Minotaur I User's Guide

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NORTHROP GRUMMAN

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PREFACE

This Minotaur I User's Guide is intended to familiarize potential space launch vehicle users with the Minotaur I launch system, its capabilities and its associated services. All data provided herein is for reference purposes only and should not be used for mission specific analyses. Detailed analyses will be performed based on the requirements and characteristics of each specific mission. The launch services described herein are available for US Government sponsored missions via the United States Air Force (USAF) Space and Missile Systems Center (SMC), Advanced Systems and Development Directorate (SMC/AD), Rocket Systems Launch Program (SMC/ADSL).

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GLOSSARY

6DOF	Six Degrees of Freedom
A/D	Arm/Disarm
AAC	Alaska Aerospace Corporation
ACAT-1	Acquisition Category 1
ACS	Attitude Control System
AFRL	Air Force Research Laboratory
AODS	All-Ordnance Destruct System
BCM	Booster Control Module
BER	Bit Error Rate
C/CAM	Collision/ Contamination Avoidance Maneuver
C/D	Command/Destruct
CBOD	Clamp Band Opening Device
CCAFS	Cape Canaveral Air Force Station
CDR	Critical Design Review
CG	Center of Gravity
CLA	Coupled Loads Analysis
CLF	Commercial Launch Facility
CVCM	Collected Volatile Condensable Mass
DIACAP	DoD Information Assurance Certification and Accreditation Process
DoD	Department of Defense
DPAF	Dual Payload Adapter Fitting
ECU	Electronic Control Unit
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
ER	Eastern Range
FAA	Federal Aviation Administration
FRR	Flight Readiness Review
FTLU	Flight Termination Logic Unit
FTS	Flight Termination System
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GN_2	gaseous nitrogen
GPB	GPS Positioning Beacon
GPS	Global Positioning System
GTO	Geosynchronous Transfer Orbit
HAPS	Hydrazine Auxiliary Propulsion System
HVAC	Heating, Ventilation, and Air Conditioning
I&T	Integration and Test
I/O	Input/Output
ICD	Interface Control Document
INS	Inertial Navigation System
IRRT	Independent Readiness Review Team
IV&V	Independent Verification and Validation
IVT	Interface Verification Test
KLC	Kodiak Launch Complex
KSC	Kennedy Space Center
LCR	Launch Control Room
LEO	Low Earth Orbit
LEV	Launch Equipment Vault
LITVC	Liquid Injection Thrust Vector Control
LOCC	Launch Operations Control Center
LRR	Launch Readiness Review
LSA	Lower Stack Assembly
LSE	Launch Support Equipment
LV	Launch Vehicle
LVD	Launch Vehicles Division
MA	Mission Assurance
MACH	Modular Avionics Control Hardware
MARS	Mid-Atlantic Regional Spaceport
MDR	Mission Design Review
MDR	Mission Dress Rehearsal
MGSE	Mechanical Ground Support Equipment
MICD	Mechanical Interface Control Drawing
MLB	Motorized Lightband
MM	Minuteman
MMODS	Modular Mechanical Ordnance Destruct System
MPA	Multiple Payload Adaptor
MPE	Maximum Predicted Environment
MPF	Minotaur Processing Facility
MRD	Mission Requirements Document
MRR	Mission Readiness Review

GLOSSARY (CONTINUED)

MST	Mission Simulation Test
NASA	National Aeronautics and Space Administration
NCU	Nozzle Control Unit
NGIS	Northrop Grumman Innovation Systems
NRE	Non-Recurring Engineering
NTO	Nitrogen Tetroxide
ODM	Ordnance Driver Module
OR	Operations Requirements
Orbital ATK	Orbital ATK, Inc.
OSP-3	Orbital Suborbital Program 3
PAF	Payload Attach Fitting
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PEM	Program Engineering Manager
PPF	Payload Processing Facility
P-POD	Poly-Pico Orbital Deployer
PRD	Program Requirements Document
RAAN	Right Ascension of Ascending Node
RCS	Roll Control System
RF	Radio Frequency
RWG	Range Working Group
S/A	Safe and Arm
SCAPE	Self-Contained Atmospheric Protective Ensemble
SMC/AD	Space and Missile Systems Center, Advanced Systems and Development Directorate
SMC/ADSL	Space and Missile Systems Center, Advanced Systems and Development Directorate, Rocket Systems Launch Program
SEB	Support Equipment Building
SLC-8	Space Launch Complex 8
SLV	Space Launch Vehicle
SMC	Space and Missile Systems Center
SRSS	Softride for Small Satellites
SSI	Spaceport Systems International
START	Strategic Arms Reduction Treaty
SV	Space Vehicle
TDRSS	Telemetry Data Relay Satellite System
TML	Total Mass Loss
TVC	Thrust Vector Control
UPC	United Paradyne Corporation
USA	Upper Stack Assembly
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
WFF	Wallops Flight Facility
WP	Work Package

1. INTRODUCTION

This User's Guide is intended to familiarize payload mission planners with the capabilities of the Orbital Suborbital Program 3 (OSP-3) Minotaur I Space Launch Vehicle (SLV) launch service. This document provides an overview of the Minotaur I system design and a description of the services provided to our customers. Minotaur I offers a variety of enhanced options to allow for maximum flexibility in satisfying the objectives of single or multiple payloads.

The user's handbook is not intended as a design document but rather it is to be used to select a launch vehicle that meets the requirements of the payload. This document describes typical environments seen on previous missions. Each spacecraft is unique and will require detailed analysis early in the program.

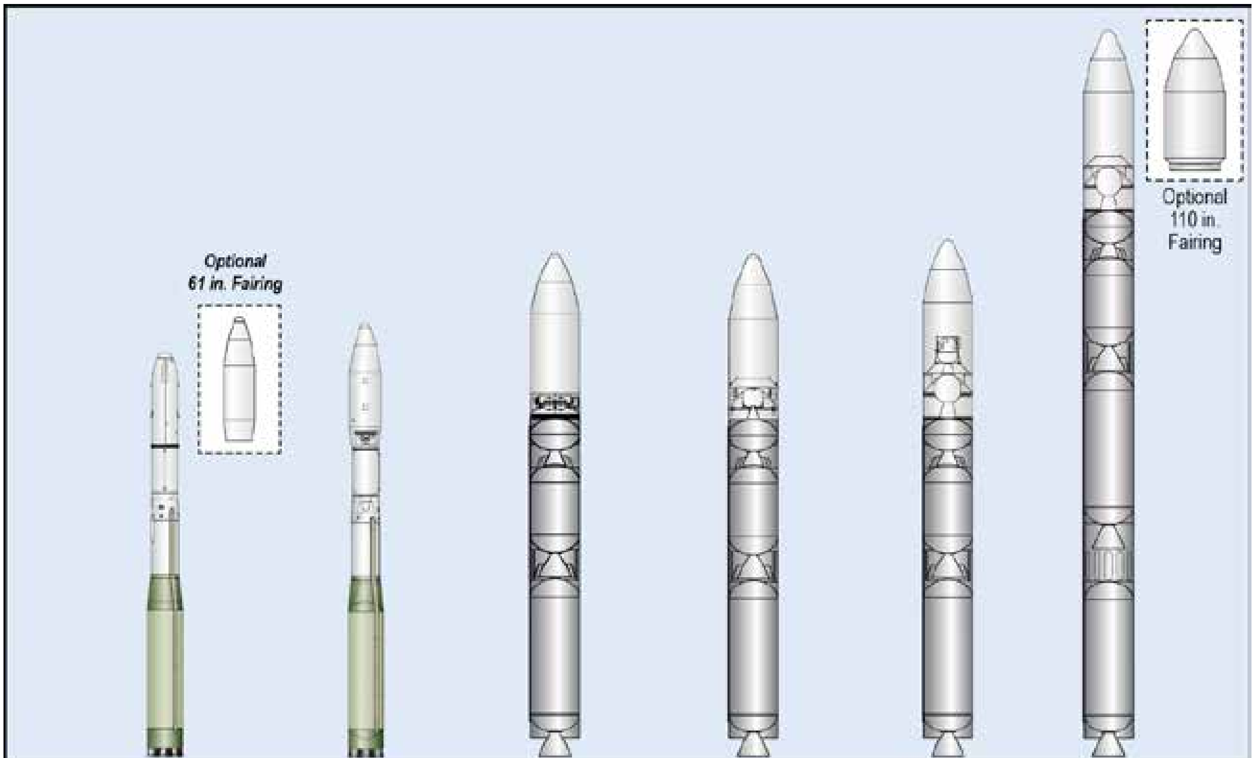
The primary mission of Minotaur I is to provide low cost, high reliability launch services to government-sponsored payloads. Minotaur I accomplishes this by using flight proven components with significant flight heritage. The philosophy of placing mission success as the highest priority is reflected in the success and accuracy of all Minotaur missions to date.

The Minotaur I launch vehicle system is composed of a flight vehicle and ground support equipment. Each element of the Minotaur I system has been developed to simplify the mission design and payload integration process and to provide safe, reliable space launch services. This User's Guide describes the basic elements of the Minotaur I system as well as optional services that are available. In addition, this document provides general vehicle performance, defines payload accommodations and environments, and outlines the Minotaur I mission integration process.

The Minotaur I system can operate from a wide range of launch facilities and geographic locations. The system is compatible with, and will typically operate from, commercial spaceport facilities and existing U.S. Government ranges at Vandenberg Air Force Base (VAFB), Cape Canaveral Air Force Station (CCAFS), Wallops Flight Facility (WFF), and Kodiak Launch Complex (KLC). This User's Guide describes Minotaur I-unique integration and test approaches (including the typical operational timeline for payload integration with the Minotaur I vehicle) and the existing ground support equipment that is used to conduct Minotaur I operations.

1.1. Minotaur Family Performance and Capability

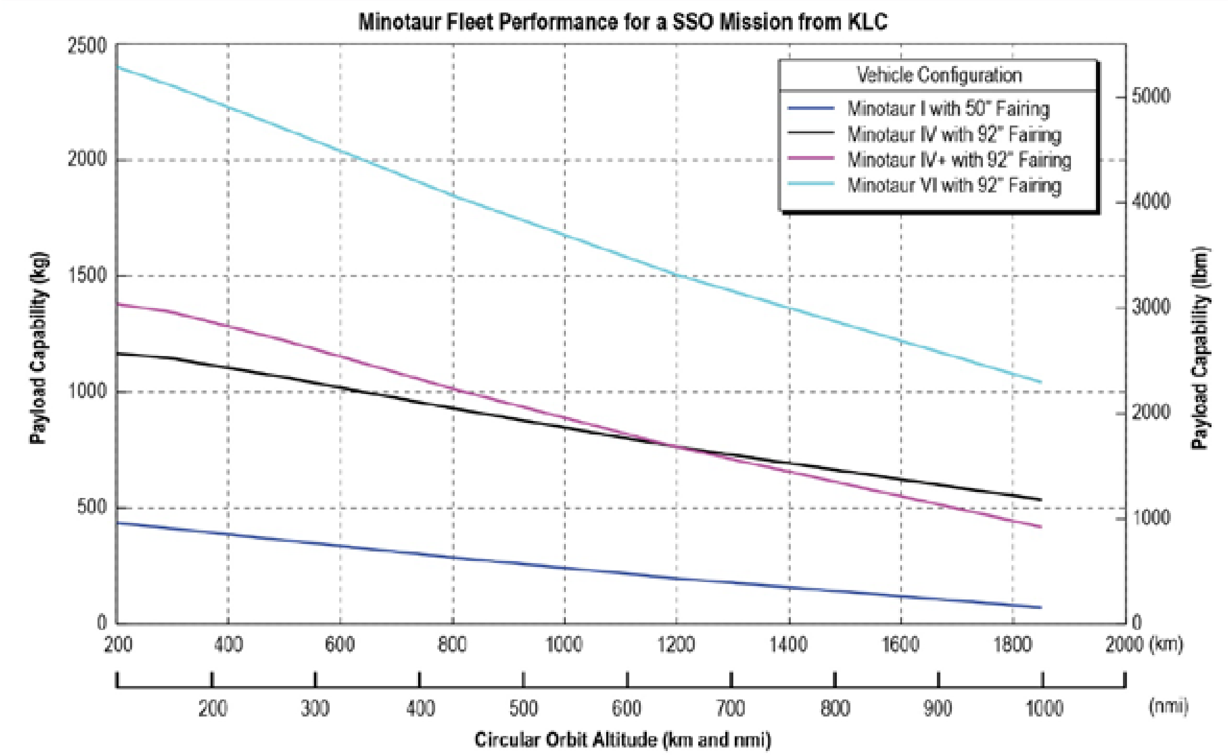
Figure 1.1-1 shows the Minotaur family of launch vehicles, which is capable of launching a wide range of payload sizes and missions. Representative space launch performance across the Minotaur fleet is shown in Figure 1.1-2 to illustrate the relative capability of each configuration. In addition to space launch capabilities, the Minotaur I Lite and Minotaur IV Lite configurations are available to meet suborbital payload needs for payloads weighing up to 3000 kg. This User's Guide covers the Minuteman-based Minotaur I. Please refer to the Minotaur IV – V – VI User's Guide for information on the Peacekeeper-based Minotaur vehicles.



