650{,}000 \times 8{,}200 + 3 \times 390{,}000 \times 10{,}660}$$

$$= -0.6\ dB$$

(ii) Strouhal parameter:

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

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

$SN(SRB)/f = 0.00151$ $D_e(SRB) = D(SRB) = 12.4$ ft

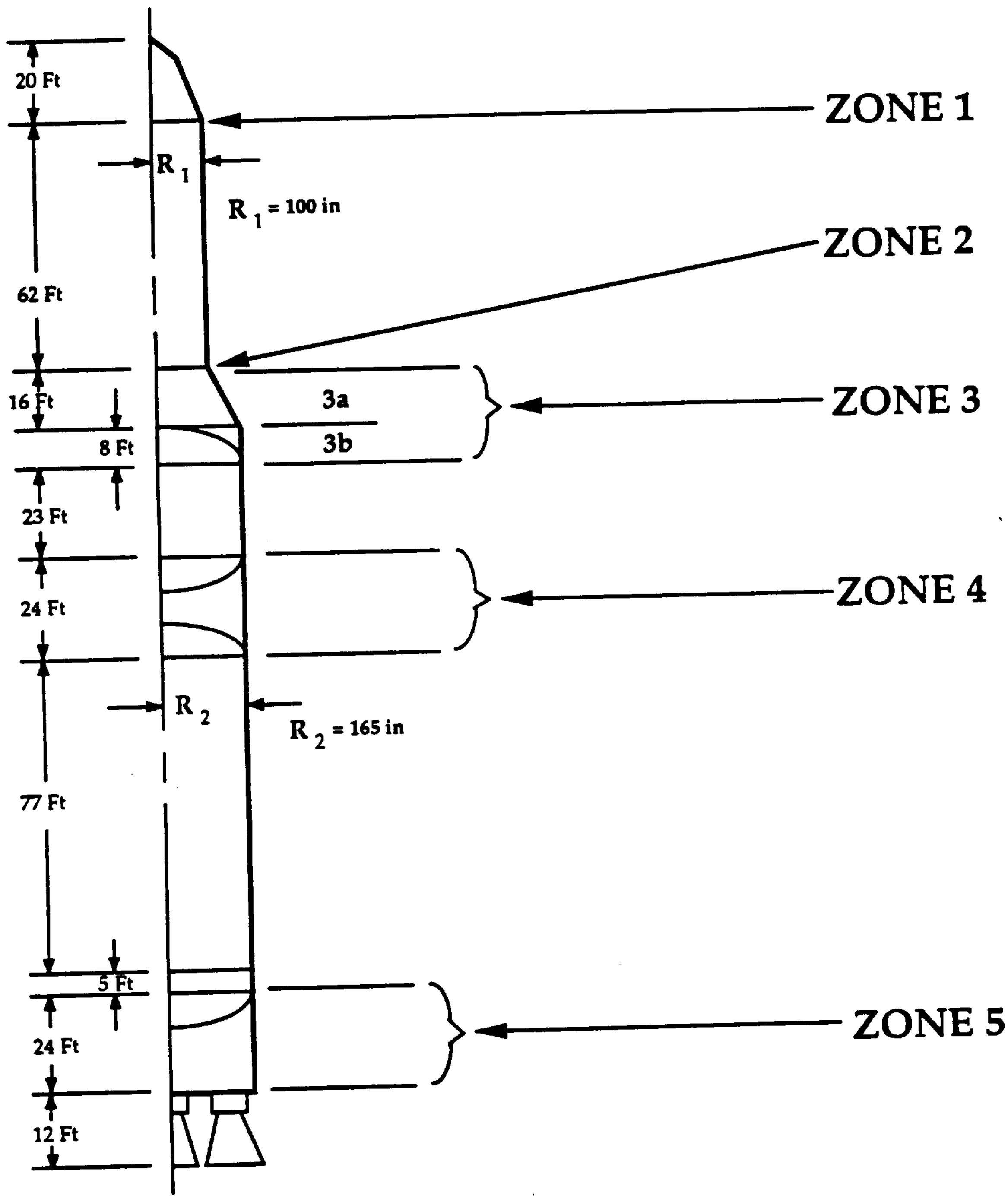



Figure 3.1 Definition of Acoustic Zones for 1.5 Stage LV

(iii) Mechanical power ratio:

$$P(SRB)/P(STS) = \frac{2 \times T(SRB) \times V(SRB)}{2 \times T(SRB) \times V(SRB) + 3 \times T(SSME) \times V(SSME)}$$

= 4.35E10/5.59E10

= 0.78

$$P(SSME)/P(STS) = \frac{3 \times T(SSME) \times V(SSME)}{2 \times T(SRB) \times V(SRB) + 3 \times T(SSME) \times V(SSME)}$$

= 1.23E10/5.59E10

= 0.22

(iv) Equivalent nozzle diameter and equivalent velocity:

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

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

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

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

(v) Strouhal parameter:

SN(STS)/f = 12.65/8741 = 0.00145

SN(1.5LV)/f = 17.76/13,934 = 0.00128

(vi) Frequency shift:

f(STS)/f(1.5 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.

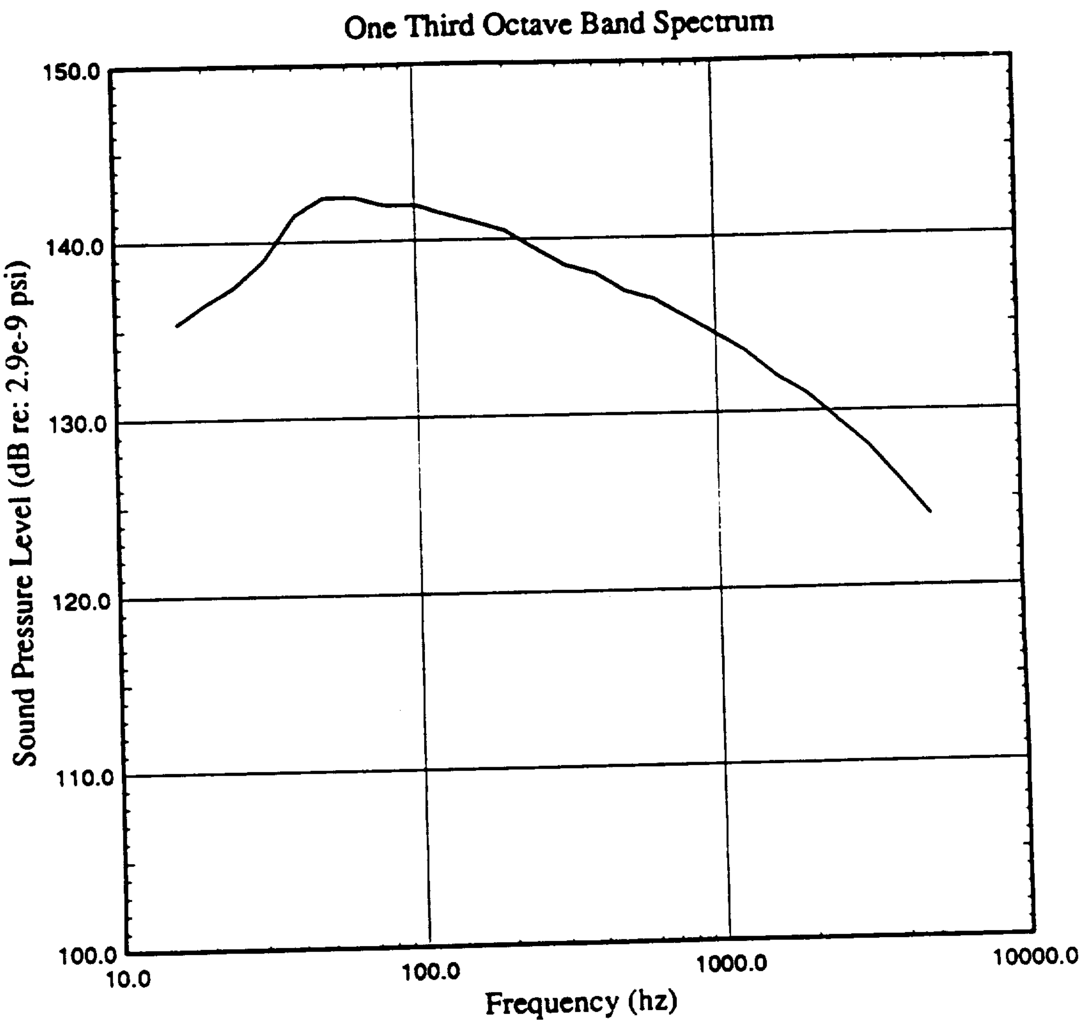



Figure 3.2

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

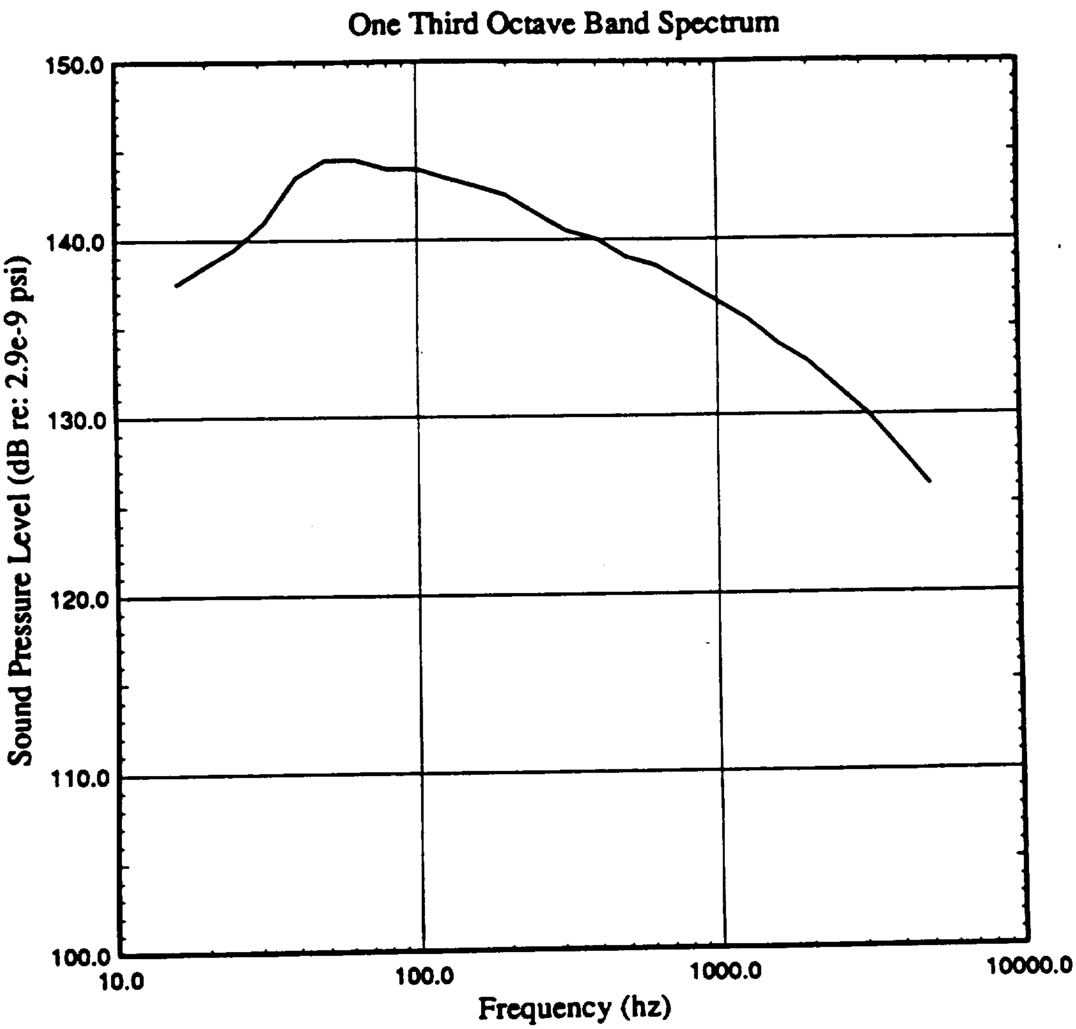



Figure 3.3

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

One Third Octave Band Spectrum

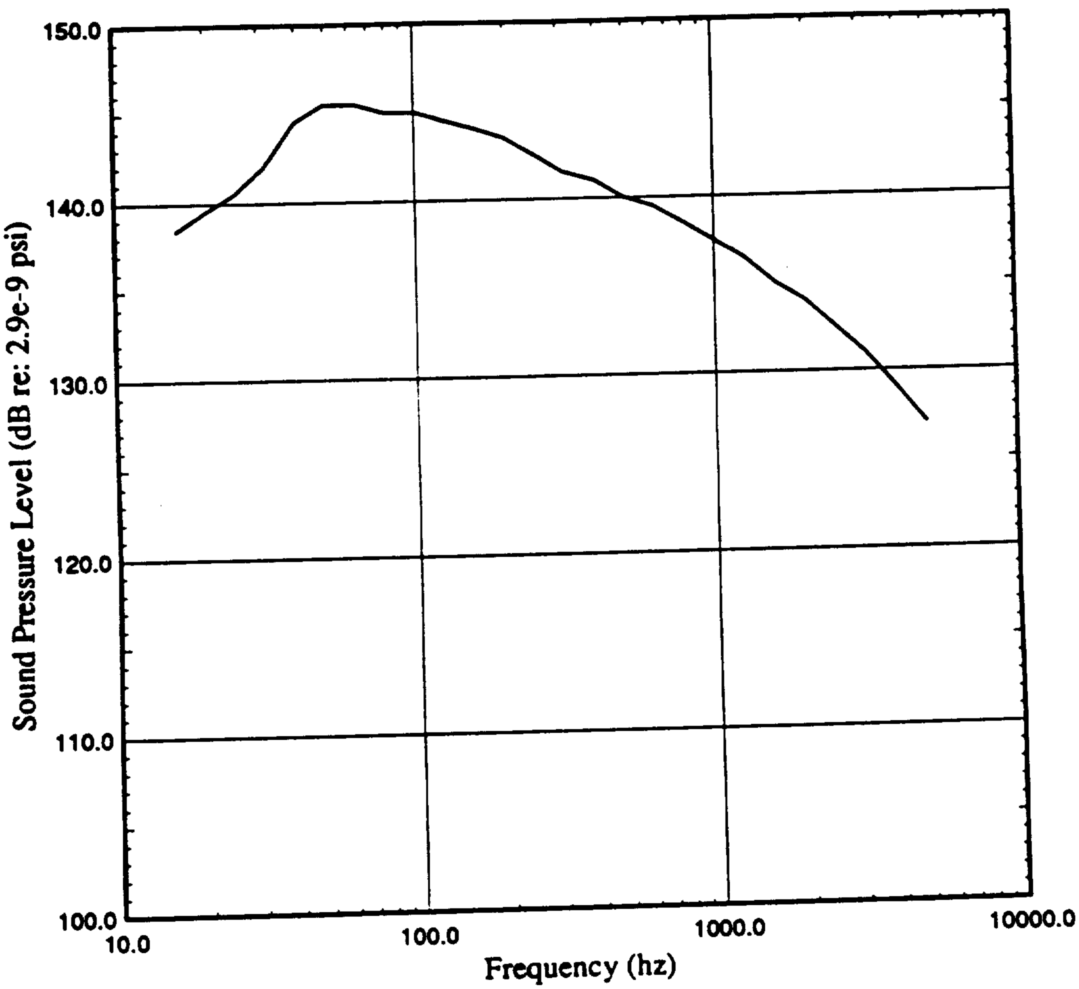



Figure 3.4

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

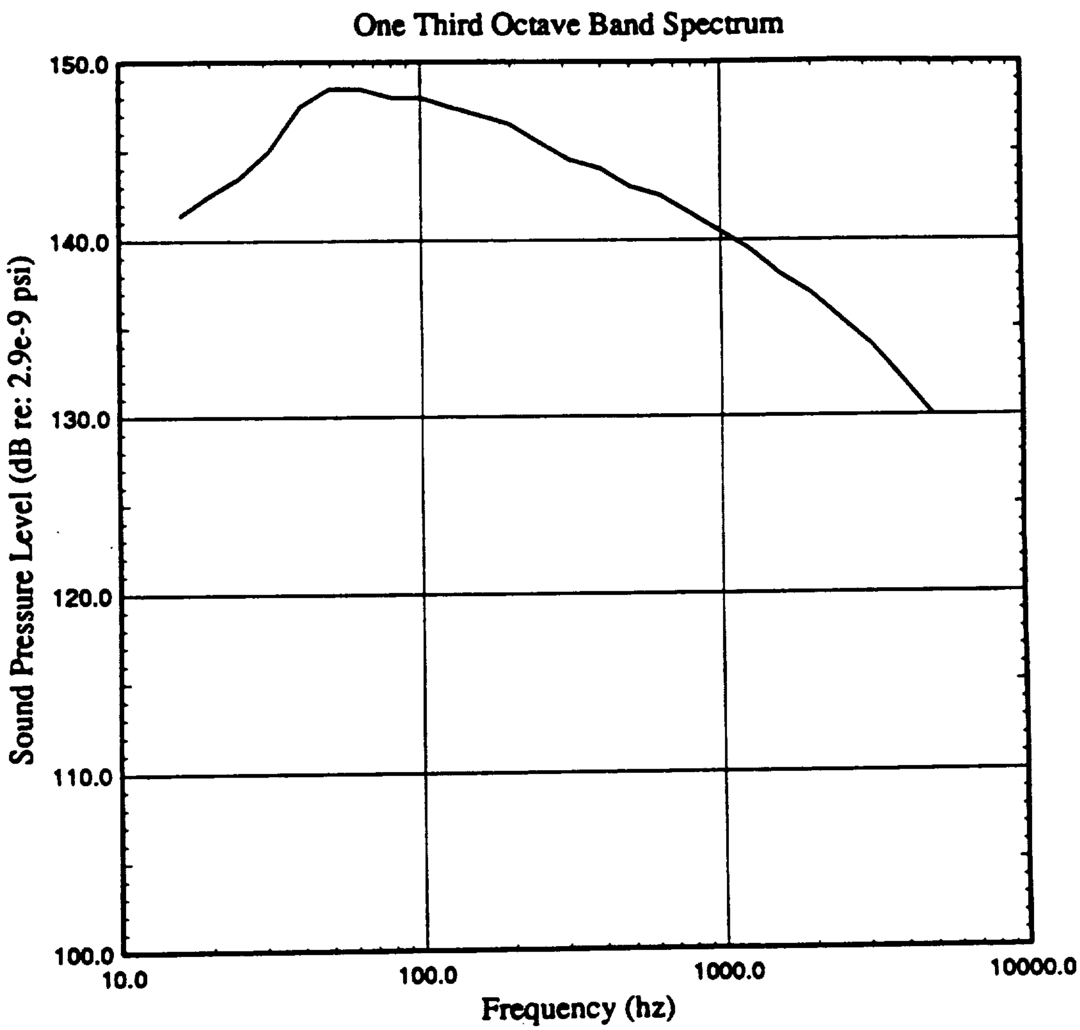



Figure 3.5

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

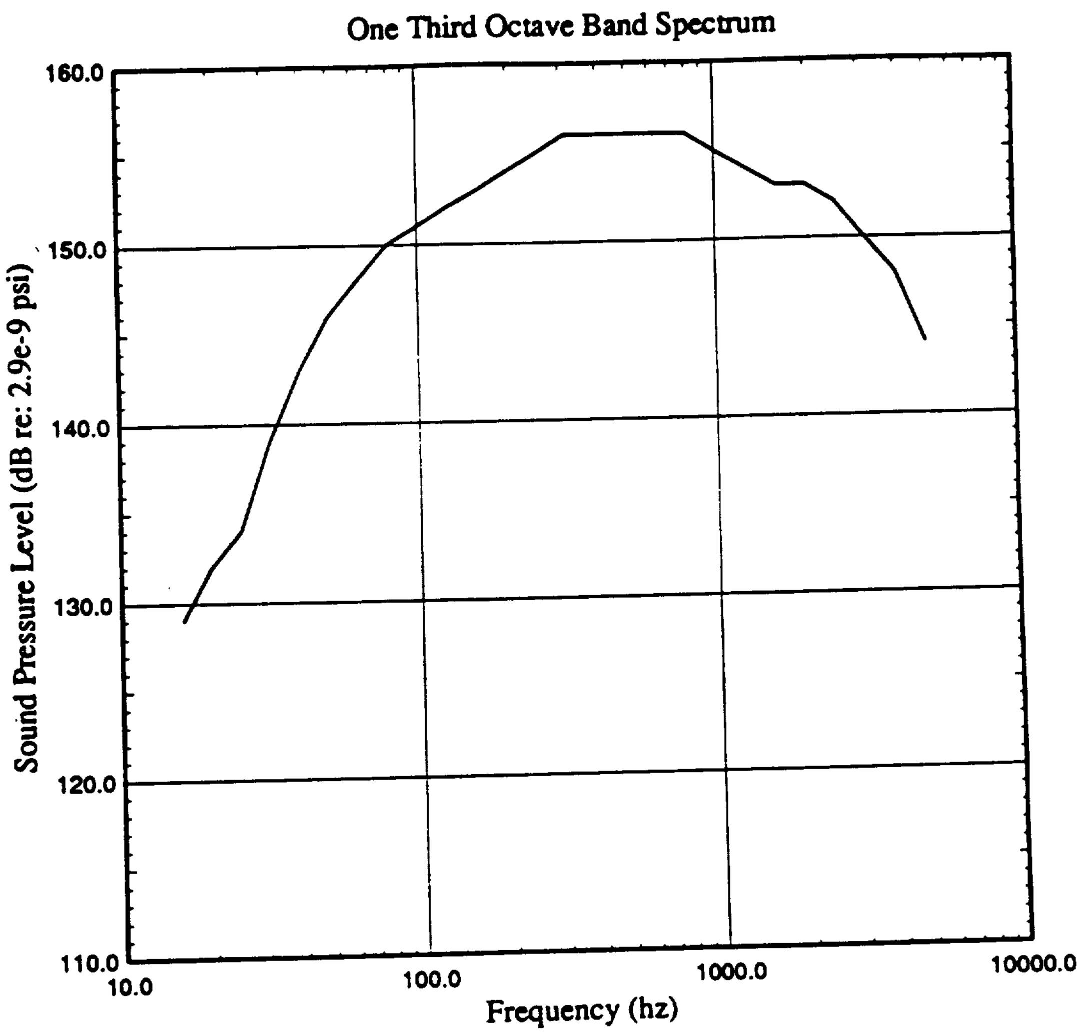



Figure 3.6

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

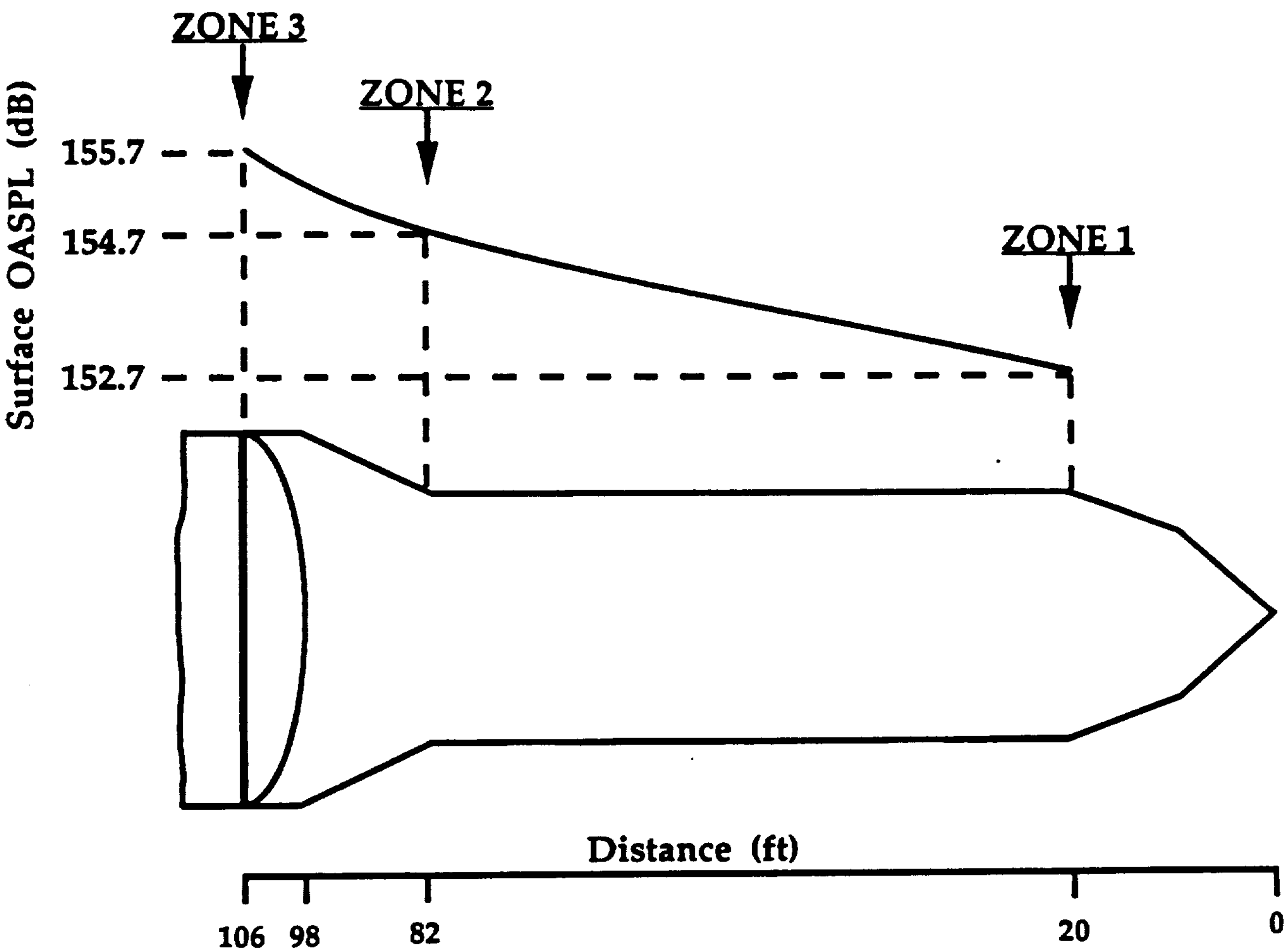



Figure 3.7

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.