	Minotaur I	Minotaur I Lite	Minotaur IV Lite	Minotaur IV	Minotaur V	Minotaur VI
S1	M55A1 (GFE)	M55A1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)
S2	SR 19 (GFE)	SR 19 (GFE)	SR-119 S2 (GFE)	SR-119 S2 (GFE)	SR-119 S2 (GFE)	SR-118 S2 (GFE)
S3	Orion 50XL	Orion 50XL	SR-120 S3 (GFE)	SR-120 S3 (GFE)	SR-120 S3 (GFE)	SR-119 S3 (GFE)
S4	Orion 38	(N/A)	Super HAPS	Orion 38 (STAR 48BV Optional)	STAR 48BV	SR-120 S4 (GFE)
S5	HAPS (Optional)	(N/A)	(N/A)	HAPS (Optional)	STAR 37	STAR 48BV
S6	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	STAR 37 (Optional)*
Application	***Spacelift***	***Suborbital/Target***	***Suborbital/Target***	***Spacelift***	***MTO/GTO/Lunar***	***LEO/MTO/GTO/Lunar***
Performance:						
	584 kg to LEO	680 kg Ballistic	3000 kg Ballistic	1591 kg to LEO (1837 kg w/Star 48BV)	650 kg to MTO 532 kg to GTO 342 kg to TLI	3144 kg to LEO 1025 kg to MTO* 866 kg to GTO* 560 kg to TLI*

LEO = 200 km, 28.5°
Ballistic = VAFB to RTS (6,600 km, 20° Reentry Angle)

Figure 1.1-1. The Minotaur Family of Launch Vehicles



Launch Vehicle	Throw Capability to 200 km Circular Orbit at 28.5° Inclination From CCAFS
Minotaur I with 50" Fairing	584 kg (1288 lbm)
Minotaur IV with 92" Fairing	1591 kg (3509 lbm)
Minotaur IV+ with 92" Fairing	1837 kg (4051 lbm)
Minotaur VI with 92" Fairing	3144 kg (6932 lbm)

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Figure 1.1-2. Space Launch Performance for the Minotaur Family Demonstrates a Wide Range of Payload Lift Capability

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2. MINOTAUR I CONFIGURATIONS

2.1. Minotaur I Launch System Overview

The Minotaur I launch vehicle, shown in Figure 2.1-1, was developed by Northrop Grumman Innovation Systems (NGIS) for the United States Air Force (USAF) to provide a cost effective, reliable and flexible means of placing small satellites into orbit. NGIS is the launch vehicle developer and manufacturer under the Orbital Suborbital Program 3 (OSP-3) contract for the U.S. Air Force. An overview of the system and available launch services is provided within this section, with specific elements covered in greater detail in the subsequent sections of this User's Guide.

Figure 2.1-1. Minotaur I Launch Vehicle

Minotaur I has been designed to meet the needs of United States Government-sponsored customers at a lower cost than commercially available alternatives through the use of surplus Minuteman boosters. OSP-3 requirements emphasize system reliability, transportability, and operation from multiple launch sites. Minotaur I draws on the successful heritage of NGIS' space launch vehicles and the Minuteman II system of the USAF to meet these requirements. NGIS has built upon these legacy systems with enhanced avionics components and advanced composite structures to meet the payload-support requirements of the OSP-3 program. Combining these improved subsystems with the long and successful history of the Minuteman II boosters has resulted in a simple, robust, self-contained launch system with a proven success record that is fully operational to support government-sponsored small satellite launches.

The Minotaur I system also includes a complete set of transportable Launch Support Equipment (LSE) designed to allow Minotaur I to be operated as a self-contained satellite delivery system. The Electrical Ground Support Equipment (EGSE) has been developed to be portable and adaptable to varying levels of infrastructure. While the Minotaur I system is capable of self-contained operation at austere launch sites using portable vans, typical operations occur from permanent facilities on established ranges.

The Minotaur I system is designed to be capable of launch from four commercial Spaceports (Alaska, California, Florida, and Mid-Atlantic), as well as from existing U.S. Government facilities at VAFB and CCAFS. A Launch Control Room (LCR) serves as the control center for conducting a Minotaur I launch and includes consoles for NGIS, range safety, and limited customer personnel. Further description of the Launch Support Equipment is provided in Section 2.4.

2.2. Minotaur I Launch Service

The Minotaur I Launch Service is provided through the combined efforts of the USAF and NGIS, along with associate contractors and Commercial Spaceports. The primary customer interface will be with the USAF Space and Missile Systems Center, Advanced Systems and Development Directorate, Rocket Systems Launch Program (SMC/ADSL). NGIS is the launch vehicle provider. This integrated team will be referred to collectively as "OSP" throughout the User's Guide. Where necessary, interfaces that are associated with a particular member of the team will be referred to directly (i.e., NGIS or ADSL).

OSP provides all of the necessary hardware, software and services to integrate, test and launch a payload into its prescribed orbit. In addition, OSP will complete all the required agreements, licenses and documentation to successfully conduct Minotaur I operations. The Minotaur I mission integration process completely identifies, documents, and verifies all spacecraft and mission requirements.

2.3. Minotaur I Launch Vehicle

The Minotaur I vehicle, shown in expanded view in Figure 2.3-1, is a four stage, inertially guided, all solid propellant ground launched vehicle. Conservative design margins, state-of-the-art structural systems, a modular avionics architecture, and simplified integration and test capability, yield a robust, highly reliable launch vehicle design. In addition, Minotaur I payload accommodations and interfaces have been designed to satisfy a wide range of potential payload requirements.

2.3.1. Lower Stack Assembly

The Lower Stack Assembly (LSA), shown in Figure 2.3.1-1, consists of the refurbished Government Furnished Equipment (GFE) Minuteman Stages 1 and 2. Only minor modifications are made to the boosters, including harness interface changes and conversion from All-Ordnance Destruct System (AODS) to Modular Mechanical Ordnance Destruct System (MMODS) Flight Termination System (FTS).

The first stage consists of the Minuteman II M55A1 solid propellant motor, Nozzle Control Units (NCU), Stage 1 Ignition Safe/Arm, S1/S2 Interstage and Stage 1 MMODS FTS. Four gimbaled nozzles provide three axis control during first stage burn. The second stage consists of a refurbished Minuteman II SR19 motor, Liquid Injection Thrust Vector Control (LITVC) subsystem, S2 ignition safe/arm device, a Roll Control System (RCS), and the Stage 2 MMODS FTS components. Attitude control during second stage burn is provided by the operational LITVC and hot gas roll control.

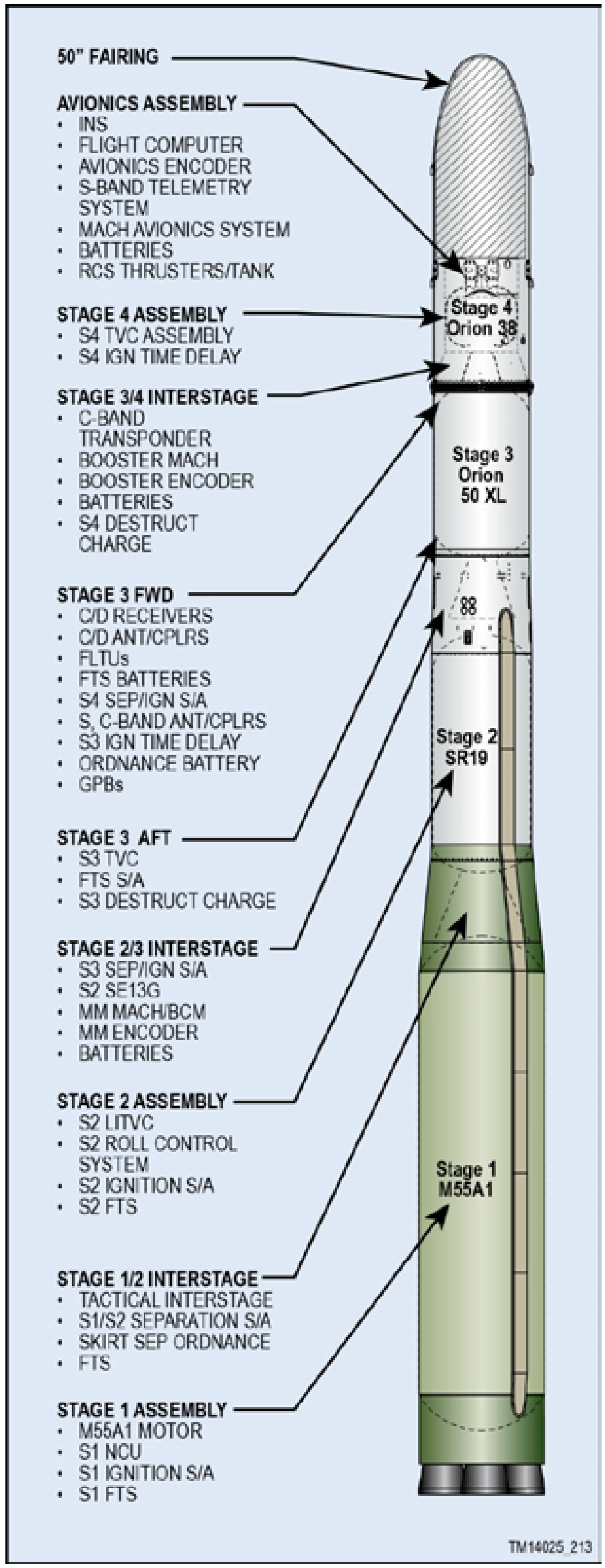

Figure 2.3-1. Minotaur I Launch Vehicle Configuration

2.3.2. Upper Stack Assembly

The Minotaur I Upper Stack is composed of the Stage 3 and 4 motors, their associated interstages, the avionics assembly, and, ultimately, the payload and payload fairing. The Stage 3 and 4 motors are the Orion 50 XL and Orion 38, respectively. These motors were originally developed for NGIS' Pegasus program and are used in a similar manner on the ground-launched Minotaur I vehicle. Common design features, materials and production techniques are applied to both motors to maximize reliability and production efficiency. The motors are fully flight qualified based on their heritage, conservative design, ground static fires and over 60 launches. Processing of the Minotaur I Upper Stack is conducted at the Minotaur Processing Facility (MPF), as shown in Figure 2.3.2-1.

Figure 2.3.1-1. Minotaur I LSA Being Lifted out of Transporter Erector

2.3.2.1. Avionics

The Minotaur I avionics system has heritage and commonality across the Minotaur fleet. The flight computer is a 32-bit multiprocessor architecture. It provides communication with vehicle subsystems, the LSE, and if required, the payload via standard RS-422 serial links and discrete I/O. The avionics system design incorporates NGIS' innovative, flight proven Modular Avionics Control Hardware (MACH). The MACH consists of standardized, function-specific modules that are combined in stacks of up to 10 modules to meet mission requirements. The functional modules from which the MACH stacks are created include power transfer, ordnance initiation, booster interface, communication, and telemetry processing. These modules provide an array of functional capability and flexibility.