$$\text{Correction Factor} = 20 \text{ Log } (q_{1.5LV}/q_{HLLV})$$

$$= 20 \text{ Log } (514/575) = -1.0 \text{ dB}$$

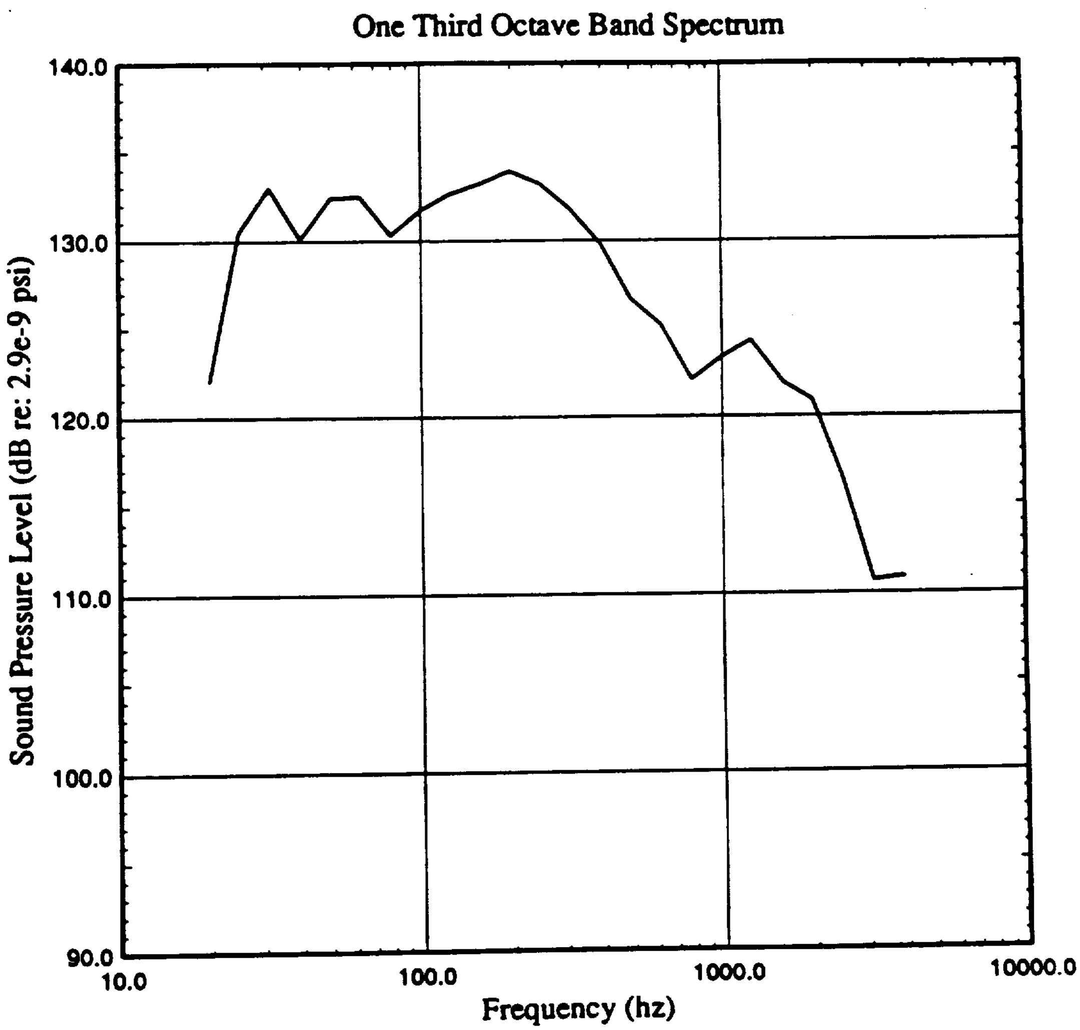



Figure 3.8

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

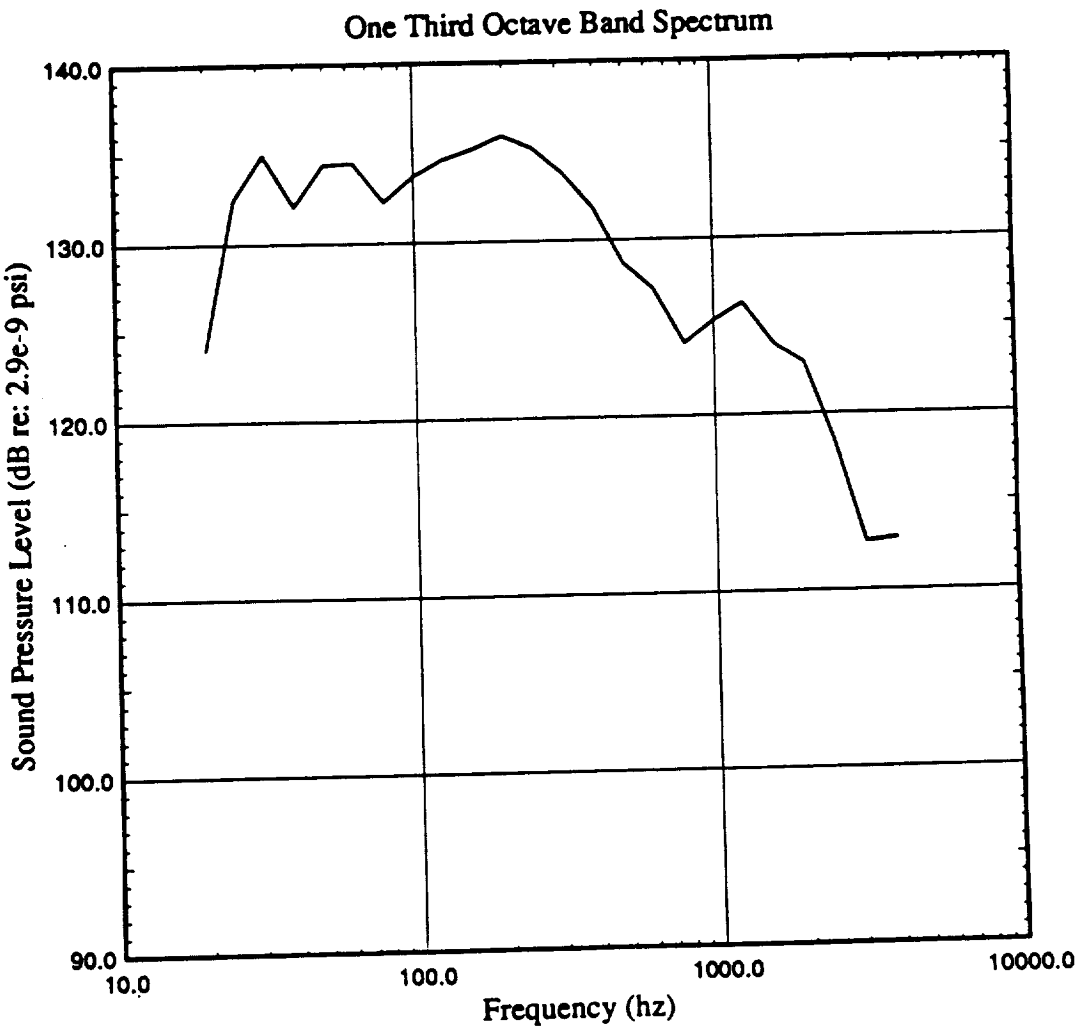



Figure 3.9
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 145.6 dB

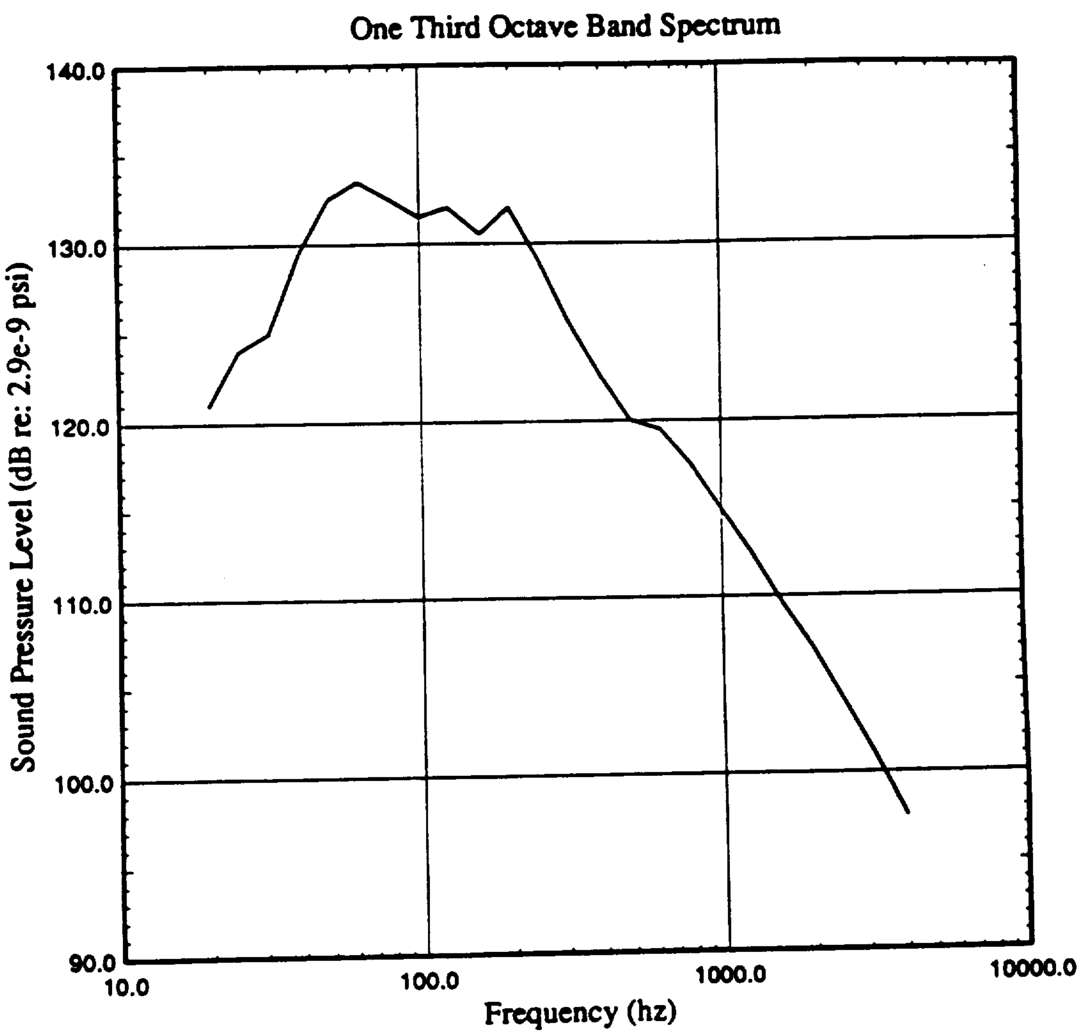



Figure 3.10

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

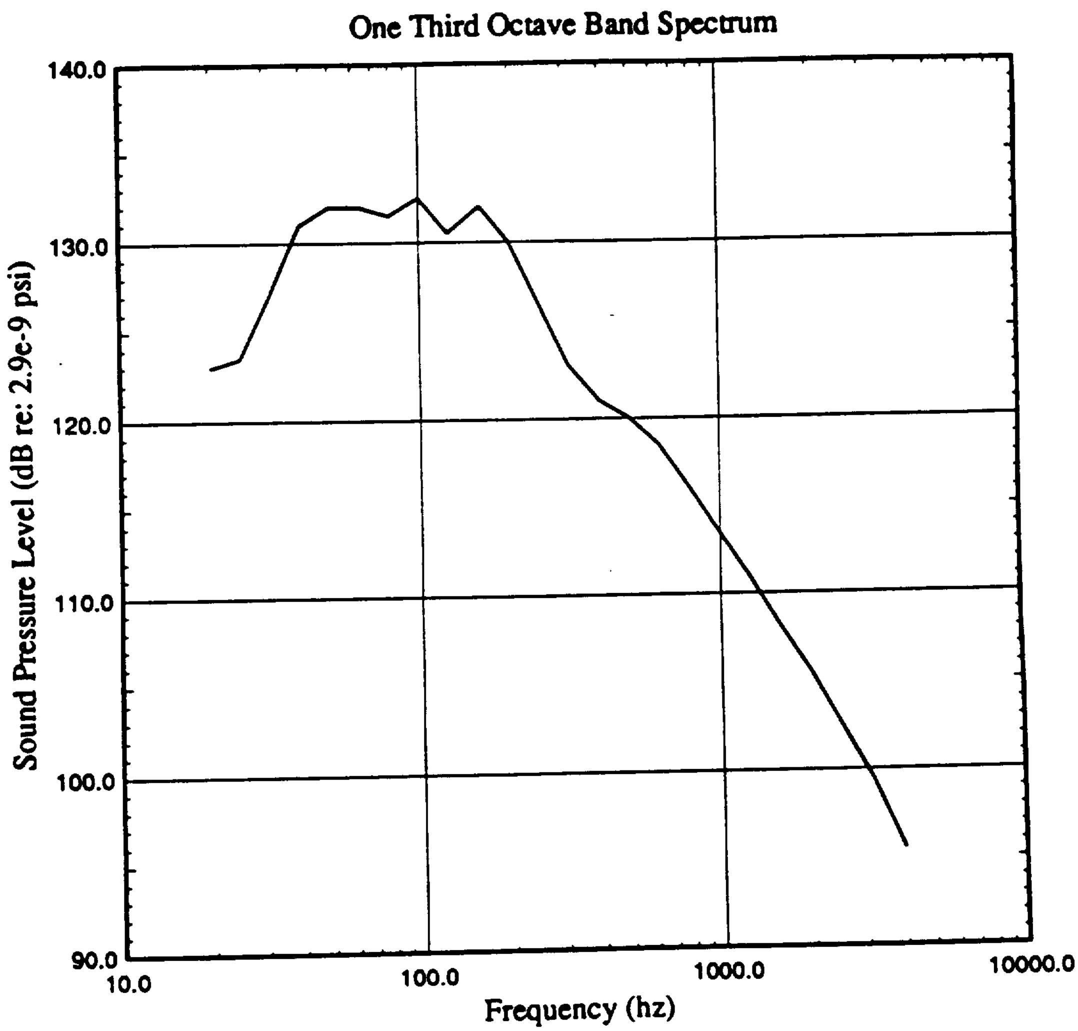



Figure 3.11

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

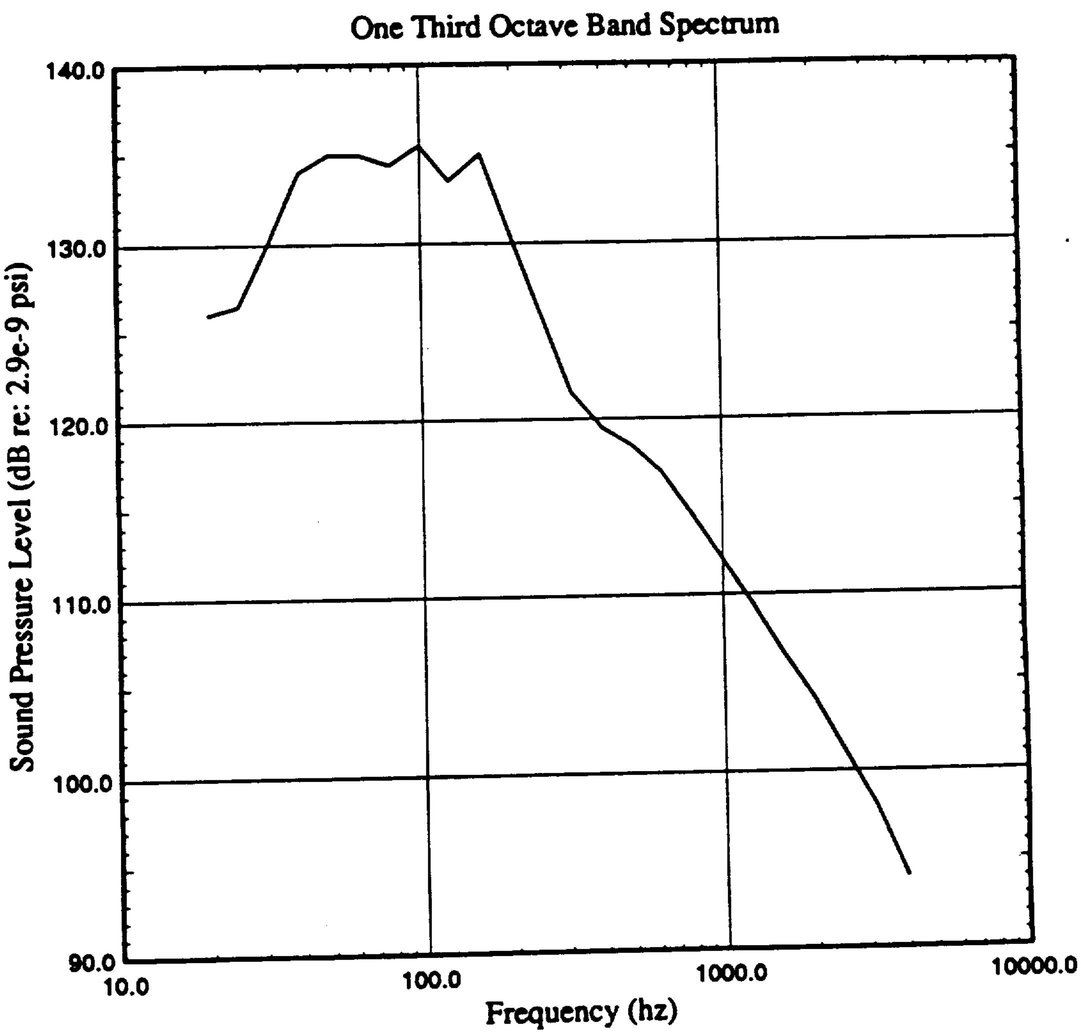



Figure 3.12
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
ZONE 4: Core Intertank Skirt OASPL = 143.9 dB

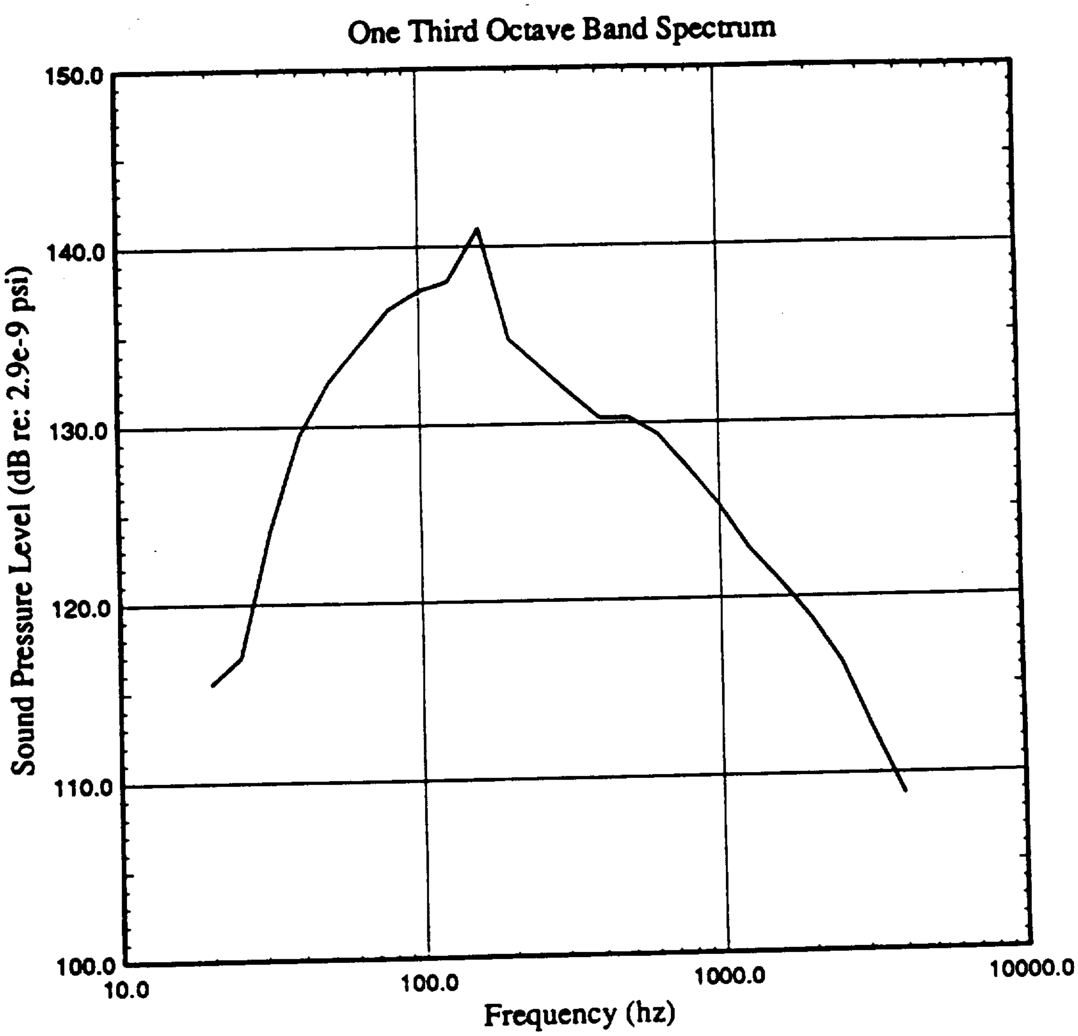



Figure 3.13
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
ZONE 5: Aft Skirt and Prop. Module OASPL = 146.6 dB

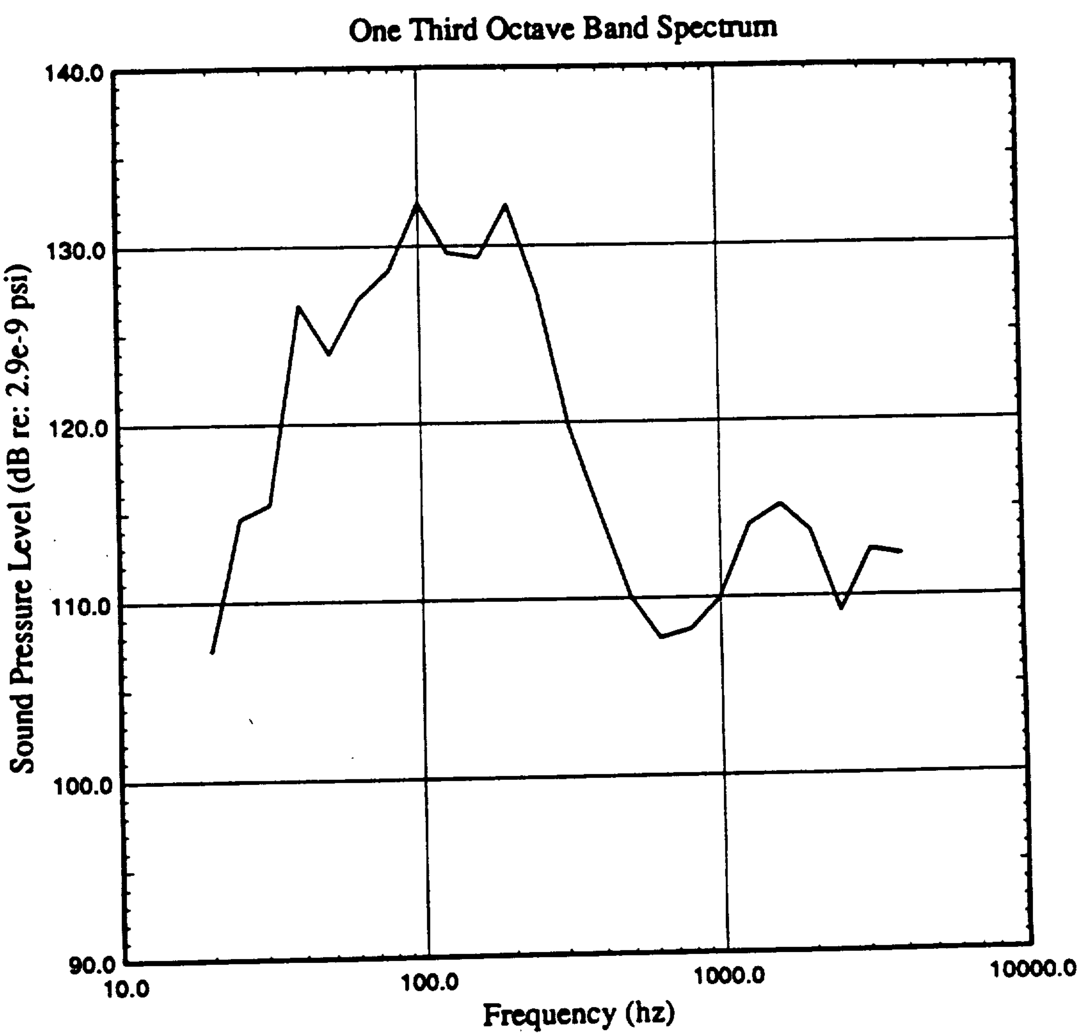



Figure 3.14

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

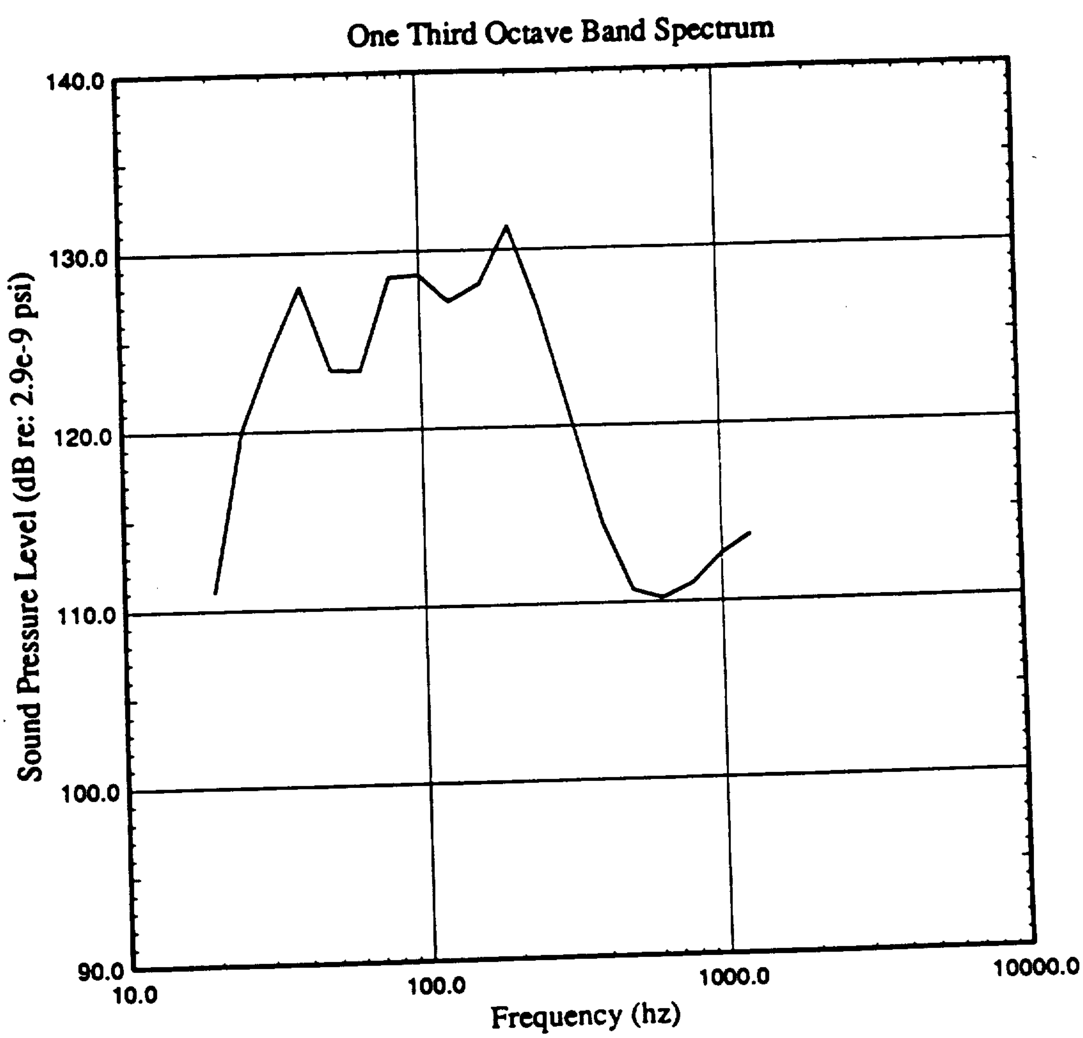



Figure 3.15
NLS 1.5-Stage, Liftoff Internal Acoustic Prediction
Standard Titan-IV 3 inch PLF Blankets included
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 137.8 dB

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

$$\text{Correction Factor} = 20 \text{ Log } (q_{1.5LV}/q_{Saturn})$$

$$= 20 \text{ Log}(627/690) = -0.8 \text{ dB}$$

### 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**

| Freq(Hz) | SPL(dB) |
|---|---|
| 20.0 | 122.0 |
| 25.0 | 130.5 |
| 31.5 | 133.0 |
| 40.0 | 130.1 |
| 50.0 | 132.4 |
| 63.0 | 132.5 |
| 80.0 | 130.3 |
| 100.0 | 131.7 |
| 125.0 | 132.6 |
| 160.0 | 133.2 |
| 200.0 | 133.9 |
| 250.0 | 133.2 |
| 315.0 | 131.8 |
| 400.0 | 129.8 |
| 500.0 | 126.7 |
| 630.0 | 125.2 |
| 800.0 | 122.1 |
| 1000.0 | 123.3 |
| 1250.0 | 124.3 |
| 1600.0 | 121.9 |
| 2000.0 | 120.9 |
| 2500.0 | 116.4 |
| 3150.0 | 110.7 |
| 4000.0 | 110.9 |

**ZONE 1 OASPL= 139.0 dB — 3 inch Blanket**

| Freq(Hz) | SPL(dB) |
|---|---|
| 20.0 | 107.2 |
| 25.0 | 114.7 |
| 31.5 | 115.5 |
| 40.0 | 126.7 |
| 50.0 | 123.9 |
| 63.0 | 127.0 |
| 80.0 | 128.6 |
| 100.0 | 132.4 |
| 125.0 | 129.6 |
| 160.0 | 129.3 |
| 200.0 | 132.3 |
| 250.0 | 127.3 |
| 315.0 | 119.8 |
| 400.0 | 114.8 |
| 500.0 | 110.1 |
| 630.0 | 107.7 |
| 800.0 | 108.2 |
| 1000.0 | 109.9 |
| 1250.0 | 114.1 |
| 1600.0 | 115.2 |
| 2000.0 | 113.7 |
| 2500.0 | 109.1 |
| 3150.0 | 112.6 |
| 4000.0 | 112.3 |

**ZONE 2 OASPL= 145.6 dB — Bare and Empty PLF**

| Freq(Hz) | SPL(dB) |
|---|---|
| 20.0 | 124.0 |
| 25.0 | 132.5 |
| 31.5 | 135.0 |
| 40.0 | 132.1 |
| 50.0 | 134.4 |
| 63.0 | 134.5 |
| 80.0 | 132.3 |
| 100.0 | 133.7 |
| 125.0 | 134.6 |
| 160.0 | 135.2 |
| 200.0 | 135.9 |
| 250.0 | 135.2 |
| 315.0 | 133.8 |
| 400.0 | 131.8 |
| 500.0 | 128.7 |
| 630.0 | 127.2 |
| 800.0 | 124.1 |
| 1000.0 | 125.3 |
| 1250.0 | 126.3 |
| 1600.0 | 123.9 |
| 2000.0 | 122.9 |
| 2500.0 | 118.4 |
| 3150.0 | 112.7 |
| 4000.0 | 112.9 |

**ZONE 2 OASPL= 137.8 dB — 3 inch Blanket**

| Freq(Hz) | SPL(dB) |
|---|---|
| 20.0 | 111.0 |
| 25.0 | 120.0 |
| 31.5 | 124.3 |
| 40.0 | 128.1 |
| 50.0 | 123.4 |
| 63.0 | 123.3 |
| 80.0 | 128.5 |
| 100.0 | 128.6 |
| 125.0 | 127.1 |
| 160.0 | 128.1 |
| 200.0 | 131.3 |
| 250.0 | 126.6 |
| 315.0 | 120.6 |
| 400.0 | 114.5 |
| 500.0 | 110.7 |
| 630.0 | 110.2 |
| 800.0 | 111.0 |
| 1000.0 | 112.6 |
| 1250.0 | 113.7 |

## Table 3.2

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

| ZONE 3a OASPL= 141.7 dB | |
|---|---|
| Freq(Hz) | SPL(dB) |
| 20.0 | 121.0 |
| 25.0 | 124.0 |
| 31.5 | 125.0 |
| 40.0 | 129.5 |
| 50.0 | 132.5 |
| 63.0 | 133.5 |
| 80.0 | 132.5 |
| 100.0 | 131.5 |
| 125.0 | 132.0 |
| 160.0 | 130.5 |
| 200.0 | 132.0 |
| 250.0 | 129.0 |
| 315.0 | 125.5 |
| 400.0 | 122.5 |
| 500.0 | 120.0 |
| 630.0 | 119.5 |
| 800.0 | 117.5 |
| 1000.0 | 115.0 |
| 1250.0 | 112.5 |
| 1600.0 | 109.5 |
| 2000.0 | 107.0 |
| 2500.0 | 104.0 |
| 3150.0 | 101.0 |
| 4000.0 | 97.5 |

| ZONE 3b OASPL= 141.2 dB | |
|---|---|
| Freq(Hz) | SPL(dB) |
| 20.0 | 123.0 |
| 25.0 | 123.5 |
| 31.5 | 127.0 |
| 40.0 | 131.0 |
| 50.0 | 132.0 |
| 63.0 | 132.0 |
| 80.0 | 131.5 |
| 100.0 | 132.5 |
| 125.0 | 130.5 |
| 160.0 | 132.0 |
| 200.0 | 130.0 |
| 250.0 | 126.5 |
| 315.0 | 123.0 |
| 400.0 | 121.0 |
| 500.0 | 120.0 |
| 630.0 | 118.5 |
| 800.0 | 116.0 |
| 1000.0 | 113.5 |
| 1250.0 | 111.0 |
| 1600.0 | 108.0 |
| 2000.0 | 105.5 |
| 2500.0 | 102.5 |
| 3150.0 | 99.5 |
| 4000.0 | 95.5 |

| ZONE 4 OASPL= 143.9 dB | |
|---|---|
| Freq(Hz) | SPL(dB) |
| 20.0 | 126.0 |
| 25.0 | 126.5 |
| 31.5 | 130.0 |
| 40.0 | 134.0 |
| 50.0 | 135.0 |
| 63.0 | 135.0 |
| 80.0 | 134.4 |
| 100.0 | 135.5 |
| 125.0 | 133.5 |
| 160.0 | 135.0 |
| 200.0 | 130.5 |
| 250.0 | 126.0 |
| 315.0 | 121.5 |
| 400.0 | 119.5 |
| 500.0 | 118.5 |
| 630.0 | 117.0 |
| 800.0 | 114.5 |
| 1000.0 | 112.0 |
| 1250.0 | 109.5 |
| 1600.0 | 106.5 |
| 2000.0 | 104.0 |
| 2500.0 | 101.0 |
| 3150.0 | 98.0 |
| 4000.0 | 94.0 |

| ZONE 5 OASPL= 146.6 dB | |
|---|---|
| Freq(Hz) | SPL(dB) |
| 20.0 | 115.5 |
| 25.0 | 117.0 |
| 31.5 | 124.0 |
| 40.0 | 129.5 |
| 50.0 | 132.5 |
| 63.0 | 134.5 |
| 80.0 | 136.5 |
| 100.0 | 137.5 |
| 125.0 | 138.0 |
| 160.0 | 141.0 |
| 200.0 | 134.8 |
| 250.0 | 133.3 |
| 315.0 | 131.8 |
| 400.0 | 130.3 |
| 500.0 | 130.3 |
| 630.0 | 129.3 |
| 800.0 | 127.3 |
| 1000.0 | 125.3 |
| 1250.0 | 122.8 |
| 1600.0 | 120.8 |
| 2000.0 | 118.8 |
| 2500.0 | 116.3 |
| 3150.0 | 112.5 |
| 4000.0 | 108.8 |



Aftermath v1.25 (orizaba) December 13, 1991

# 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 | 138.5 |
| 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.)

| Freq(Hz) | ZONE 3a OASPL= 152.4 dB SPL(dB) | ZONE 3b OASPL= 145.4 dB SPL(dB) | ZONE 4 OASPL= 135.5 dB SPL(dB) | ZONE 5 OASPL= 135.0 dB SPL(dB) |
|---|---|---|---|---|
| 20.0 | 136.3 | 141.4 | 106.1 | 106.1 |
| 25.0 | 139.3 | 135.6 | 108.3 | 108.3 |
| 31.5 | 133.0 | 131.6 | 105.9 | 105.9 |
| 40.0 | 139.1 | 134.2 | 114.4 | 114.4 |
| 50.0 | 140.4 | 132.2 | 115.0 | 115.0 |
| 63.0 | 144.5 | 130.7 | 121.5 | 121.5 |
| 80.0 | 147.0 | 137.6 | 127.4 | 127.4 |
| 100.0 | 140.2 | 131.6 | 124.3 | 124.3 |
| 125.0 | 142.7 | 128.6 | 125.7 | 125.7 |
| 160.0 | 141.9 | 128.9 | 130.2 | 130.2 |
| 200.0 | 139.1 | 124.6 | 125.2 | 122.0 |
| 250.0 | 133.8 | 122.0 | 120.2 | 118.0 |
| 315.0 | 135.2 | 125.0 | 123.0 | 121.8 |
| 400.0 | 130.3 | 124.0 | 120.8 | 119.6 |
| 500.0 | 127.1 | 121.9 | 120.6 | 119.4 |
| 630.0 | 125.4 | 120.6 | 119.5 | 118.3 |
| 800.0 | 122.3 | 114.8 | 116.1 | 114.9 |
| 1000.0 | 120.0 | 112.1 | 113.0 | 111.8 |
| 1250.0 | 121.2 | 115.9 | 114.3 | 113.1 |
| 1600.0 | 120.7 | 114.6 | 112.9 | 111.7 |
| 2000.0 | 111.8 | 105.2 | 103.5 | 102.3 |
| 2500.0 | 112.8 | 106.4 | 104.4 | 103.2 |
| 3150.0 | 112.1 | 104.6 | 104.3 | 103.1 |
| 4000.0 | 107.8 | 99.8 | 96.5 | 95.3 |

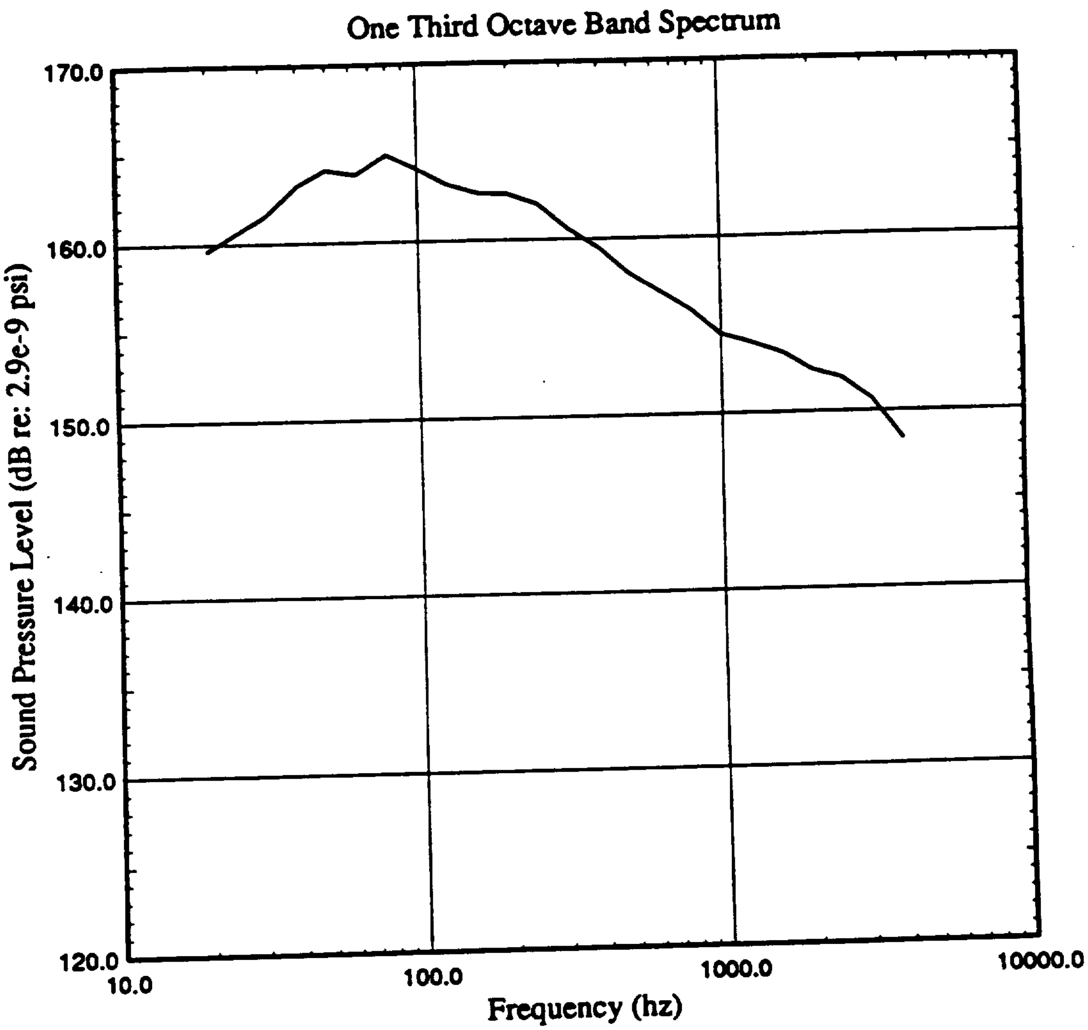



Figure 3.16
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 1: PLF-Fwd Cone-Cyl Junction OASPL = 174.5 dB