Figure 2.3.2-1. Minotaur I Upper Stack Assembly Processing at Minotaur Processing Facility at VAFB

2.3.2.2. Attitude Control Systems

The Minotaur I Control System provides three-axis attitude control throughout boosted flight and coast phases. Stages 1 and 2 utilize the Minuteman Thrust Vector Control (TVC) systems. The Stage 1 TVC is a four-nozzle hydraulic system, while the Stage 2 system combines liquid injection for pitch and yaw control with hot gas roll control. Stages 3 and 4 utilize the same TVC systems as Minotaur IV. They combine single-nozzle electromechanical TVC for pitch and yaw control with a three-axis cold-gas Attitude Control System (ACS) resident in the avionics section providing roll control.

Attitude control is achieved using a three-axis autopilot. Stages 1 and 2 fly a pre-programmed attitude profile based on trajectory design and optimization. Stage 3 uses a set of pre-programmed orbital parameters to place the vehicle on a trajectory toward the intended insertion apse. The extended coast between Stages 3 and 4 is used to orient the vehicle to the appropriate attitude for Stage 4 ignition based upon a set of pre-programmed orbital parameters and the measured performance of the first three stages. Stage 4 utilizes energy management to place the vehicle into the proper orbit. After the final boost phase, the three-axis cold-gas attitude control system is used to orient the vehicle for spacecraft separation, contamination and collision avoidance and downrange downlink maneuvers. The autopilot design is a modular object oriented software design, so additional payload requirements such as rate control or celestial pointing can be accommodated with minimal additional development.

2.3.2.3. Telemetry Subsystem

The Minotaur I telemetry subsystem provides real-time health and status data of the vehicle avionics system, as well as key information regarding the position, performance and environment of the Minotaur I vehicle. This data is used by both NGIS and the range safety personnel to evaluate system performance. The Minotaur I baseline telemetry subsystem provides a number of dedicated payload discrete (bi-level) and analog telemetry monitors through dedicated channels in the launch vehicle encoder. The baseline telemetry system has a 1.5 Mbps data rate for both payload and Minotaur launch vehicle telemetry. To allow for flexibility in supporting evolving mission requirements, the output data rate can be selected over a wide range from 2.5 kbps to 10 Mbps (contingent on link margin and Bit Error Rate (BER) requirements). The telemetry subsystem nominally utilizes Pulse Code Modulation (PCM) with a RNRZ-L format. Other types of data formats, including NRZ-L, S, M, and Bi-phase may be implemented if required to accommodate launch range limitations. Furthermore, the launch vehicle telemetry system has the capability to take payload telemetry as an input, randomize if required, and downlink that dedicated payload link from launch through separation. That capability is available as a non-standard option.

The Enhanced Telemetry option as described in the Enhancements section 8.5 augments the existing baseline telemetry system by providing a dedicated telemetry link with a baseline data rate of 2 Mbps. This Enhanced Telemetry link is used to provide further insight into the mission environment due to additional payload, LV, or experiment data acquisition requirements. Supplementary instrumentation or signals such as strain gauges, temperature sensors, accelerometers, analog, or digital data can be configured to meet payload mission-specific requirements.

An Over the Horizon Telemetry option can also be added to provide real-time telemetry coverage during ground-based telemetry receiving site blackout periods. The Telemetry Data Relay Satellite System (TDRSS) is used for this capability, and has been successfully demonstrated on past Minotaur missions. Close to the time when telemetry coverage is lost by ground based telemetry receiving sites, the LV switches telemetry output to the TDRSS antenna and points the antenna towards the designated satellite. The TDRSS then relays the telemetry to the ground where it is routed to the Launch Control Room for real-time telemetry updates. Reference Enhancements Section 8.8 for further details on this Over the Horizon Telemetry option.

Minotaur telemetry is subject to the provisions of the Strategic Arms Reduction Treaty (START). START treaty provisions require that certain Minotaur I telemetry be unencrypted and provided to the START treaty office for dissemination to the signatories of the treaty.

2.3.3. Payload Interface

Minotaur provides for a standard non-separating payload interface, with the option of adding an NGIS-provided payload separation system. NGIS will provide all flight hardware and integration services necessary to attach non-separating and separating payloads to the Minotaur launch vehicle. Additional mechanical interface diameters and separation system configurations can readily be provided as an enhanced option as described in Section 5.0. Further detail on payload electrical, mechanical and launch support equipment interfaces are detailed in Section 5.0.

Because of its design flexibility, Minotaur can accommodate and has flown missions with multiple spacecraft. This capability, described in more detail in Section 5.0 of this User's Guide, permits two or more smaller payloads to share the cost of a Minotaur I launch, resulting in a lower launch cost for each as compared to other launch options. Furthermore, NGIS can accommodate small payloads when there is excess payload and/or mass capability.

2.3.4. Payload Fairing

The baseline Minotaur I 50" fairing, shown in Figure 2.3.4-1, is identical to the Pegasus fairing design and has been successfully deployed in over 40 Pegasus and Minotaur I missions. Due to differences in vehicle loads and environments, the Minotaur I implementation allows for a larger payload envelope than Pegasus. The Minotaur I payload fairing consists of two composite shell halves, a nose cap integral to one shell half, and a separation system. Each shell half is composed of a cylinder and ogive sections.

Options for payload access doors and enhanced cleanliness are available. A larger 61" diameter fairing is also available. Further details on both fairings are included in Section 5.1.

Figure 2.3.4-1. Minotaur I 50" Fairing and Handling Fixtures

2.4. Launch Support Equipment

The Minotaur I LSE is designed to be readily adaptable to varying launch site configurations with minimal unique infrastructure required. The EGSE consists of readily transportable consoles that can be housed in various facility configurations depending on the launch site infrastructure. The EGSE is composed of three primary functional elements: Launch Control, Vehicle Interface, and Telemetry Data Reduction. The Launch Control and Telemetry Data Reduction consoles are located in the Launch Control Room (LCR), or mobile launch equipment van depending on available launch site accommodations. The Vehicle Interface consoles are located at the launch pad in a permanent structure, typically called a Launch Equipment Vault (LEV). Fiber optic connections from the Launch Control to the Vehicle Interface consoles are used for efficient, high bandwidth communications, eliminating the need for copper wire between locations. The Vehicle Interface consoles provide the junction from fiber optic cables to the cables that directly interface with the vehicle. Figure 2.4-1 depicts the functional block diagram of the LSE. All Minotaur EGSE is compliant with the Department of Defense Instruction 8510.01, DoD Information Assurance Certification and Accreditation Process (DIACAP). Some launch sites have a separate Support Equipment Building (SEB) that can accommodate additional payload equipment.

The LCR serves as the control center during the launch countdown. The number of personnel that can be accommodated is dependent on the launch site facilities. At a minimum, the LCR will accommodate NGIS personnel controlling the vehicle, two Range Safety representatives (ground and flight safety), and the Air Force Mission Manager. Mission-unique, customer-supplied payload consoles and equipment can be supported in the LCR and payload equipment at the launch pad can be supported in the LEV or SEB, if available, within the constraints of the launch site facilities. Interface to the payload through the Minotaur I payload umbilicals provides the capability for direct monitoring of payload functions. Payload personnel accommodations will be handled on a mission-specific basis.

All of the Mechanical Ground Support Equipment (MGSE) used to support the Minotaur integration, test and launch is currently in use and launch demonstrated. MGSE fully supports all Minotaur configurations and are routinely static load tested to safety factors in compliance with NGIS internal and Range requirements.