Aftermath v1.25 (orizaba) December 7, 1991

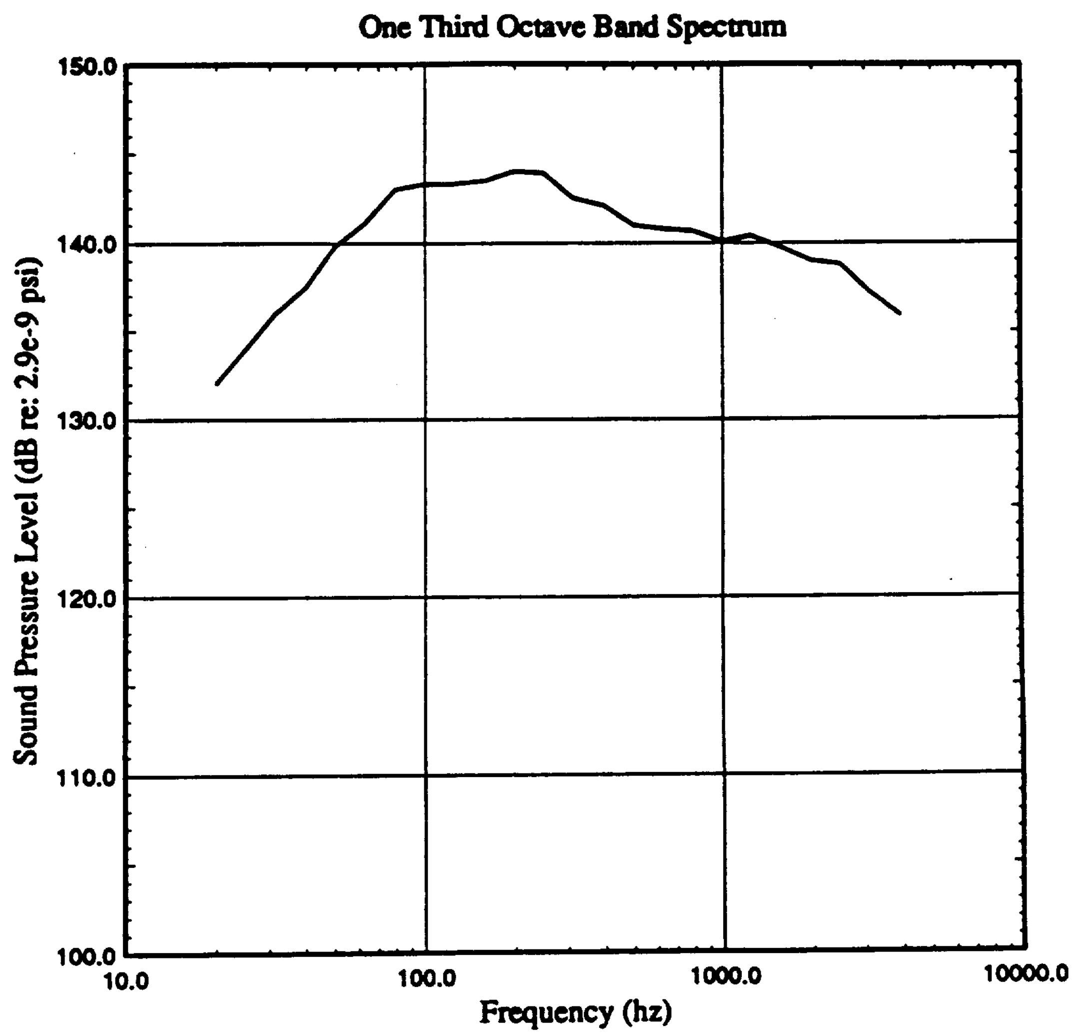



Figure 3.17

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

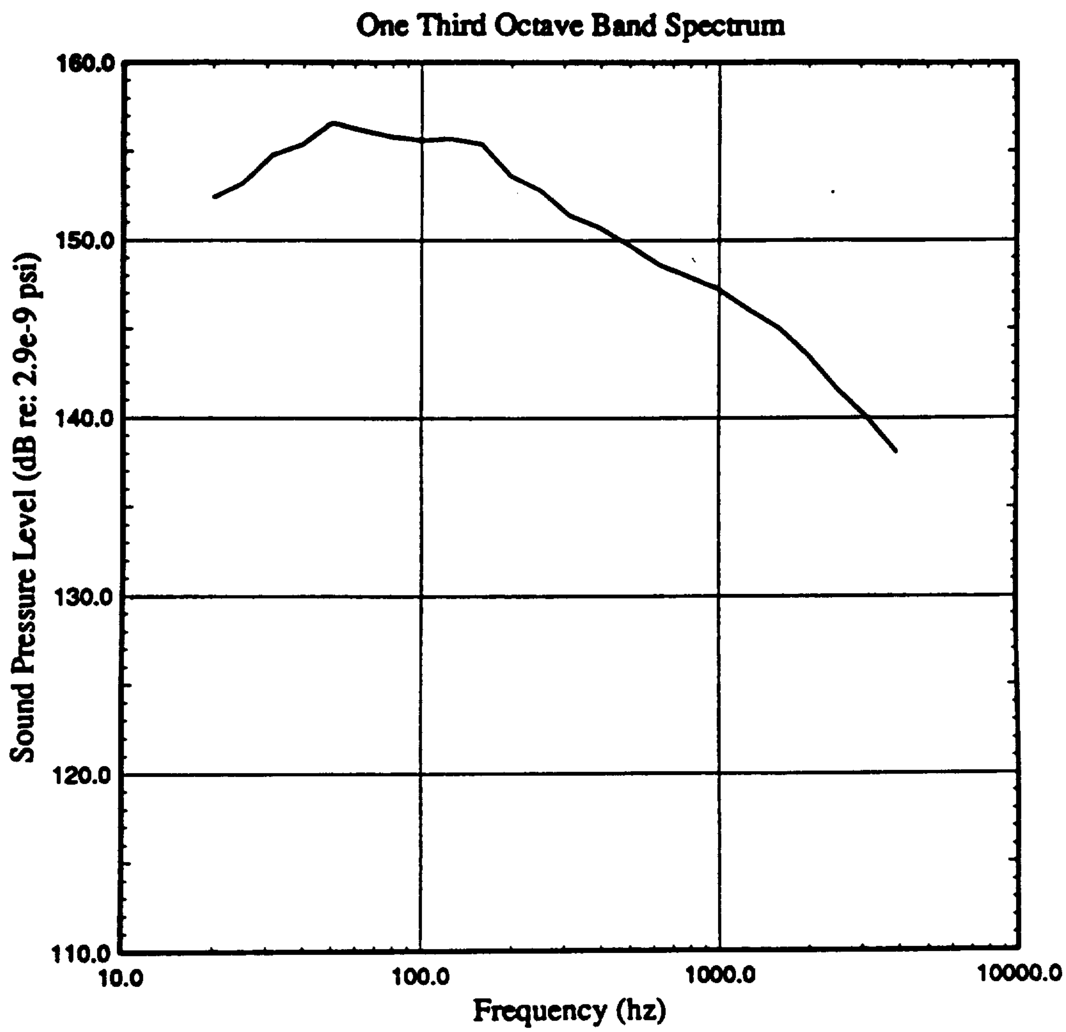



Figure 3.18
NLS 1.5-Stage, Aerodynamic Acoustic External Surface Prediction
ZONE 3a: PLF/Core Adapter, Conic Frustrum OASPL = 166.5 dB