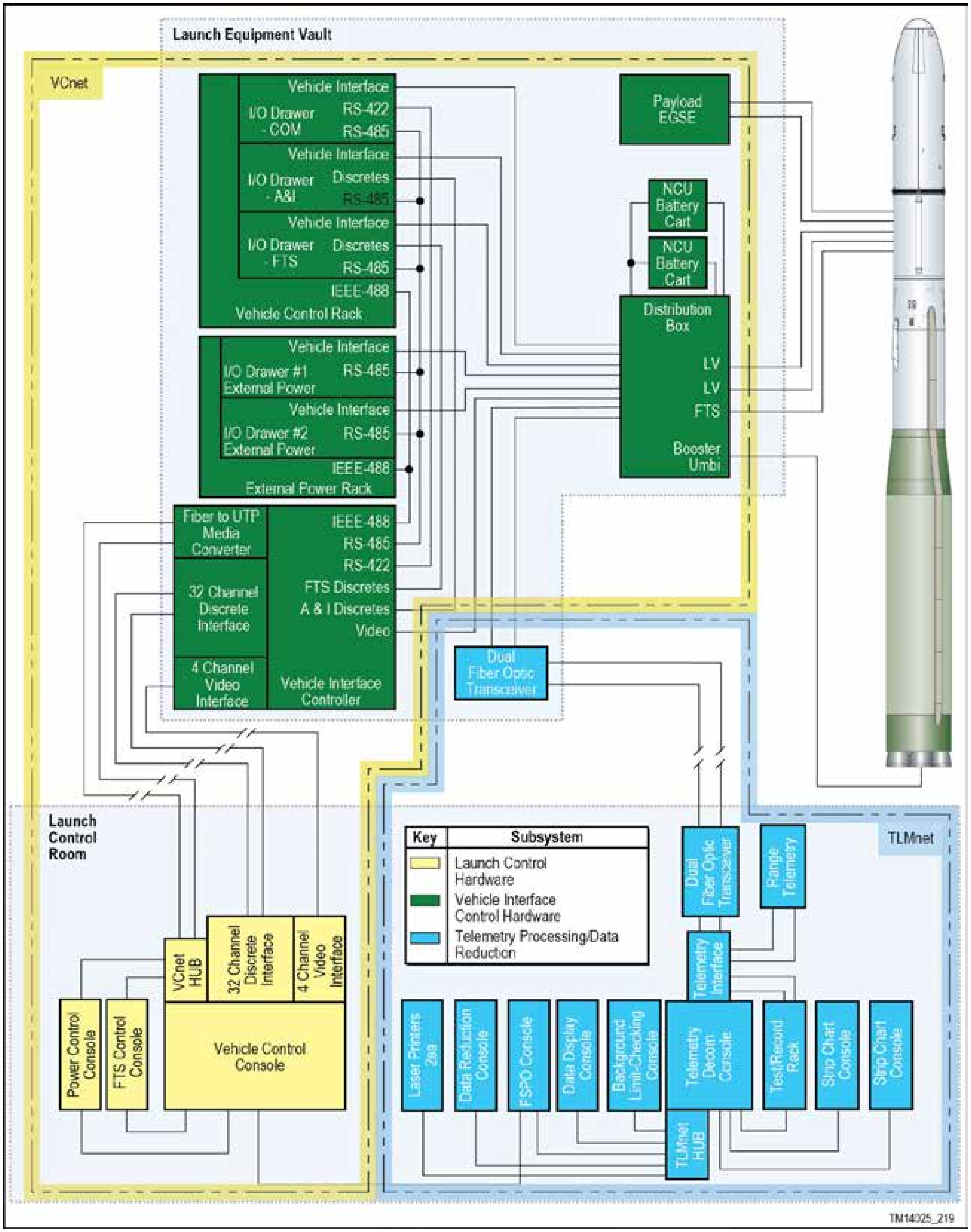

Figure 2.4-1. Minotaur I EGSE Configuration

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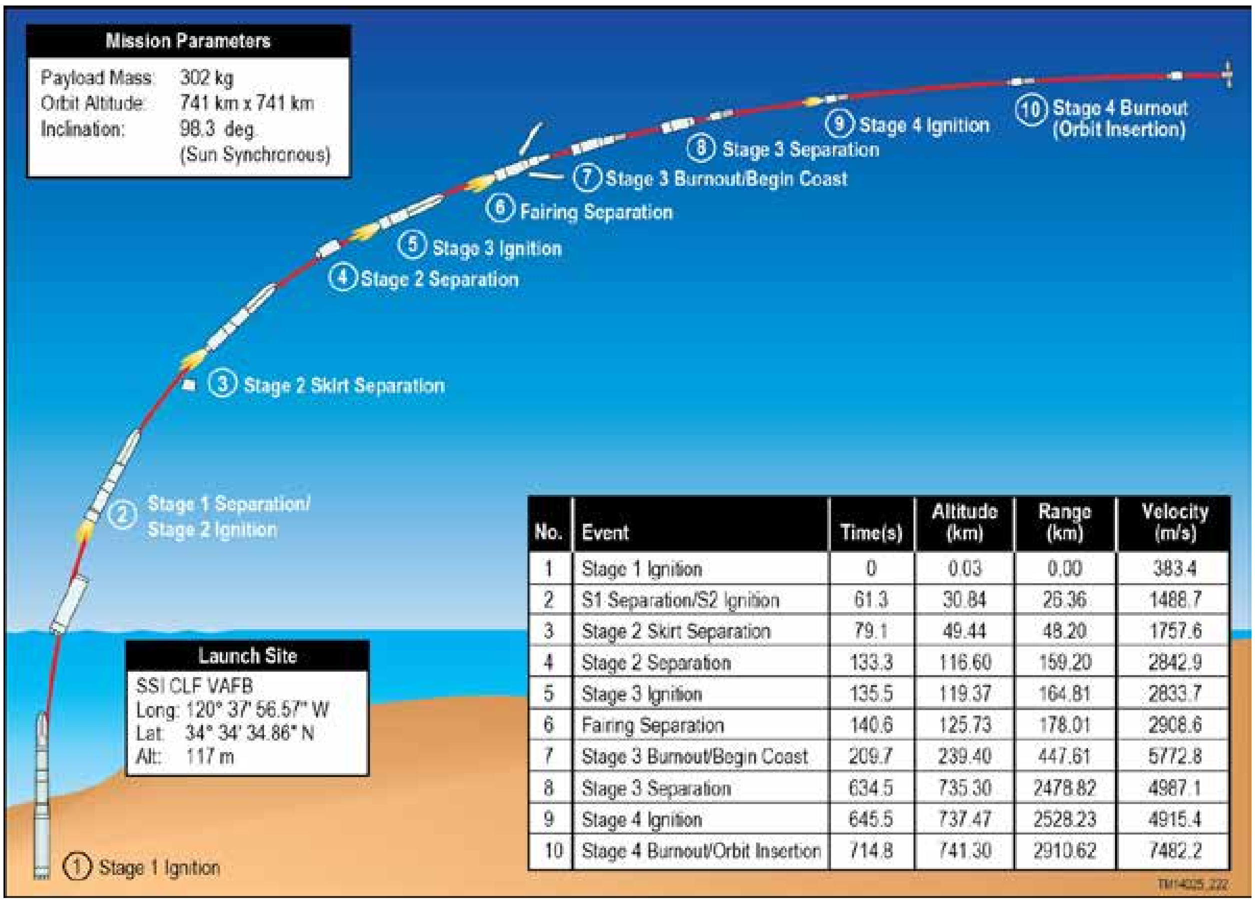
3. GENERAL PERFORMANCE

3.1. Mission Profiles

Minotaur I can attain a range of posigrade and retrograde inclinations through the choice of launch sites made available by the readily adaptable nature of the Minotaur I launch system. A generic mission profile to a sun-synchronous orbit is shown in Figure 3.1-1. All performance parameters presented within this User's Guide are typical for most expected payloads. However, performance may vary depending on unique payload or mission characteristics. Specific requirements for a particular mission must be coordinated with OSP. Once a mission is formally initiated, the requirements will be documented in the Mission Requirements Document (MRD). The MRD is the requirement kick off document that initiates the contractual agreement and flows the payload requirements to NGIS. The MRD establishes the data required to begin formal trajectory analysis as well as Coupled Loads Analyses (CLAs). Further detail will be captured in the Payload-to-Launch Vehicle Interface Control Document (ICD).



No.	Event	Time(s)	Altitude (km)	Range (km)	Velocity (m/s)
1	Stage 1 Ignition	0	0.03	0.00	383.4
2	S1 Separation/S2 Ignition	61.3	30.84	26.36	1488.7
3	Stage 2 Skirt Separation	79.1	49.44	48.20	1757.6
4	Stage 2 Separation	133.3	116.60	159.20	2842.9
5	Stage 3 Ignition	135.5	119.37	164.81	2833.7
6	Fairing Separation	140.6	125.73	178.01	2908.6
7	Stage 3 Burnout/Begin Coast	209.7	239.40	447.61	5772.8
8	Stage 3 Separation	634.5	735.30	2478.82	4987.1
9	Stage 4 Ignition	645.5	737.47	2528.23	4915.4
10	Stage 4 Burnout/Orbit Insertion	714.8	741.30	2910.62	7482.2

Figure 3.1-1. Minotaur I Generic Mission Profile

3.2. Launch Sites

Depending on the specific mission, Minotaur I can operate from East and West Coast launch sites as illustrated in Figure 3.2-1. The corresponding range inclination capabilities are shown in Figure 3.2-2. Specific performance parameters are presented in Section 3.3. The baseline launch site for Minotaur I is VAFB.

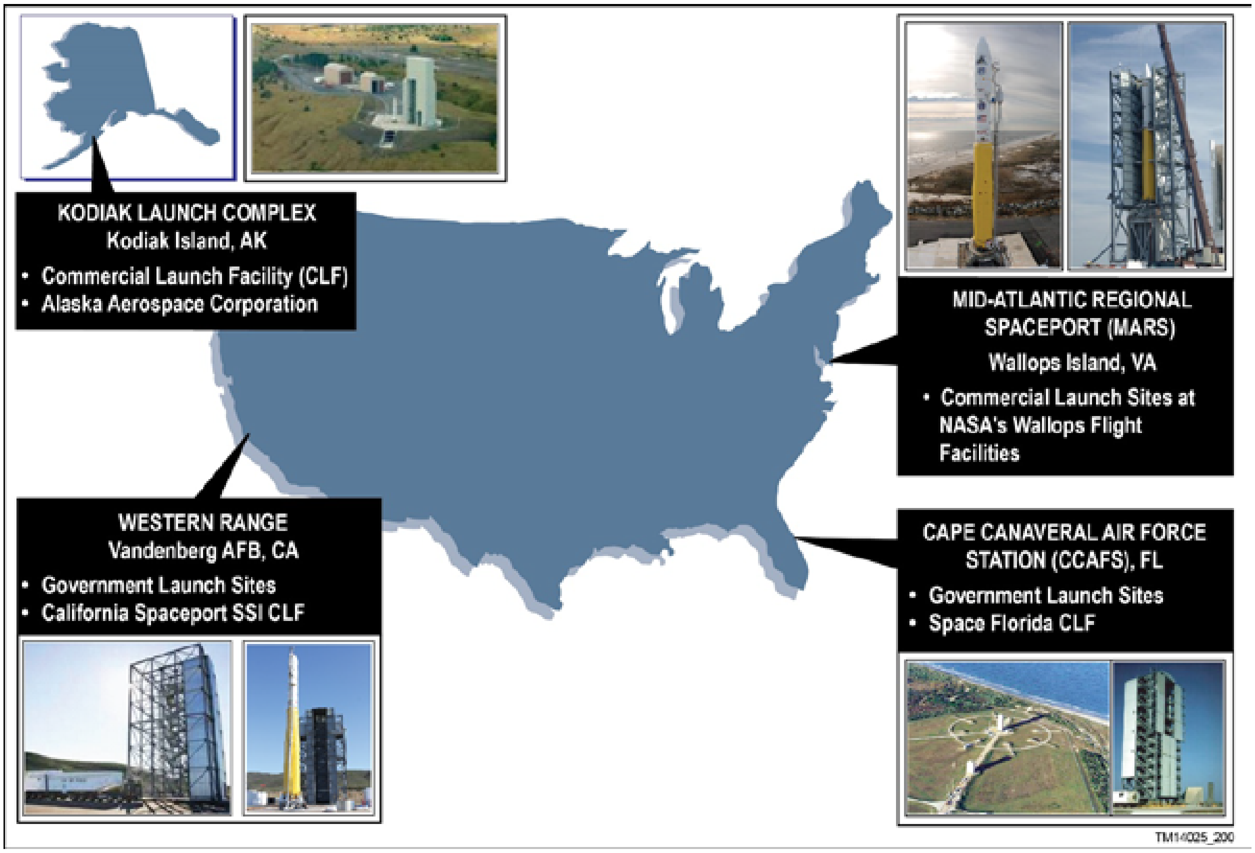


Figure 3.2-1. Flexible Processing and Portable GSE Allows Operations from Multiple Ranges or Austere Site Options

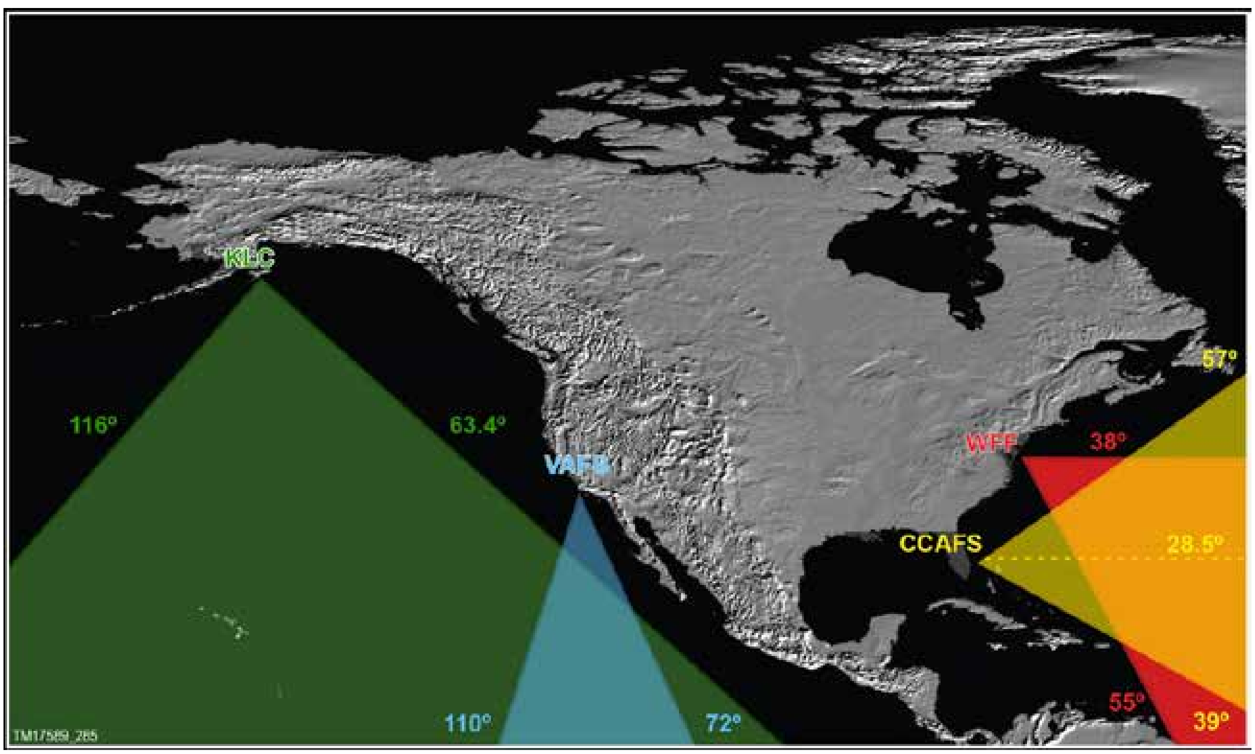


Figure 3.2-2. Launch Site Inclinations

3.2.1. Western Launch Sites

For missions requiring high inclination orbits (greater than 60°), launches can be conducted from facilities at VAFB or Kodiak Island, AK, as shown in Figure 3.2-2. Inclinations below 72° from VAFB are possible, but require an out-of-plane dogleg, thereby reducing payload capability. Minotaur I is nominally launched from the California Spaceport facility, Space Launch Complex 8 (SLC-8) operated by Spaceport Systems International (SSI), on South VAFB. The launch facility at Kodiak Island, operated by the Alaska Aerospace Corporation (AAC) has been used for both orbital and suborbital launches, including past launches of Minotaur IV.