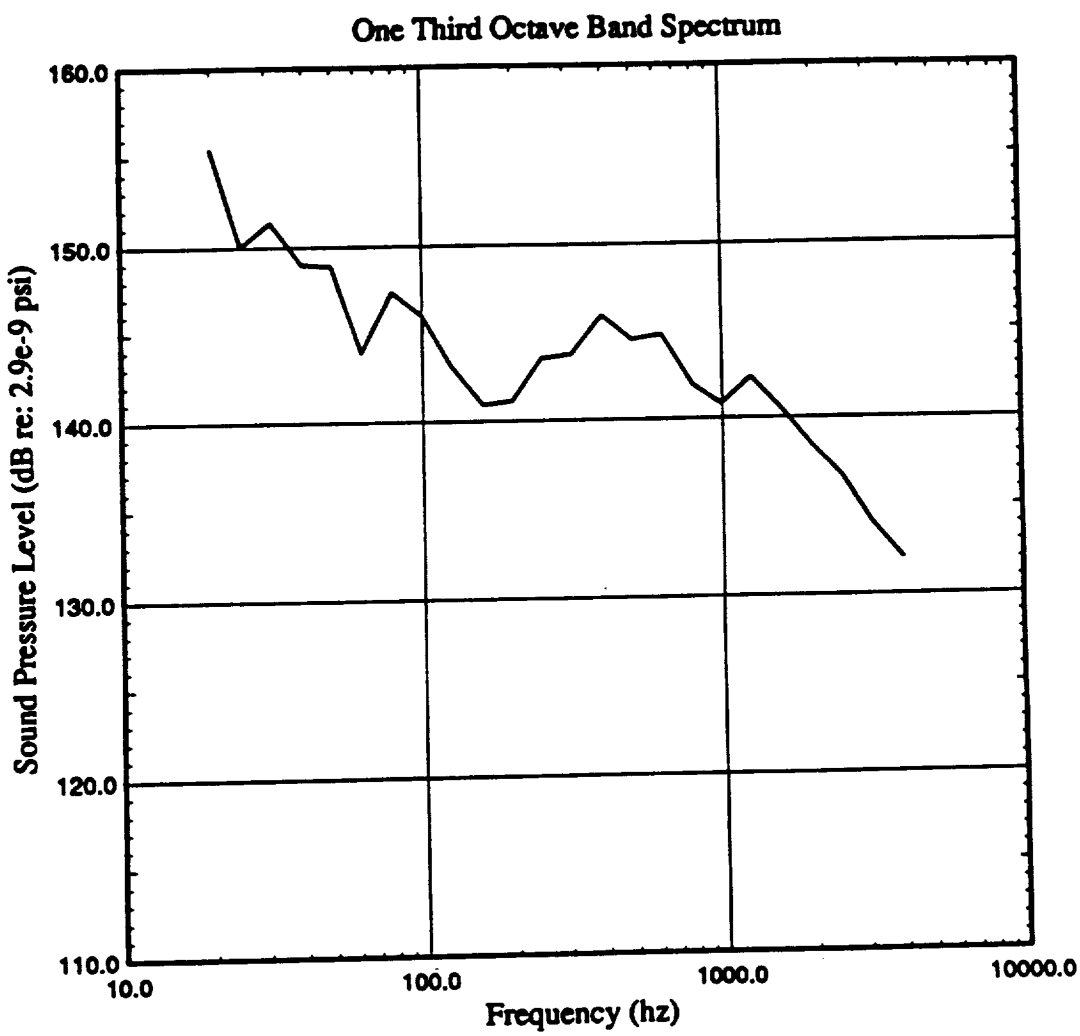



Figure 3.19

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

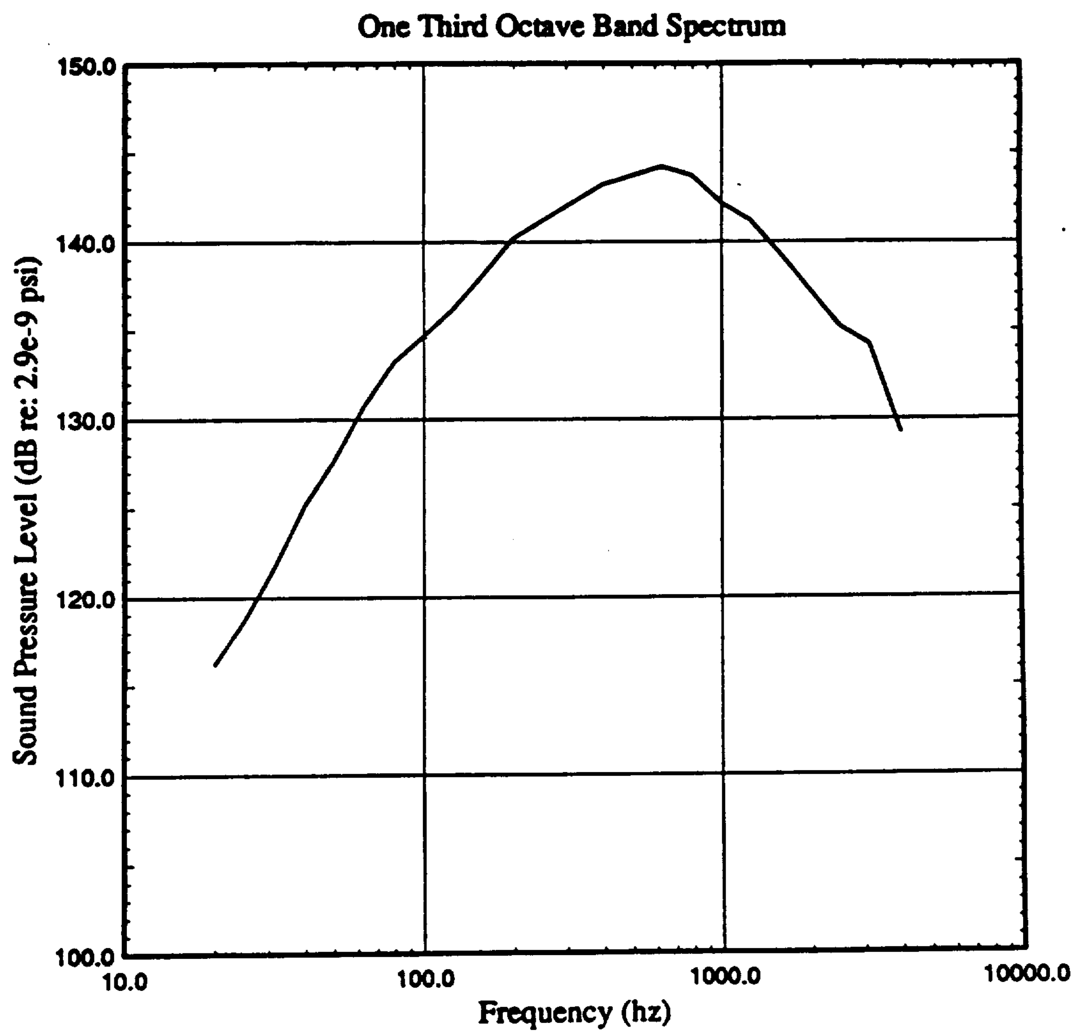



Figure 3.20

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

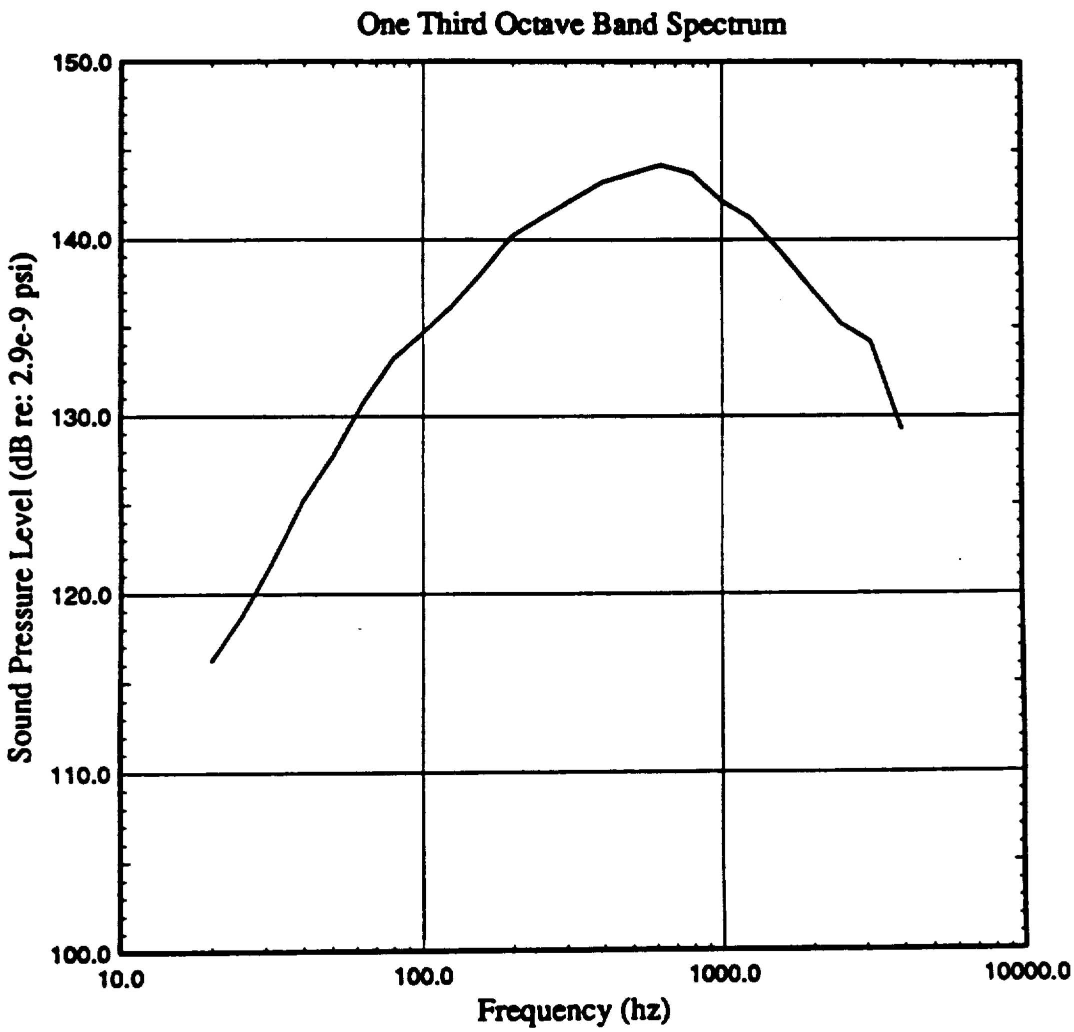



Figure 3.21

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

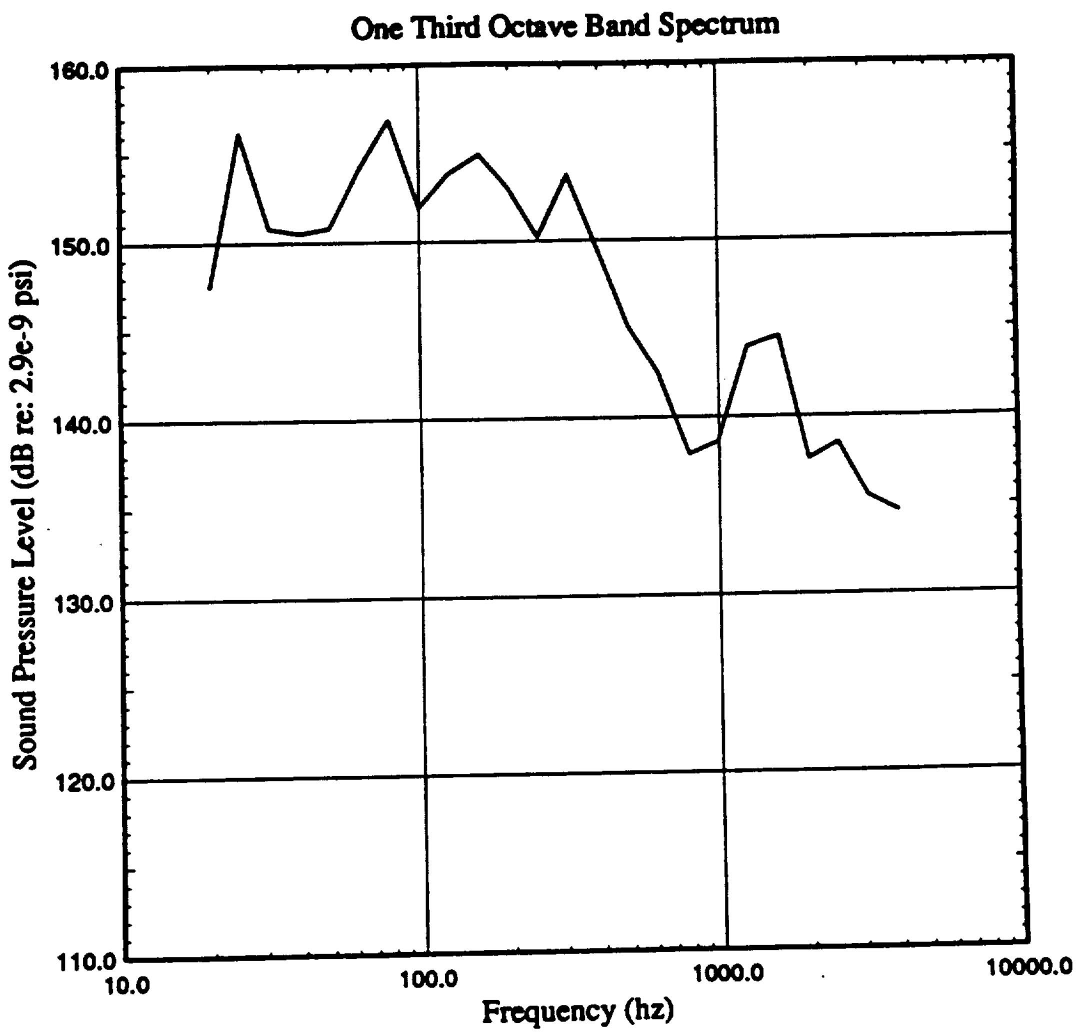



Figure 3.22

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

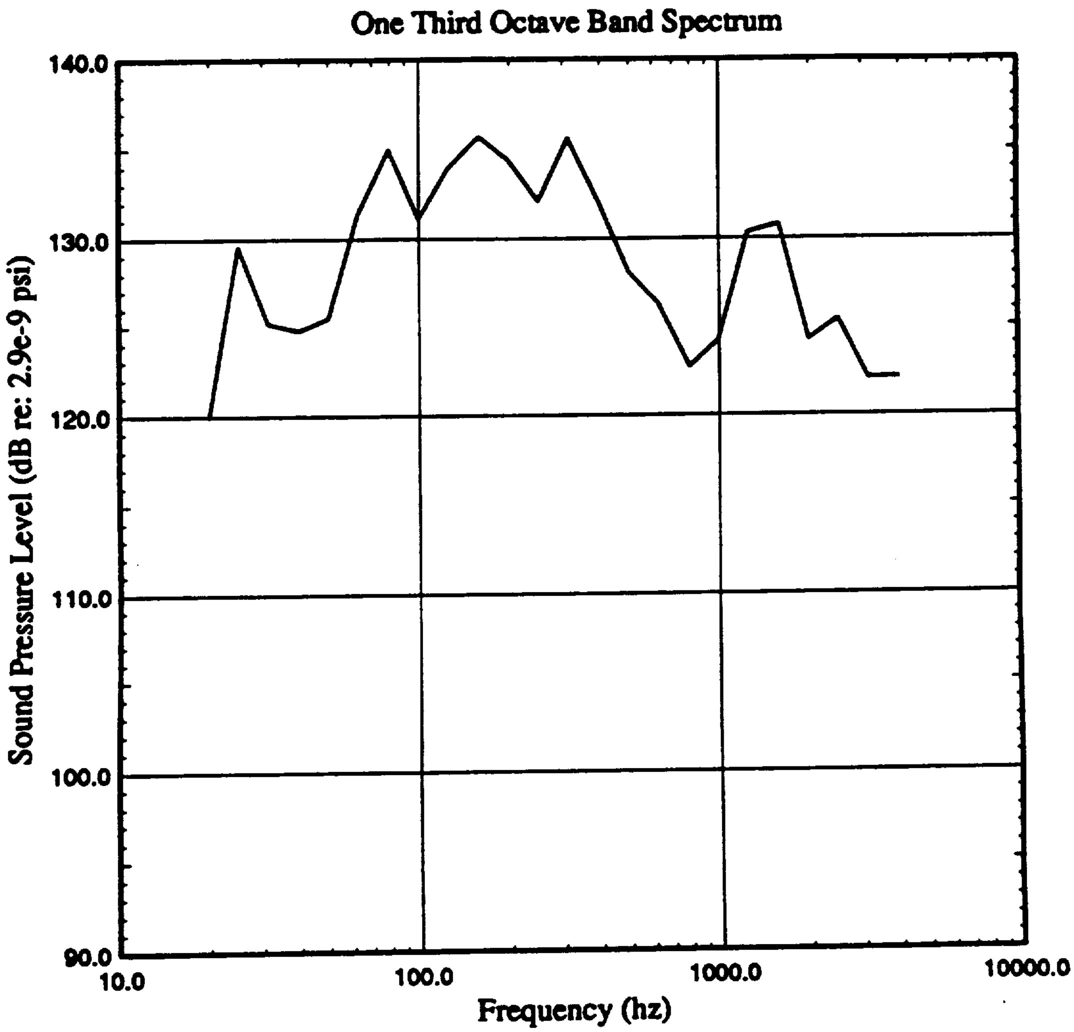



Figure 3.23
NLS 1.5-Stage, Aerodynamic Internal Acoustic Prediction
Bare and Empty Payload Fairing
ZONE 2: PLF-Aft PLF/Adapter Junction OASPL = 144.5 dB

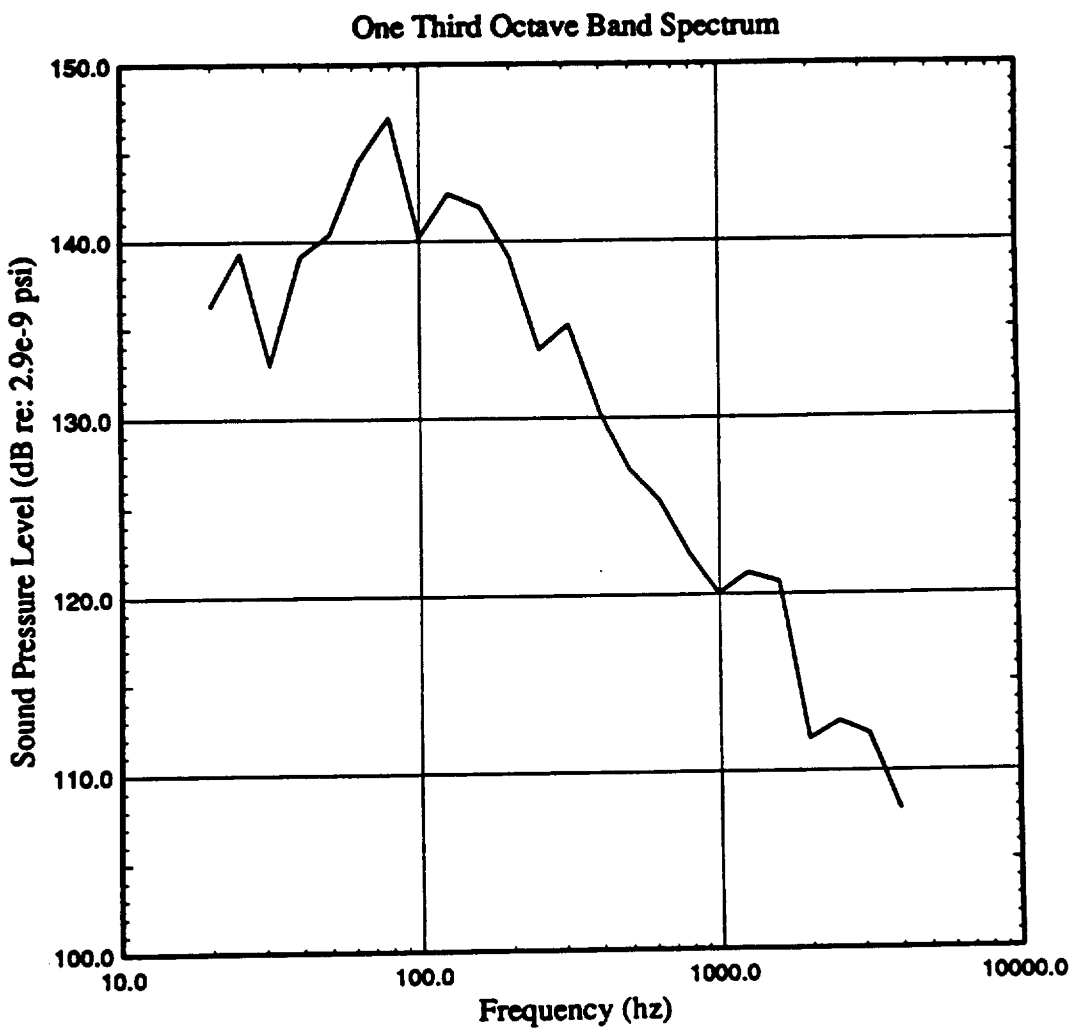



Figure 3.24

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

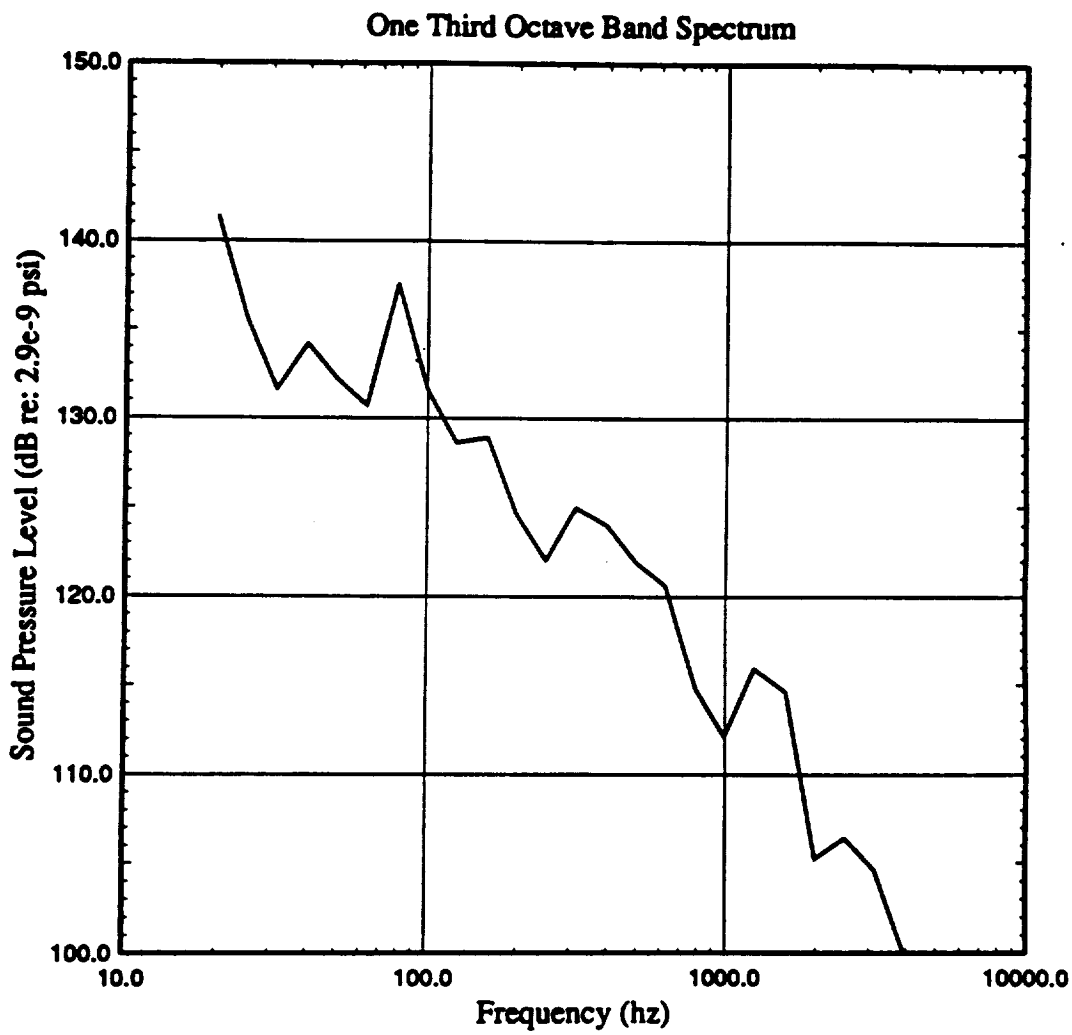



Figure 3.25

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

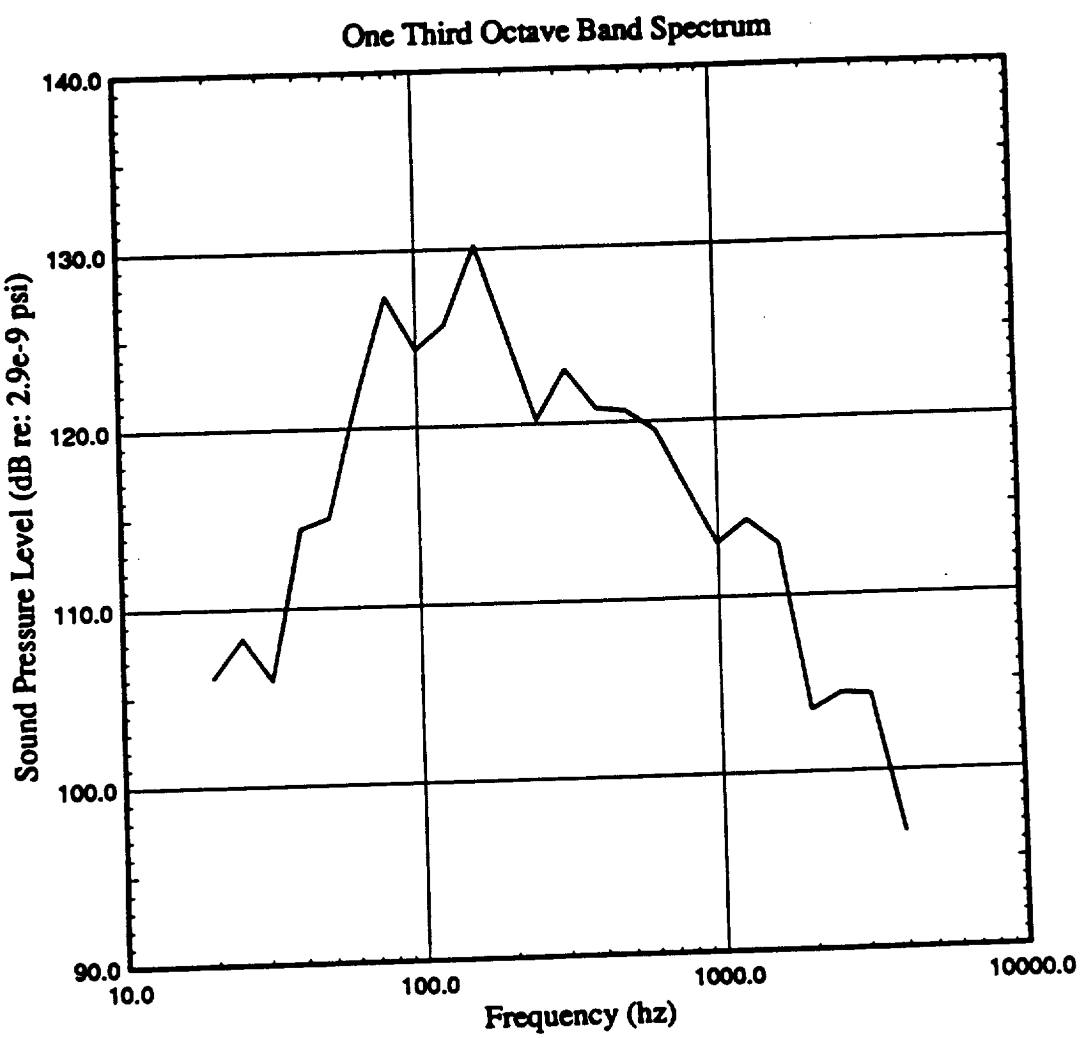



Figure 3.26

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

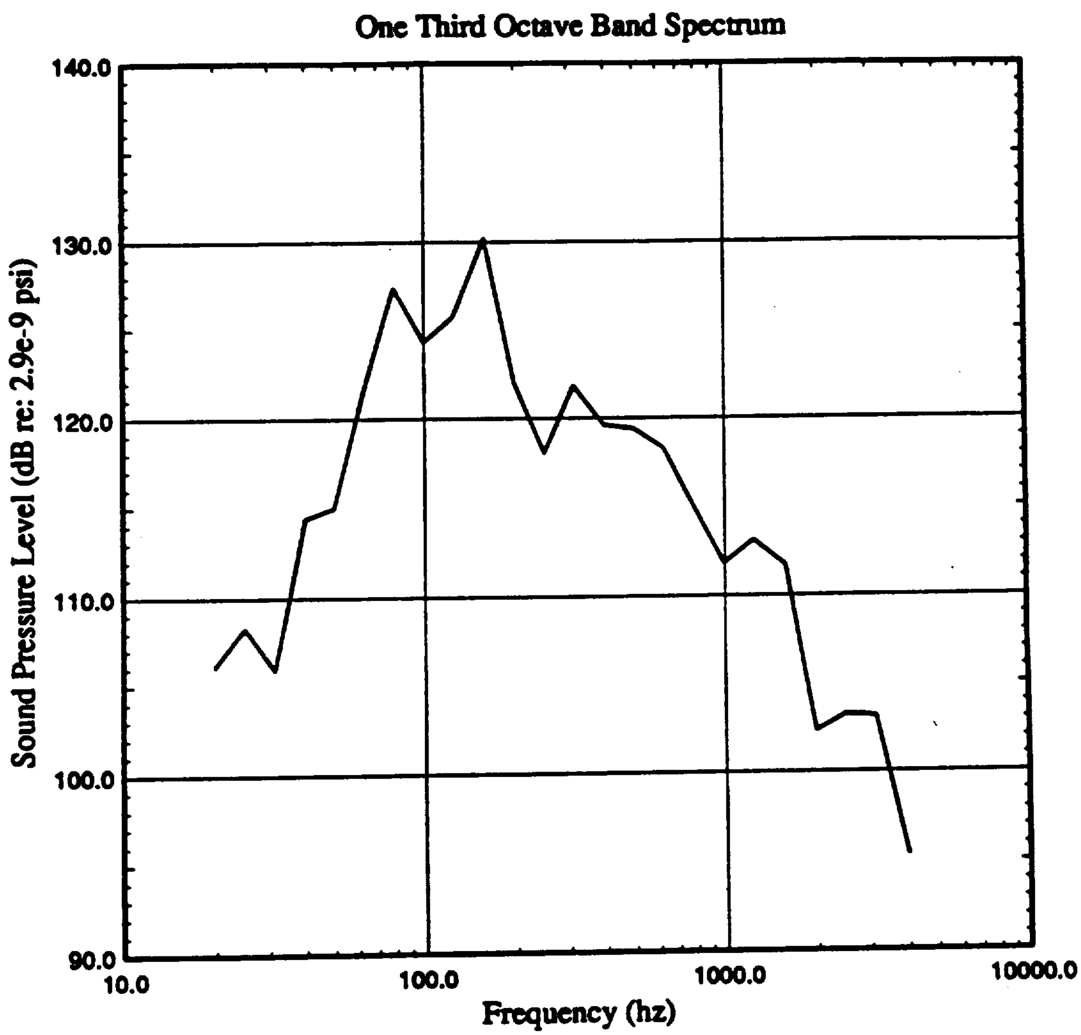



**Figure 3.27**

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

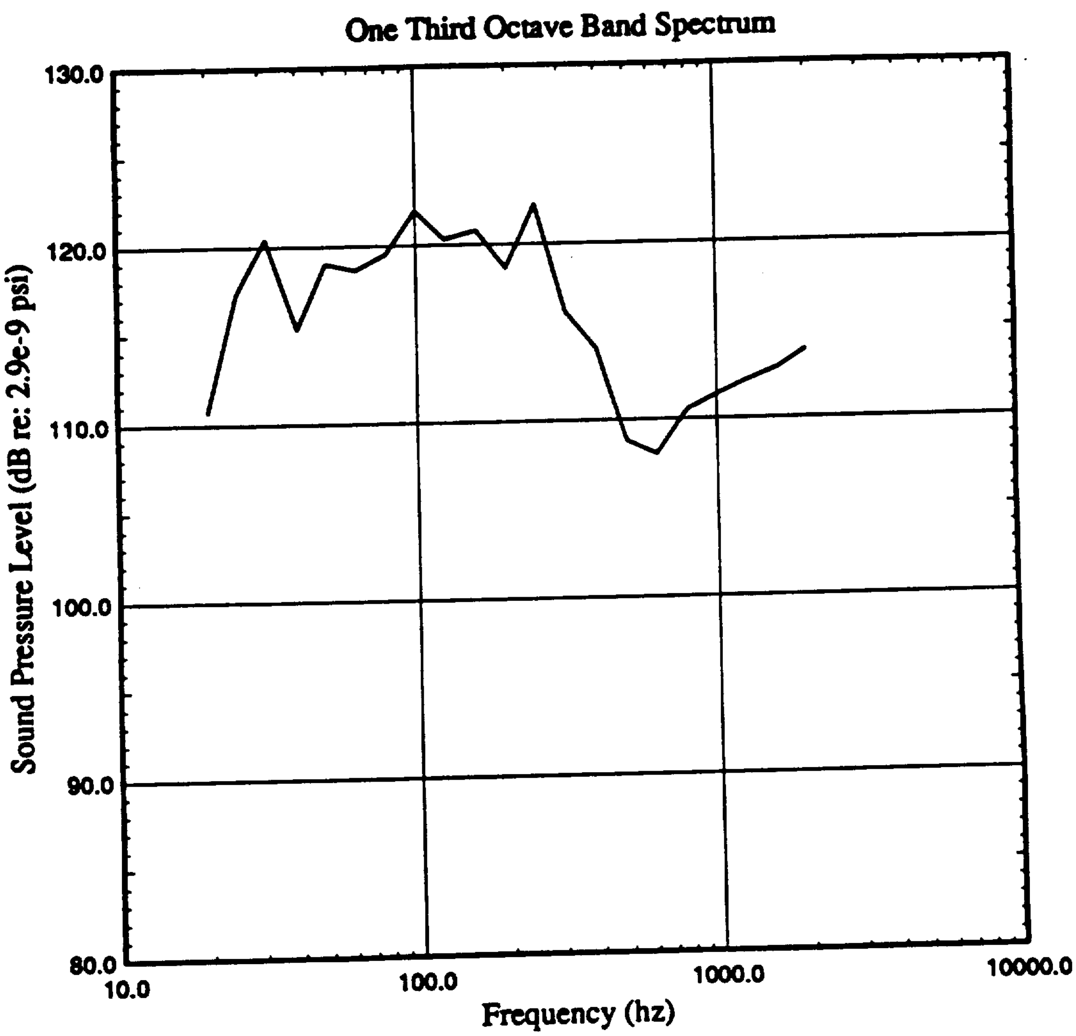



Figure 3.28

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

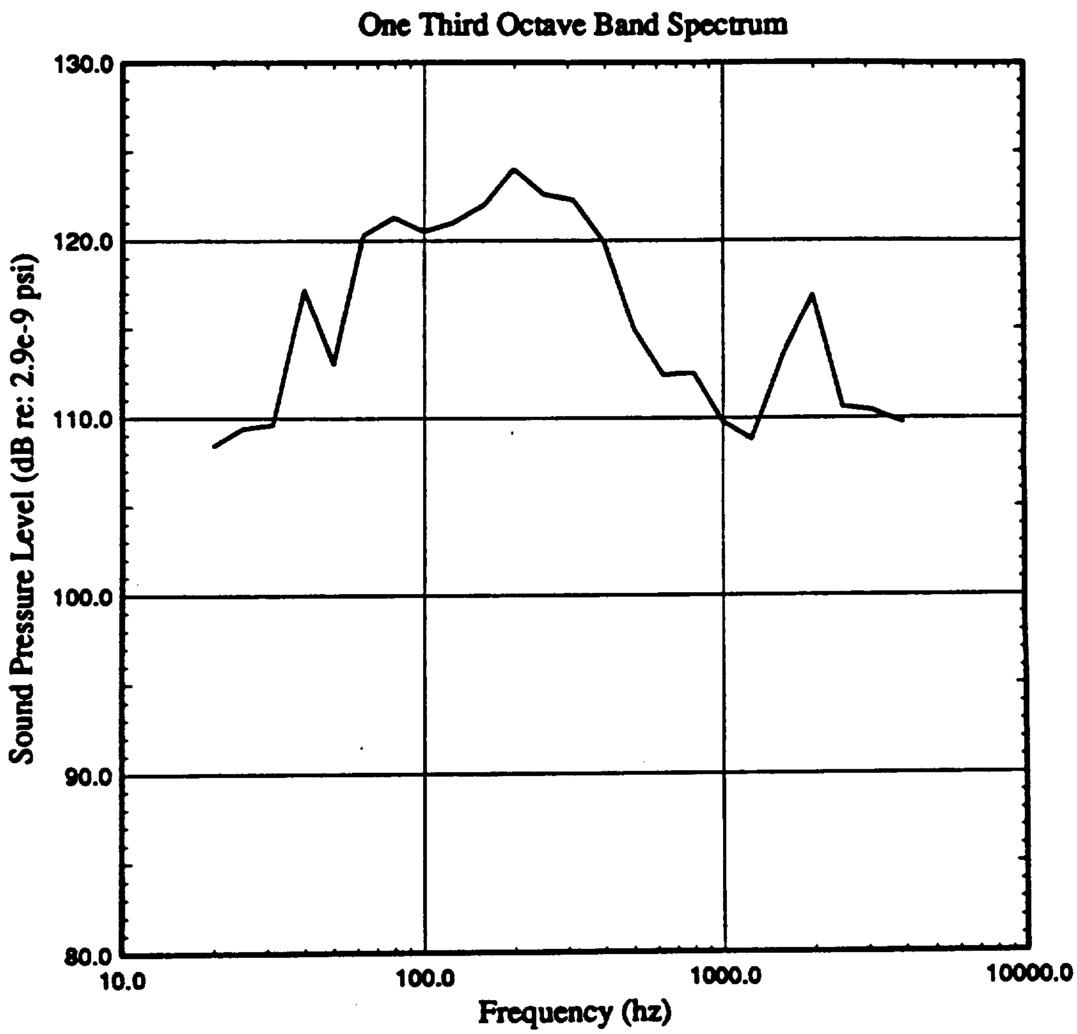



Figure 3.29

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

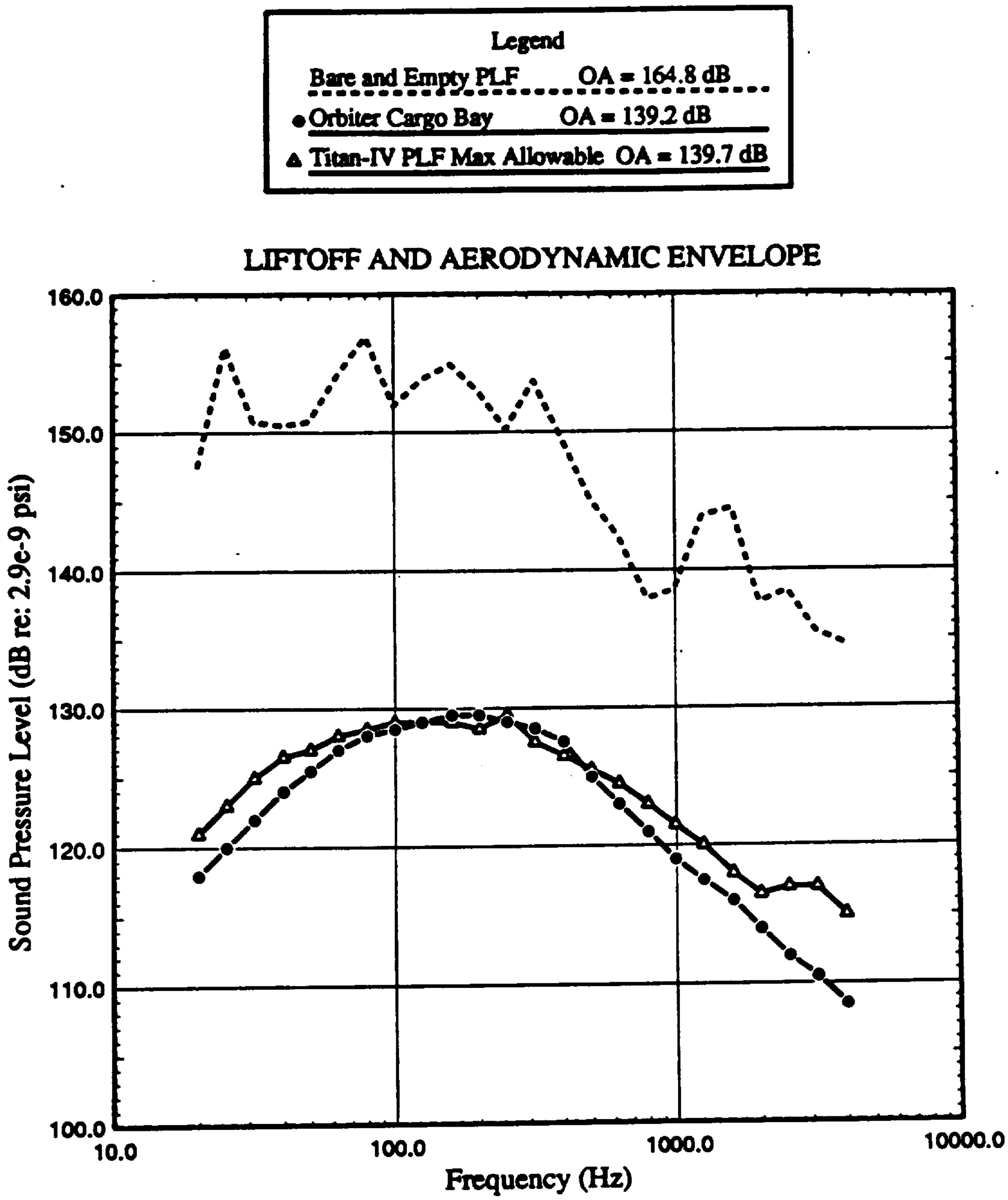



Figure 3.30

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

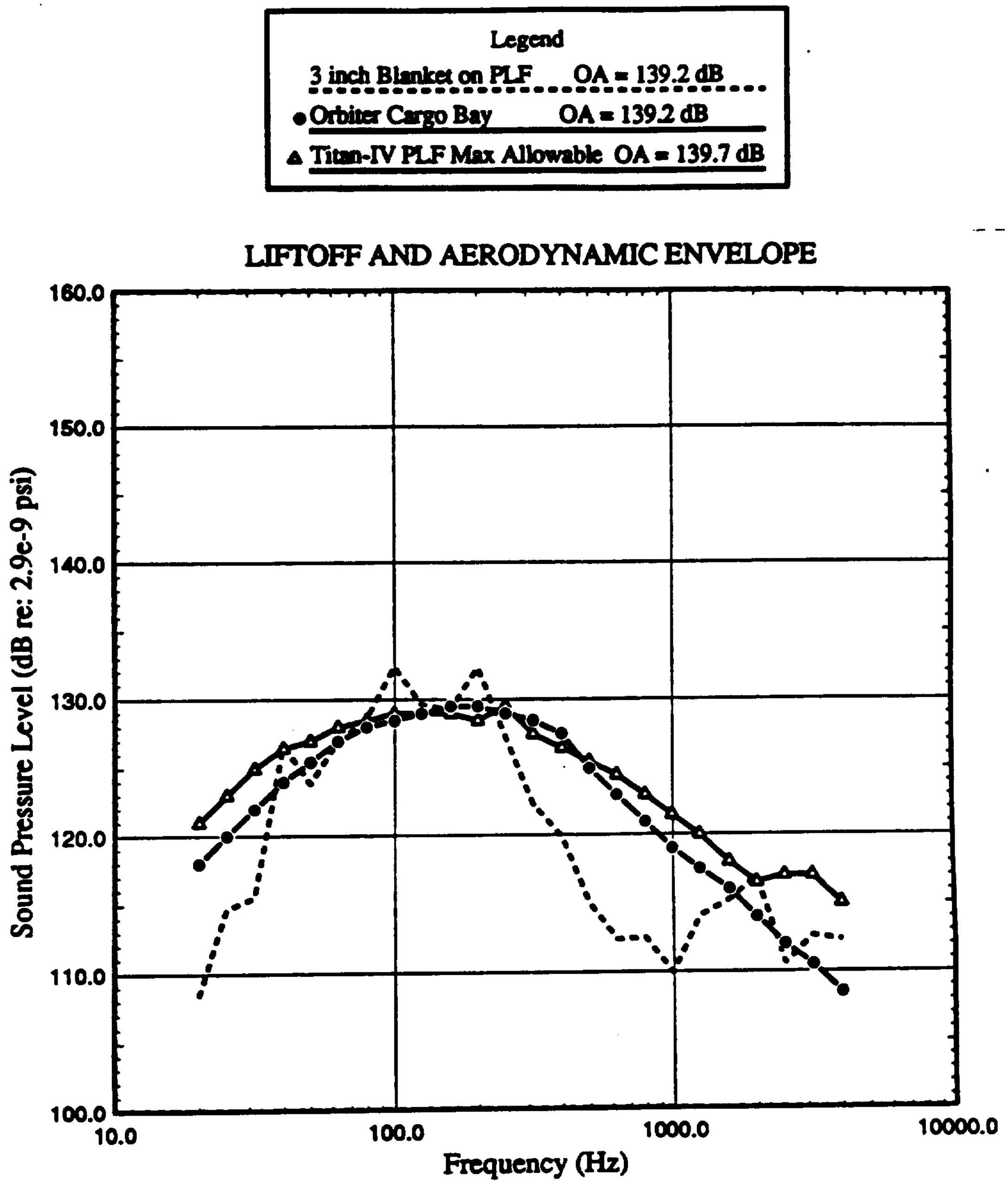



Figure 3.31

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

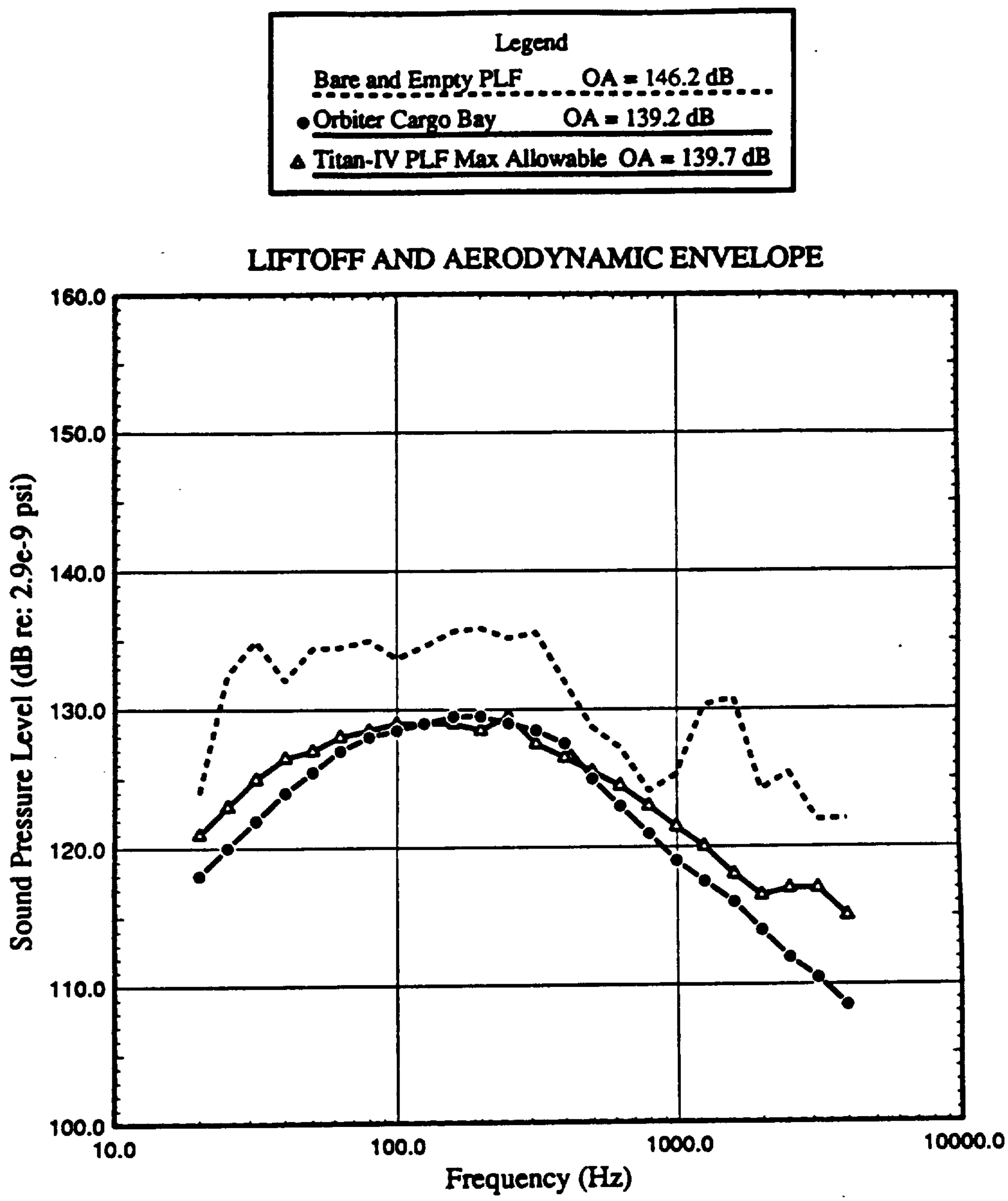



Figure 3.32

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

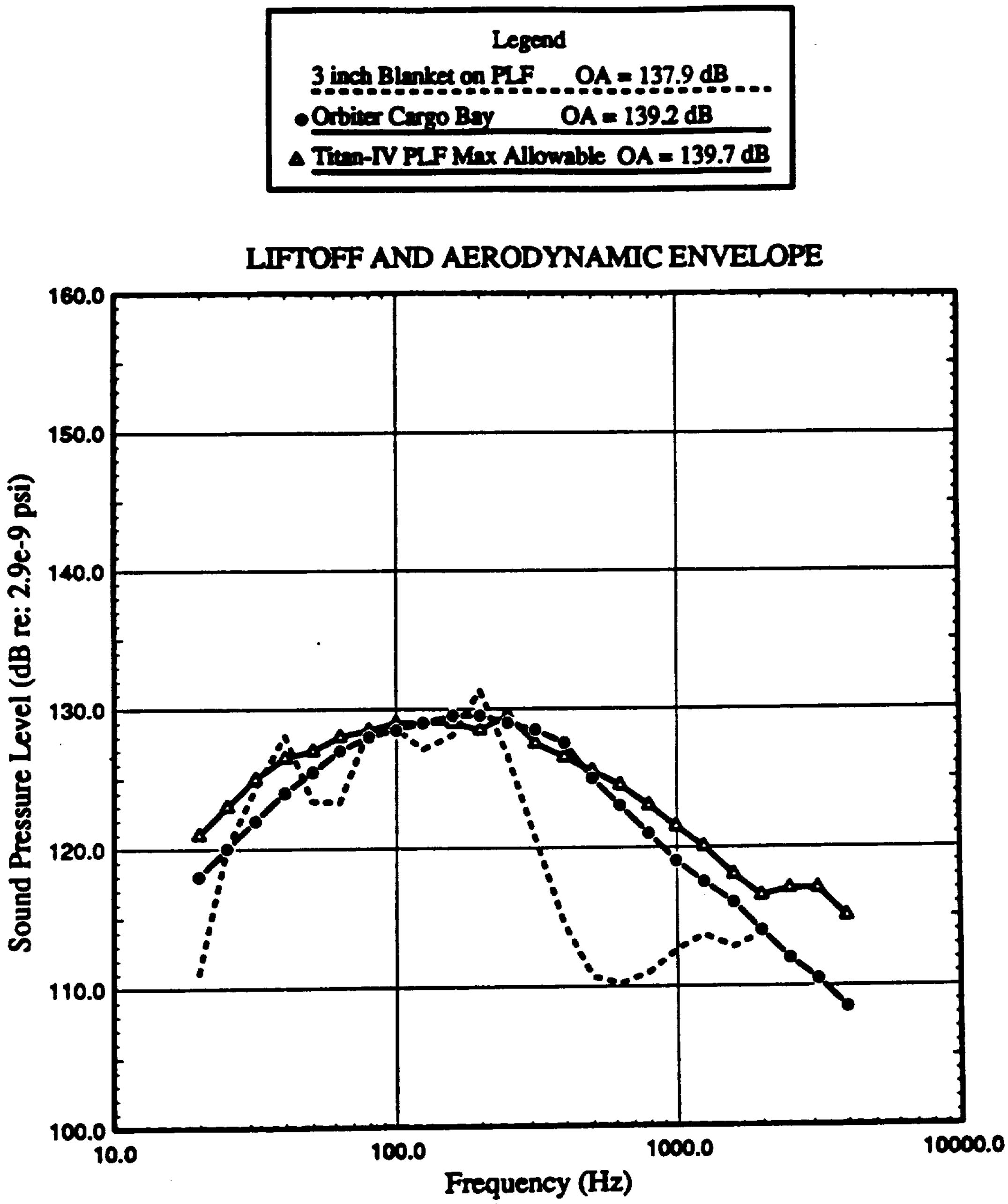



Figure 3.33

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 exeedance 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 supression 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.

7.0 REFERENCES

1. N. S. Dougherty, "6.4 Percent Scale Model SSV Liftoff Acoustic Verification Testing For Western Test Range: Test Program at MSFC," Rockwell International Report No. STS 84-0014, March 1984.

2. "Payload Bay Acoustic and Vibration Data from STS-5 Flight," DATE Report 006, NASA GSFC, Greenbelt, Maryland, May 1983.

3. A. C. Cho, N. S. Dougherty and S. H. Guest, "Scale Model Acoustic Test of SSV for VAFB," Proc. Shuttle Payload Dynamic Environments Workshop, JPL, Jan 1984.

4. L. C. Sutherland, ed., "Sonic and Vibration Environments for Ground Facilities -- A Design Manual," Wyle Labs Report WR 68-2, 1968.

5. E. Yoshida, "Titan 34D Fairing Acoustic Test Report," McDonnell Douglas Report No. MDC G8006, July 1979.

6. S. Barrett, R. B. Lowe and R. L. Foss, "Final Test Report: Acoustic Test on Ariane 4 Payload Fairing in Toulouse, France," Martin Marietta Interoffice Memo 5486/CB-88-516 (Proprietary), November 1988.

7. W. P. Rader, "Acoustic Characteristics of a Composite Payload Fairing," Paper #3-2, Proc. Spacecraft Dynamic Environments TIM, JPL, March 1989.

8. L. F. Bradford and K. E. Elliott, "Titan IV 7.9 Percent Scale Model Wind Tunnel Test -- Acoustic Test Report," Martin Marietta Report MCR-88-2754, May 1989.

9. Informal data communication, D. Reed (NASA/MSFC, ED-33) to R. Foss (MMAG/SLS), November 1991.

# 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.


1. R. W. Mustain, "Dynamic Environments of the S-IV and S-IVB Saturn Vehicles," Shock & Vibration Bulletin No. 33 Part 2, Feb 1964.

2. C. M. Ailman, "Wind Tunnel Investigations of the Fluctuating Pressures at the Surface of 2.75% Saturn Models," in Acoustic Fatigue in Aerospace Structures (W. J. Trapp and D. M. Forney, editors), Syracuse University Press, Binghampton, N.Y., 1965.

3. W. V. Morgan, et al, "The Use of Acoustic Scale Models for Investigating Near Field Noise of Jet and Rocket Engines," WADD Tech Rept 61, April 1961.