3.2.2. Eastern Launch Sites

For easterly launch azimuths to achieve orbital inclinations between 28.5° and 55°, launches can be conducted from facilities at Cape Canaveral Air Force Station, FL (CCAFS) or Wallops Island, VA (WFF). Launches from Florida will nominally use the Space Florida launch facilities at LC-46 on CCAFS. Typical inclinations are from 28.5° to 50°; however, higher inclination trajectories may be accommodated by using northerly ascent trajectories. These would need to consider the potential of European overflight and require range safety assessment. The Mid-Atlantic Regional Spaceport (MARS) facilities at the WFF may be used for inclinations from 37.8° to 55°. Some inclinations and/or altitudes may have reduced performance due to range safety considerations and will need to be evaluated on a case-by-case mission-specific basis.

3.2.3. Alternate Launch Sites

Other launch facilities can be readily used given the flexibility designed into the Minotaur I vehicle, ground support equipment, and the various interfaces. NGIS has experience launching vehicles from a variety of sites around the world. To meet the requirements of performing mission operations from alternative, austere launch sites, NGIS can provide self-contained, transportable shelters for launch operations as an unpriced option. The mobile equivalent of the LCR is the Launch Support Van (LSV), and the mobile LEV is the Launch Equipment Van.

3.3. Performance Capability

Minotaur I performance curves for circular orbits of various altitudes and inclinations are detailed in Figure 3.3-1 through Figure 3.3-8 for launches from all four Spaceports in metric and English units. These performance curves provide the total mass above the standard, non-separating interface. The mass of the separation system and any Payload Attach Fitting (PAF) that is attached to the 38.81" interface, is to be accounted for in the payload mass allocation. Table 3.3-1 shows a number of common options and the mass associated with each.

Table 3.3-1. Common Mission Options and Associated Masses (These Masses Must Be Subtracted from the LV Performance)

Option	Total Mass (kg) *(These Masses Must Be Subtracted from the LV Performance)*	Portion of Total Mass That Remains with SV Post Separation (kg)
Enhanced Telemetry	9.85	0
TDRSS	8.54	0
38" NGIS Separation System[1]	12.24	4.0
38" RUAG Low Shock Separation System (937S)[1]	19.89	6.16
38" Lightband[1]	8.85	2.52
38" Softride and Ring[2]	9 to 18	0

Notes:
1. For more information on these separation system options, refer to Table 5.2.5-1.
2. A range is provided for the softride option; actual mass is based on payload requirements.

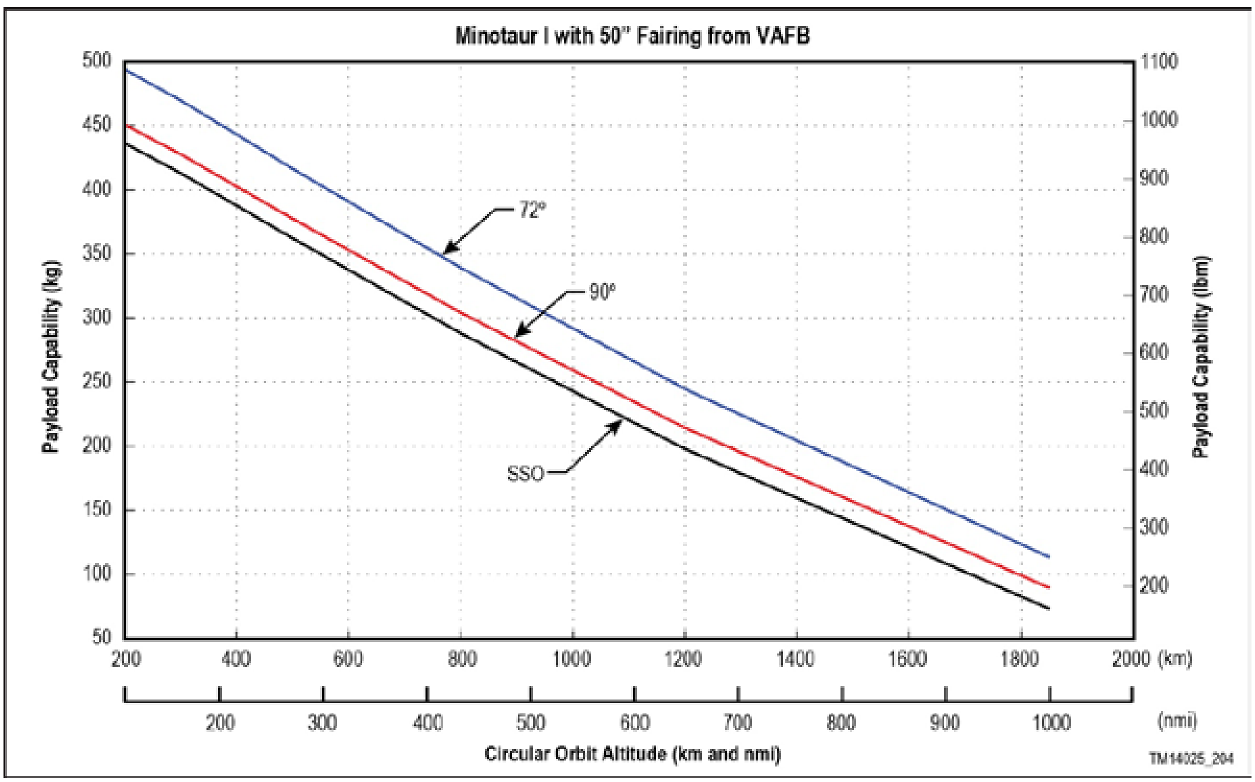


Figure 3.3-1. Minotaur I Performance Curves for VAFB Launches

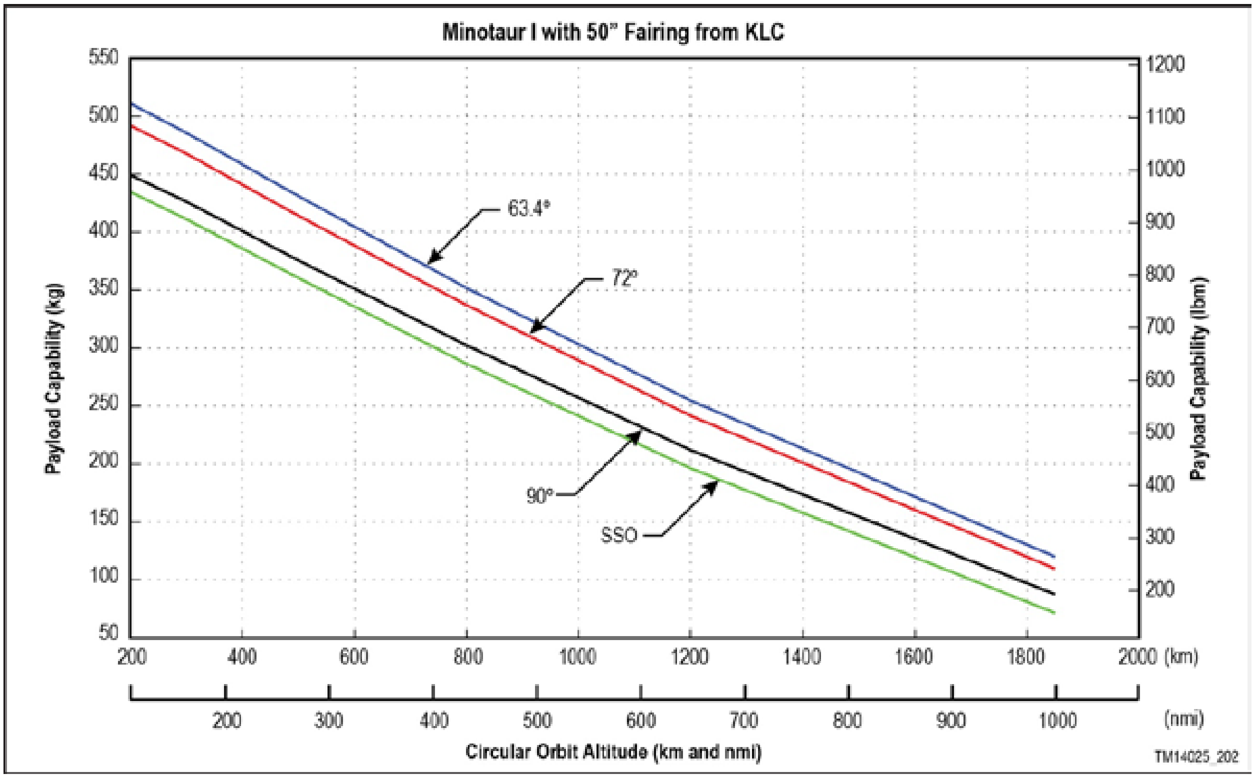


Figure 3.3-2. Minotaur I Performance Curves for KLC Launches

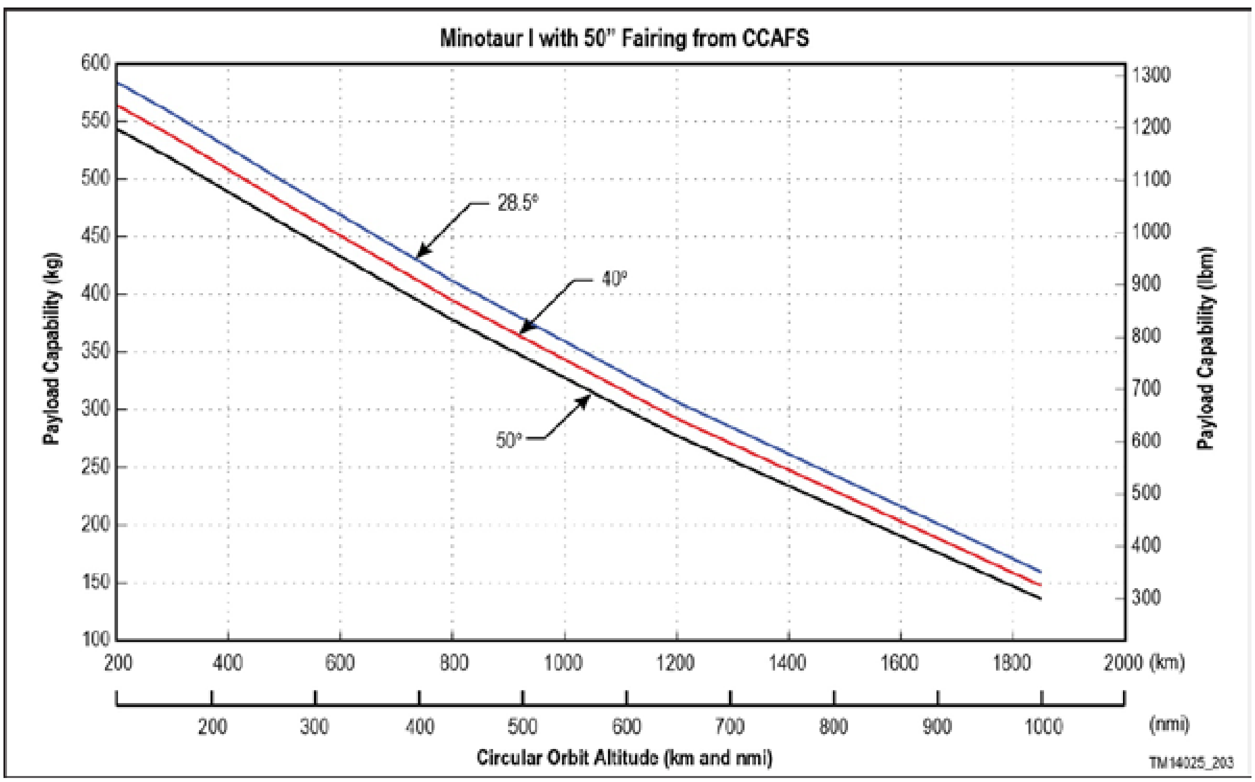
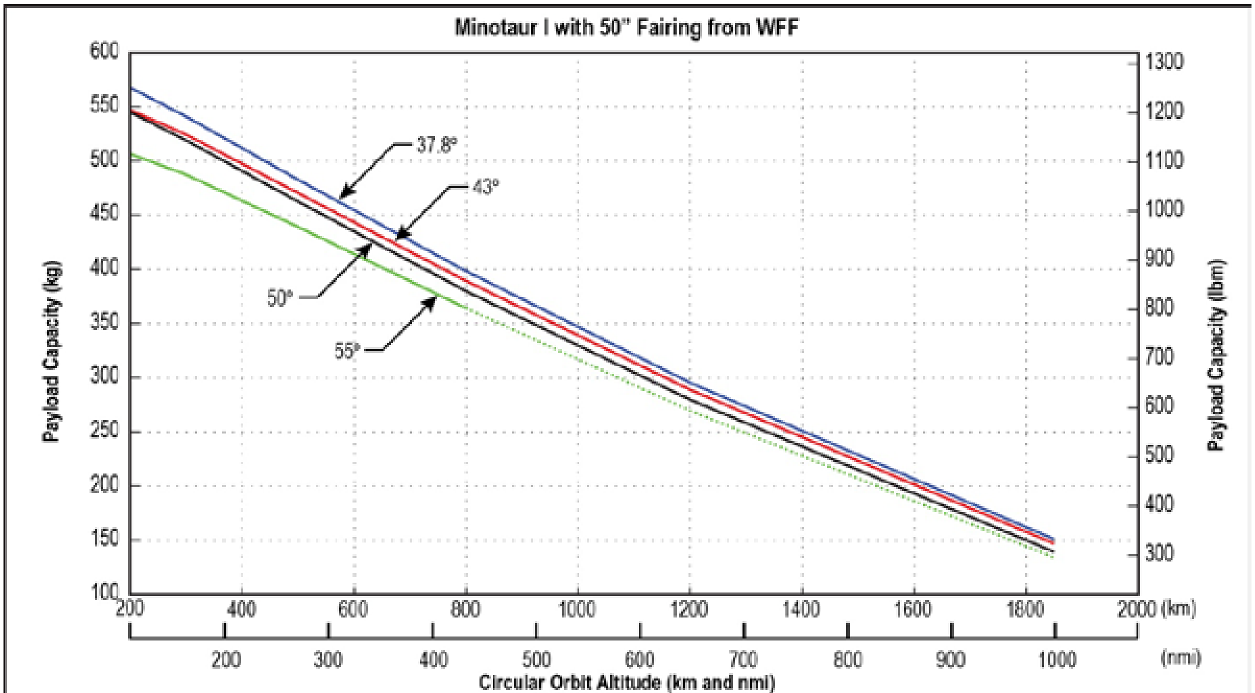


Figure 3.3-3. Minotaur I Performance Curves for CCAFS Launches



NOTE: 1. For missions requiring an inclination between 43 and 50 degrees, there is a performance impact to avoid Bermuda overflight.
2. Dotted areas indicate where small adjustments to the launch trajectory are required at this altitude/inclination combination due to potential of stage drops over inhabited land. Contact NGIS for case-by-case evaluation and impacts to payload capability.

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Figure 3.3-4. Minotaur I Performance Curves for WFF Launches

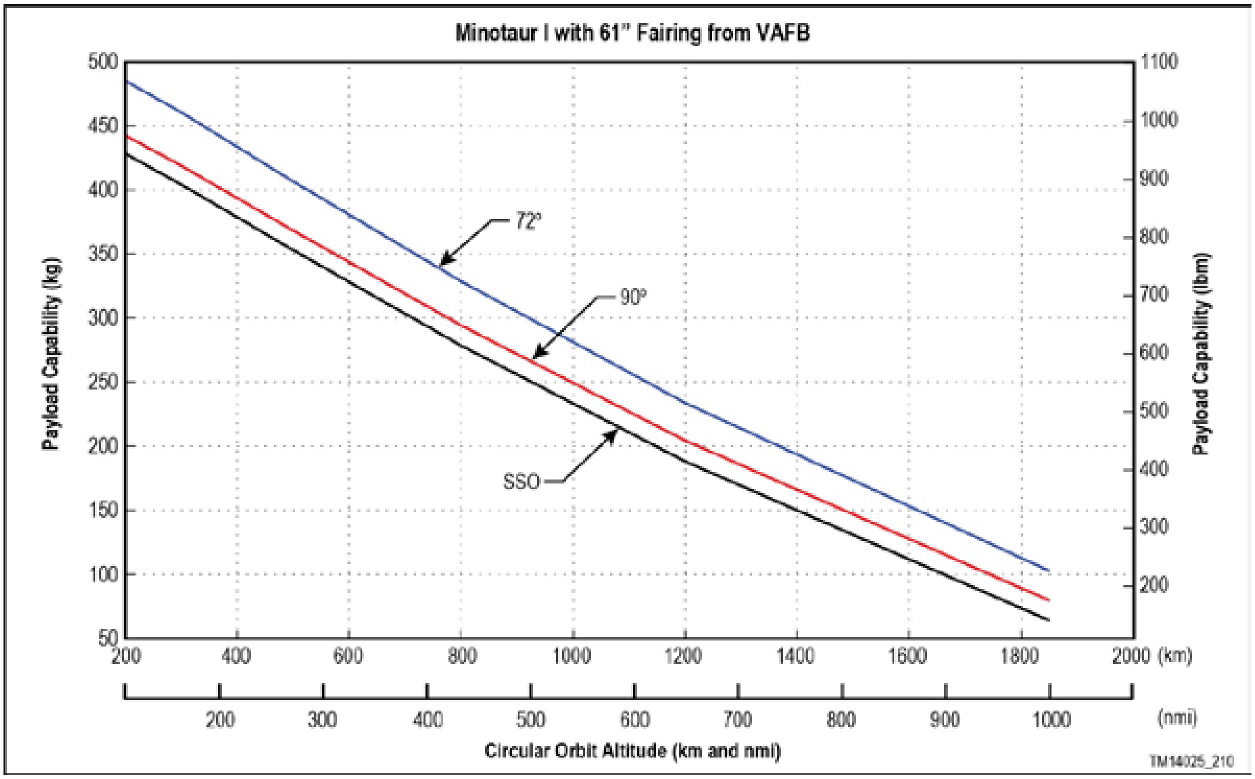


Figure 3.3-5. Minotaur I with 61" Fairing Performance Curves for VAFB Launches

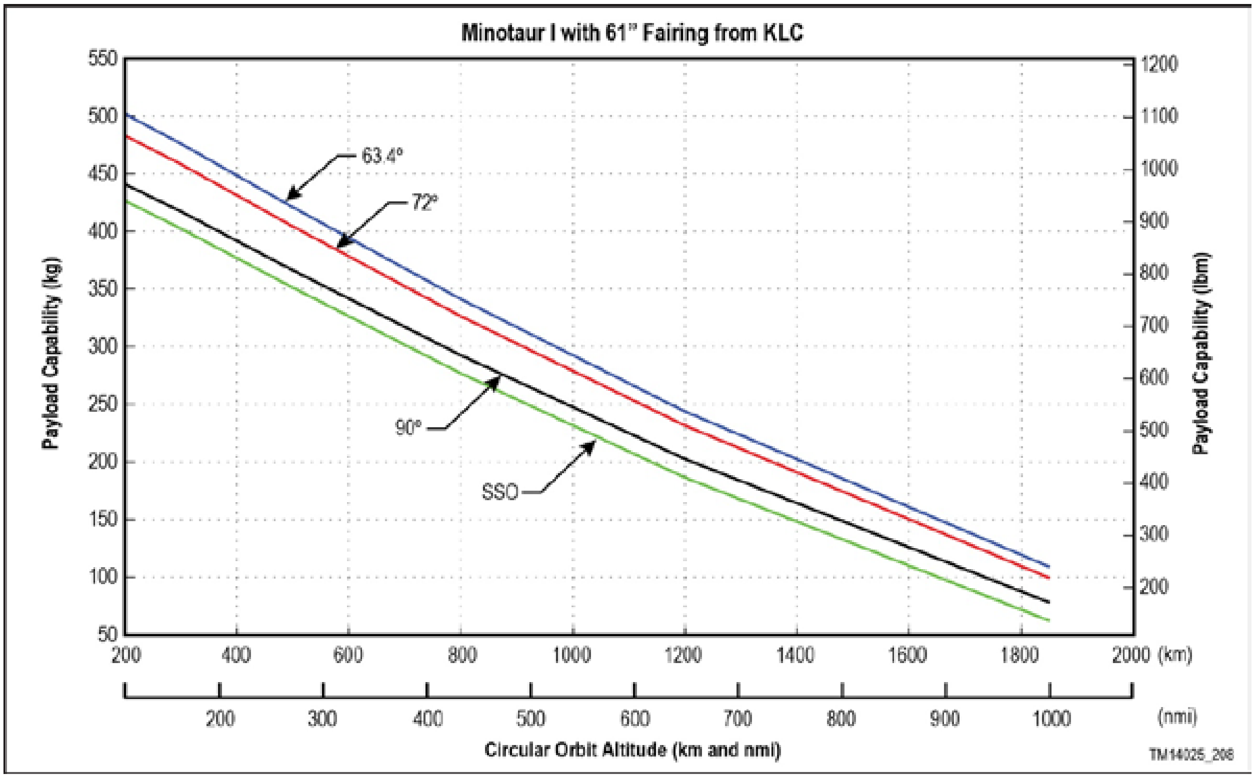


Figure 3.3-6. Minotaur I with 61" Fairing Performance Curves for KLC Launches

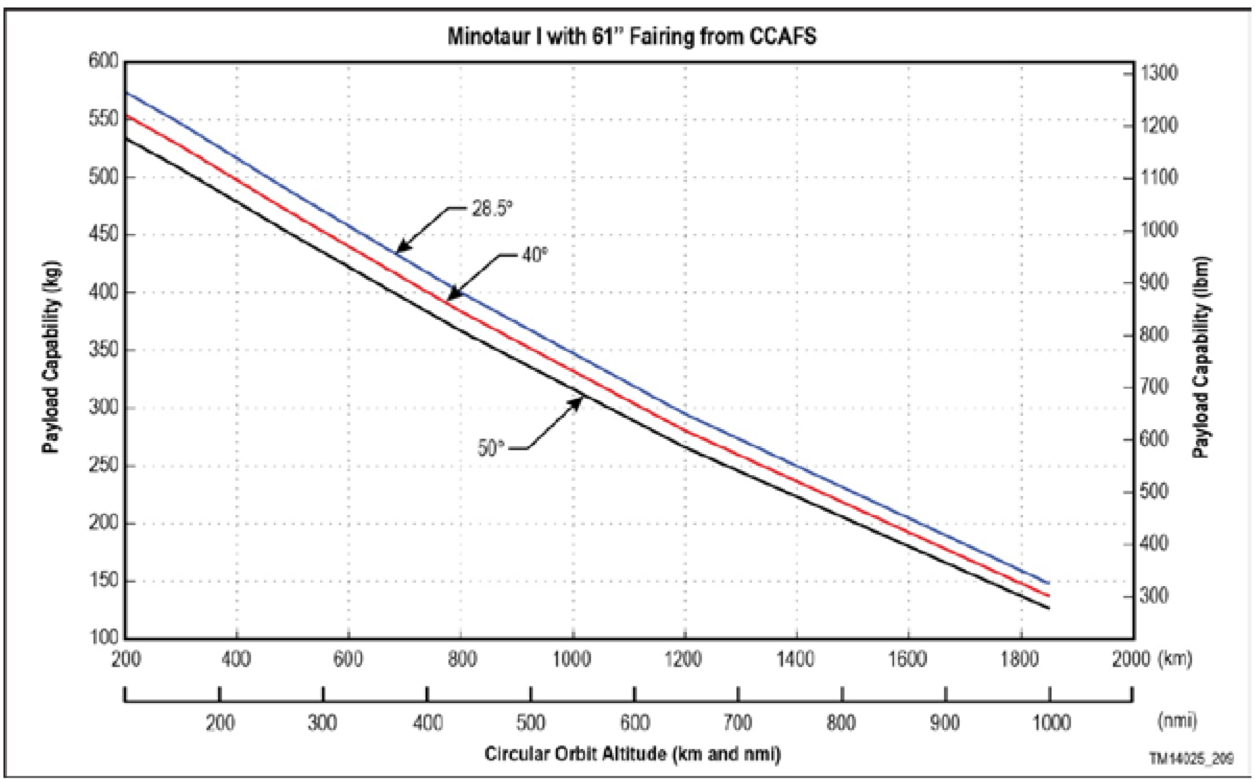
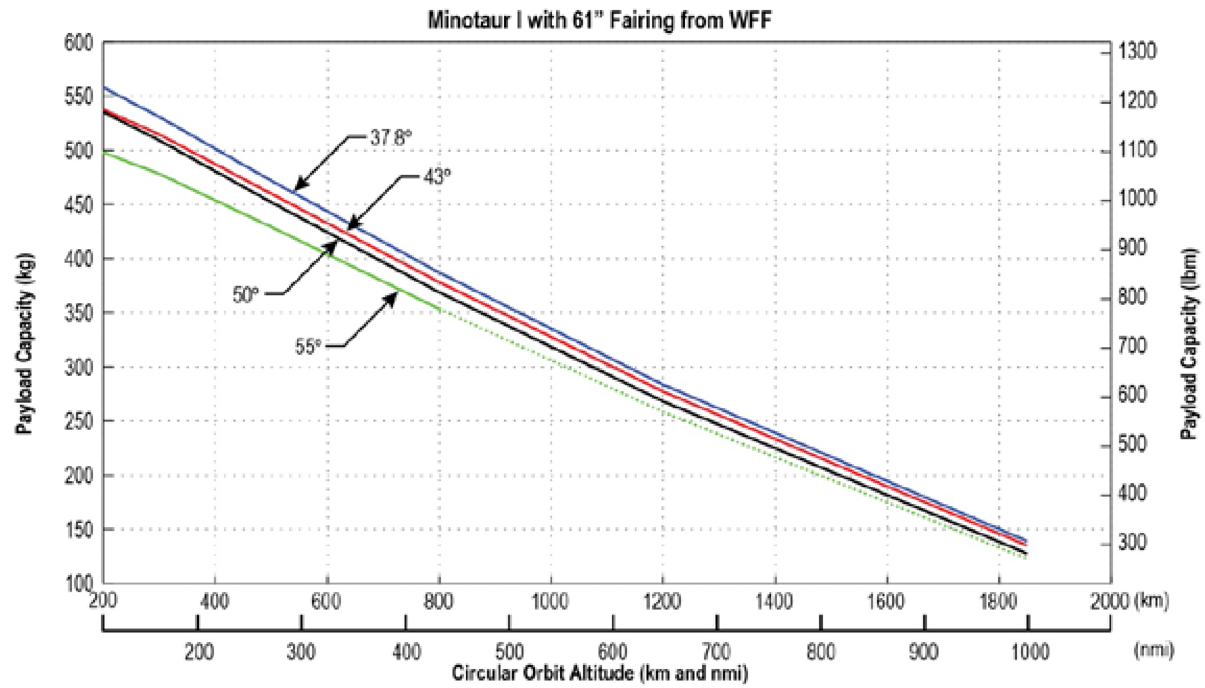