4. D. A. Bias and P. A. Franken, "Notes on Scaling Jet and Exhaust Noise," Jour. Acoust. Soc. Am., Vol 33, pp 1171-1173, 1961.

5. P. A. Franken and F. M. Wiener, "Estimation of Noise Levels at the Surface of a Rocket Powered Vehicle," Shock & Vibration Bulletin No. 31 Part3, April 1963.

6. D. A. Bias, "A Review of Flight and Wind Tunnel Measurements of Boundary Layer Pressure Fluctuations and Induced Structural Response," Bolt, Beranek & Newman (BBN) Report No. 1269; also published as NASA CR-626, 1966.

7. W. H. Mayes, D. A. Hilton and C. A. Hardesty, "In-Flight Noise Measurements for Three Project Mercury Vehicles," NASA TN D-977, January 1962.

8. D. A. Hilton, "In-Flight Aerodynamic Noise Measurements on a Scout Launch Vehicle," NASA TN D-1818, 1963.

9. G. W. Jones and J. T. Foughner, "Investigation of Buffet Pressures on Models of Large Manned Launch Vehicle Configurations," NASA TN D-1633, 1963.

10. M. V. Lowson, "The Fluctuating Pressures Due to Shock Interactions with Turbulence and Sound," Wyle Labs Report WR-66-35, June 1966.

11. A. L. Kistler, "Surface Pressure Fluctuations Produced by Attached and Separated Supersonic Boundary Layer," AGARD Report 458, 1963.

12. P. A. Franken, "Sound-Induced Vibrations of Cylindrical Vehicles," Jour. Acoust. Soc Am., Vol 34, pp 453-454, 1962.

13. R. H. Lyon, "Random Noise and Vibration in Space Vehicles," Shock & Vibration Monograph SVM-1, Shock & Vibration Information Center, US Dept of Defense, 1967.

14. L. F. Bradford and K. Elliott, "Titan IV 7.9% Scale Model Wind Tunnel Acoustic Test Report," Martin Marietta Report MCR-88-2754, May 1989.

15. R. E. May, "Titan/CELV Wind Tunnel Test Report," Martin Marietta Report MCR-86-2516, Suppt 1, May 1986.

16. W. P. Rader, "Comparison of Commercial Titan CT-03 and Titan IV Flight Acoustic Data," Martin Marietta Interoffice Memo 5486/CB-90-535, November 1990.

17. C. S. Tanner, "Development of Titan 34D and Titan IV Acoustic Spectra," Proc. Spacecraft Dynamic Environments TIM, JPL, September 1988.

18. C. S. Tanner, "Universal Acoustic Design Environment for Expendable Launch Vehicles," Aerospace Corporation Interoffice Memo 91.5451.59-11, March 1991.

19. R. Ashbrook, "Titan IV Vehicle K-1 Acoustic and Vibration Test Results," Proc. Spacecraft Dynamic Environments TIM, JPL, September 1989.

20. W. P. Rader, "Titan II Acoustic Evaluation," Martin Marietta Report MCR-89-867 (Proprietary), October 1989.

21. S. Barrett, R. B. Lowe and R. L. Foss, "Final Test Report: Acoustic Test on Ariane 4 Payload Fairing in Toulouse, France," Martin Marietta Interoffice Memo 5486/CB-88-516 (Proprietary), November 1988.

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 (psf) | 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 |

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

| 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 (psf) | 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 |
| 10 | 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 (psf) | 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

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

**Derived Parameters** (Effective Nozzle Diameter, Effective Exit Velocity, Areal Weights)