Figure 3.3-7. Minotaur I with 61" Fairing Performance Curves for CCAFS Launches



NOTE: 1. For missions requiring an inclination between 43 and 50 degrees, there is a performance impact to avoid Bermuda overflight.
2. Dotted areas indicate where small adjustments to the launch trajectory are required at this altitude/inclination combination due to potential of stage drops over inhabited land. Contact NGIS for case-by-case evaluation and impacts to payload capability. TM14025_211a

Figure 3.3-8. Minotaur I with 61" Fairing Performance Curves for WFF Launches

3.4. Injection Accuracy

Minotaur I injection accuracy limits are summarized in Table 3.4-1. Better accuracy can likely be provided depending on specific mission characteristics. For example, heavier payloads will typically have better insertion accuracy, as will higher orbits. Furthermore, an enhanced option for increased insertion accuracy is also available (Section 8.9). It utilizes the flight proven Hydrazine Auxiliary Propulsion System (HAPS) developed on the Pegasus program.

Table 3.4-1. Minotaur I Injection Accuracy

Error Type	Tolerance (Worst Case)	Error Source
Altitude (Insertion Apse)	±18.5 km (10 nmi)	Stage 4 motor performance uncertainty and guidance algorithm uncertainty
Altitude (Non-Insertion Apse)	±92.6 km (50 nmi)	Stage 4 motor performance and guidance algorithm uncertainty and navigation (INS) error
Altitude (Mean)	±55.6 km (30 nmi)	Stage 4 motor performance and guidance algorithm uncertainty and navigation (INS) error
Inclination	±0.2°	Guidance algorithm uncertainty and navigation (INS) error

3.5. Payload Deployment

Following orbit insertion, the Minotaur I Stage 4 avionics subsystem can execute a series of ACS maneuvers to provide the desired initial payload attitude prior to separation. This capability may also be used to incrementally reorient Stage 4 for the deployment of multiple spacecraft with independent attitude requirements. Either an inertially-fixed or spin-stabilized attitude may be specified by the customer. The maximum spin rate for a specific mission depends upon the spin axis moment of inertia of the payload and the amount of ACS propellant needed for other attitude maneuvers. Table 3.5-1 provides the typical payload pointing and spin rate accuracies.

Table 3.5-1. Typical Pre-Separation Payload Pointing and Spin Rate Accuracies

Error Type		Angle	Rate
3-Axis	Yaw	±1.0°	≤1.0°/sec
	Pitch	±1.0°	≤1.0°/sec
	Roll	±1.0°	≤1.0°/sec
Spinning	Spin Axis	±1.0°	≤10 rpm
	Spin Rate	--	±3°/sec

3.6. Payload Separation

Payload separation dynamics are highly dependent on the mass properties of the payload and the particular separation system utilized. The primary parameters to be considered are payload tip-off and the overall separation velocity.

Payload tip-off refers to the angular velocity imparted to the payload upon separation due to payload Center of Gravity (CG) offsets and an uneven distribution of torques and forces. Separation system options are discussed further in Section 5.2.5. NGIS performs a mission-specific tip-off analysis for each payload.

Separation velocities are driven by the need to prevent recontact between the payload and the Minotaur I final stage after separation. The value will typically be 0.6 to 0.9 m/sec (2 to 3 ft/sec).

3.7. Collision/Contamination Avoidance Maneuver

Following orbit insertion and payload separation, the Minotaur final stage will perform a Collision/ Contamination Avoidance Maneuver (C/CAM). The C/CAM minimizes both payload contamination and the potential for recontact between Minotaur I hardware and the separated payload. NGIS will perform a recontact analysis for post separation events.

A typical C/CAM begins shortly after payload separation. The launch vehicle performs a 90° yaw maneuver designed to direct any remaining motor impulse in a direction which will increase the separation distance between the two bodies. After a delay to allow the distance between the spacecraft and Stage 4 to increase to a safe level, the launch vehicle begins a "crab-walk" maneuver to impart a small amount of delta velocity, increasing the separation between the payload and the final stage.

Following the completion of the C/CAM maneuver as described above and any remaining maneuvers, such as separating other small secondary payloads or downlinking of delayed telemetry data, the ACS valves are opened and the remaining ACS nitrogen propellant is expelled to meet international space debris guidelines.

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4. PAYLOAD ENVIRONMENT

CAUTION

The predicted environments provided in this user's guide are for initial planning purposes only.

Environments presented here bound a generic mission and should not be used in mission specific analyses. Mission specific levels are provided as a standard service and documented or referenced in the mission ICD.

This section provides details of the predicted environmental conditions that the payload will experience during Minotaur ground operations, powered flight, and launch system on-orbit operations. The predicted environments provided in this user's guide are for initial planning purposes only.

Minotaur ground operations include payload integration and encapsulation within the fairing, subsequent transportation to the launch site and final vehicle integration activities. Powered flight begins at Stage 1 ignition and ends at Stage 4 burnout. Minotaur I post-boost operations begin after Stage 4 burnout and end following payload separation. To more accurately define simultaneous loading and environmental conditions, the powered flight portion of the mission is further subdivided into smaller time segments bounded by critical flight events such as motor ignition, stage separation, and transonic crossover.

The environmental design and test criteria presented have been derived using measured data obtained from many difference sources, including data from previous flights, motor static fire tests, and other NGIS system development tests and analyses. These criteria are applicable to Minotaur I configurations using both the standard 50 in. and optional 61 in. diameter fairing. The predicted levels presented are intended to be representative of a standard mission. Payload mass, geometry and structural components vary greatly and will result in significant differences from mission to mission.

Dynamic loading events that occur throughout various portions of the flight include steady state acceleration, transient low frequency acceleration, acoustic impingement, random vibration, and pyrotechnic shock events.

4.1. Steady State and Transient Acceleration Loads

Design limit load factors due to the combined effects of steady state and low frequency transient accelerations are largely governed by payload characteristics. A mission-specific Coupled Loads Analysis (CLA) will be performed, with customer provided finite element models of the payload, in order to provide precise load predictions. Results will be referenced in the mission specific ICD. For preliminary design purposes, NGIS can provide initial CG netloads given a payload's mass properties, CG location and bending frequencies.

4.1.1. Transient Loads

During upper stage burnout, prior to staging, the transient loads are relatively benign. There are significant transient loads that occur at both Stage 2 and Stage 3 ignition. During the transient portion of these ignition events, the steady state axial loads are relatively nonexistent. Transient loads are highly dependent on payload mass, CG, natural frequencies, and moment of inertias as well as the chosen separation system and Payload Attach Fitting (PAF). All of these were varied to develop a range of transient lateral accelerations at the typical dominant event and are shown as a function of payload mass in Figure 4.1.1-1.

Preliminary and final CLAs will be performed for each Minotaur mission where the payload finite element model is coupled to the vehicle model. Forcing functions have been developed for all significant flight events and load cases. Results from the CLA are reported in the Acceleration Transformation Matrix (ATM) and Load Transformation Matrix (LTM) as requested by the payload provider.

A payload isolation system is available as a non-standard option and is described in Section 8.10. This system has been demonstrated to significantly reduce transient dynamic loads that occur during flight.

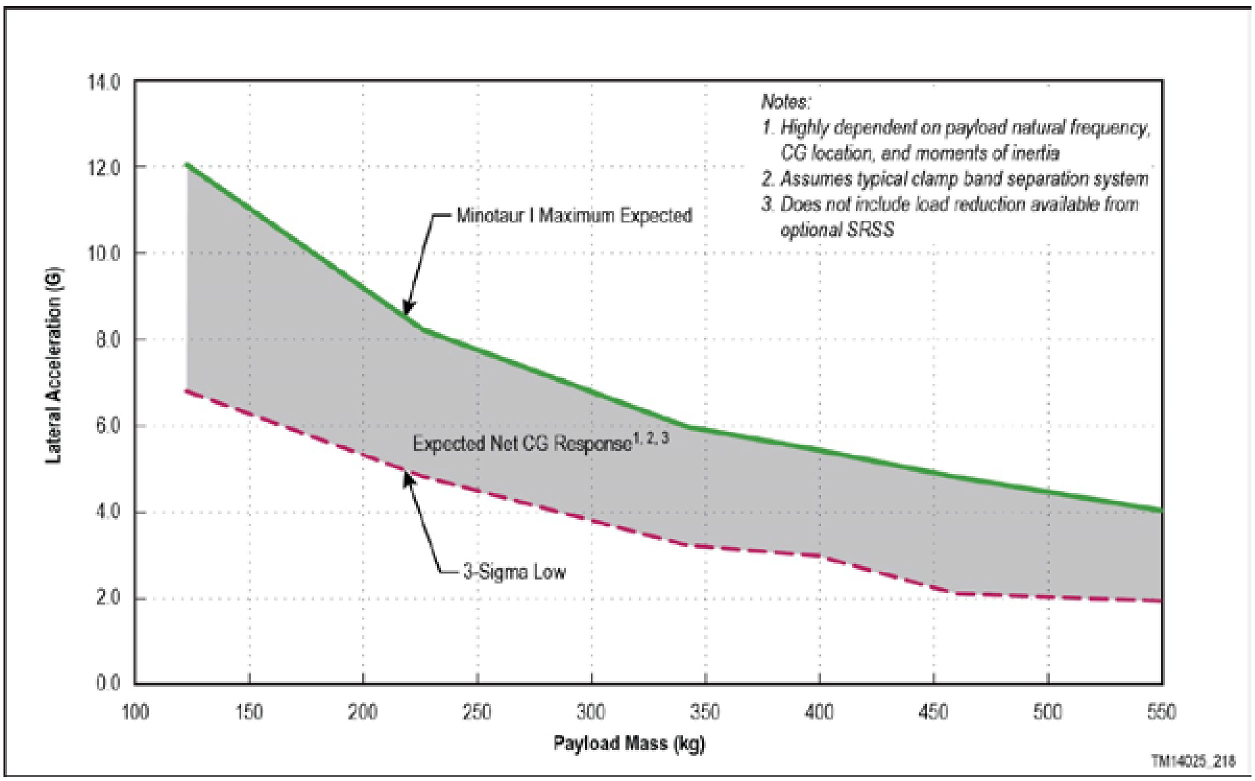


Figure 4.1.1-1. Payload CG Net Transient Lateral Acceleration Envelope

4.1.2. Steady-State Acceleration

Steady-state vehicle accelerations are determined from the vehicle rigid body analysis. Drag, wind and motor thrust are applied to a vehicle model. A Monte Carlo analysis is performed to determine variations in vehicle acceleration due to changes in winds, motor performance and aerodynamics. The steady-state accelerations must be added to transient accelerations from the CLA to determine the maximum expected payload acceleration. Maximum steady state accelerations are dependent on the payload mass, enhancements chosen, and vehicle configuration. The maximum level can potentially occur during either Stage 3 or 4 burn. Figure 4.1.2-1 depicts the maximum steady-state axial acceleration at burnout for each stage as a function of payload mass. Lateral steady state accelerations are typically below 0.5 G's.

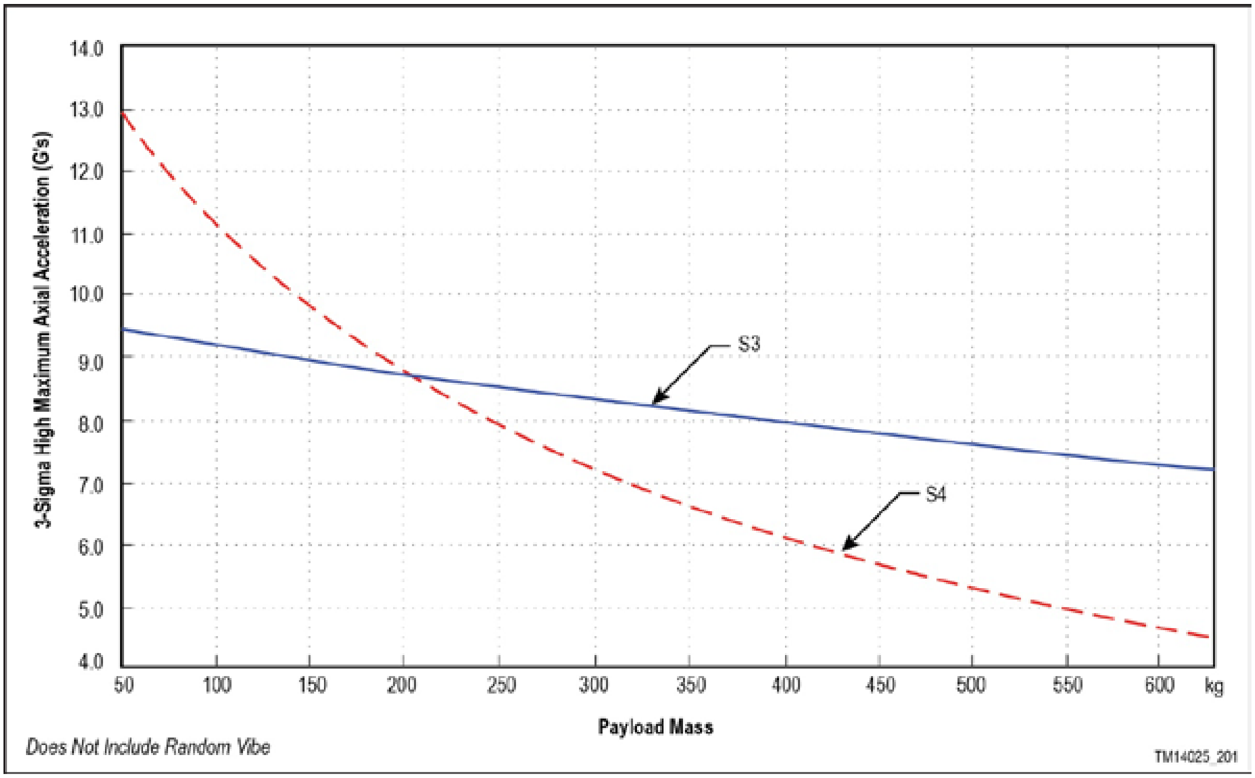


Figure 4.1.2-1. Minotaur I 3-Sigma Maximum Axial Acceleration as a Function of Payload Mass

4.2. Payload Vibration Environment

The in-flight random vibration curve shown in Figure 4.2-1 encompasses all flight vibration environments.

4.3. Payload Acoustic Environment

The acoustic levels during lift-off and powered flight will not exceed the flight limit levels shown in Figure 4.3-1. If the vehicle is launched over a flame duct, the acoustic levels can be expected to be lower than shown. This has been demonstrated with flight data.

4.4. Payload Shock Environment

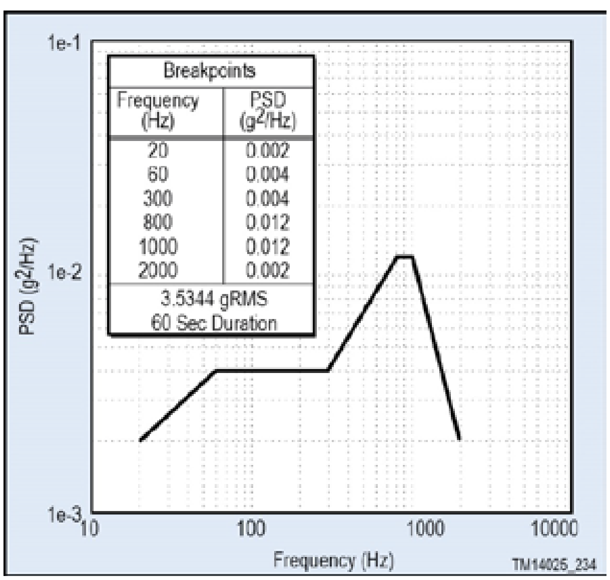
The maximum shock response spectrum at the base of the payload from the launch vehicle will not exceed the flight limit levels in Figure 4.4-1 (LV to Payload). For missions that utilize an NGIS-supplied separation system, the maximum expected shock (LV to Payload) will be the level shown for the chosen separation system. For missions that do not utilize an NGIS-supplied separation system, the maximum expected shock (LV to Payload) is provided and denoted as "Stage 3/4 Separation Shock at Payload I/F."

For all missions, the shock response spectrum at the base of the payload from payload events should not exceed the levels in Figure 4.4-2 (Payload to LV). Shock above this level could require requalification of launch vehicle components.

4.5. Payload Structural Integrity and Environments Verification

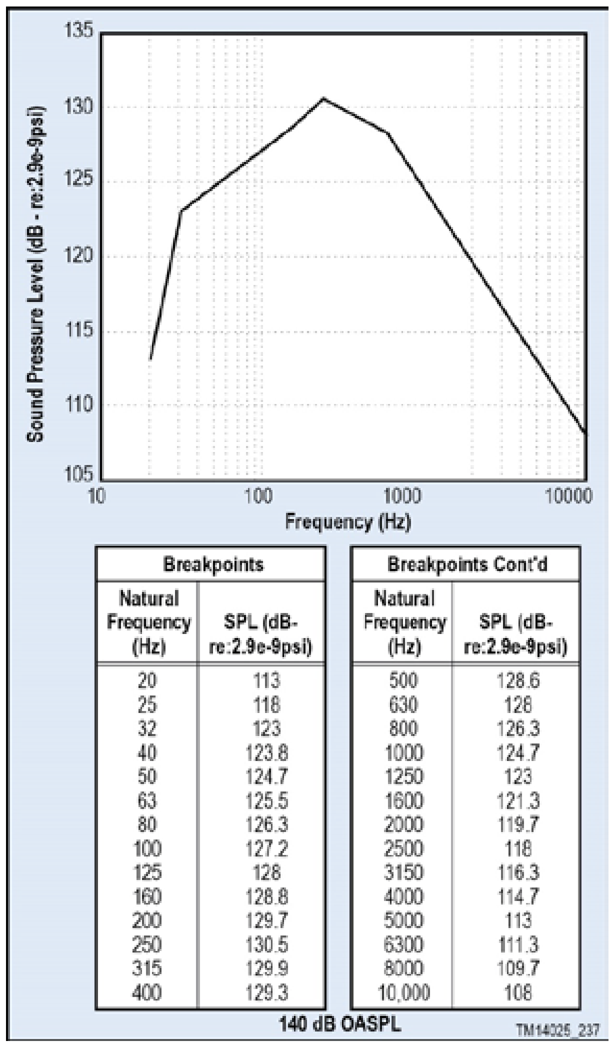
The payload must possess sufficient strength, rigidity, and other characteristics required to survive the handling and flight load conditions with margin in a manner that assures both safety and mission success.

Sufficient payload testing and/or analysis must be performed to show adequate margin to the environments and loads specified in Sections 4.1 through



Frequency (Hz)	PSD (g^2/Hz)
20	0.002
60	0.004
300	0.004
800	0.012
1000	0.012
2000	0.002

Figure 4.2-1. Payload Random Vibration Environment during Flight



Natural Frequency (Hz)	SPL (dB-re:2.9e-9psi)	Natural Frequency (Hz)	SPL (dB-re:2.9e-9psi)
20	113	500	128.6
25	118	630	128
32	123	800	126.3
40	123.8	1000	124.7
50	124.7	1250	123
63	125.5	1600	121.3
80	126.3	2000	119.7
100	127.2	2500	118
125	128	3150	116.3
160	128.8	4000	114.7
200	129.7	5000	113
250	130.5	6300	111.3
315	129.9	8000	109.7
400	129.3	10,000	108

Figure 4.3-1. Payload Acoustic Environment during Liftoff and Flight

4.4. The payload design should comply with the testing and design factors of safety as found in MIL-HNBK-340A (ref. MIL-STD-1540B) and NASA GEVS Rev. A, June '96. The payload organization must provide NGIS with a list of the tests and test levels to which the payload was subjected prior to payload arrival at the integration facility.

4.6. Thermal and Humidity Environments

The thermal and humidity environment to which the payload may be exposed during vehicle processing and pad operations are defined in the following sections.

4.6.1. Ground Operations

The payload environment will be maintained by a Heating, Ventilation, and Air Conditioning (HVAC) Environmental Control Unit (ECU). The HVAC provides conditioned air to the payload in the Payload

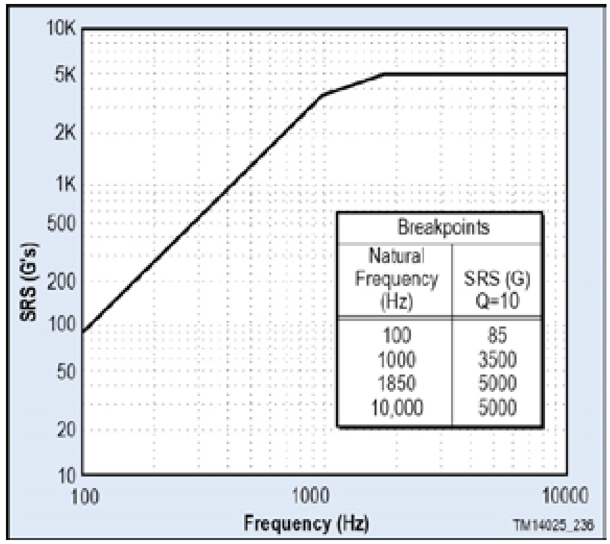


Figure 4.4-2. Maximum Shock Environment – Payload to Launch Vehicle

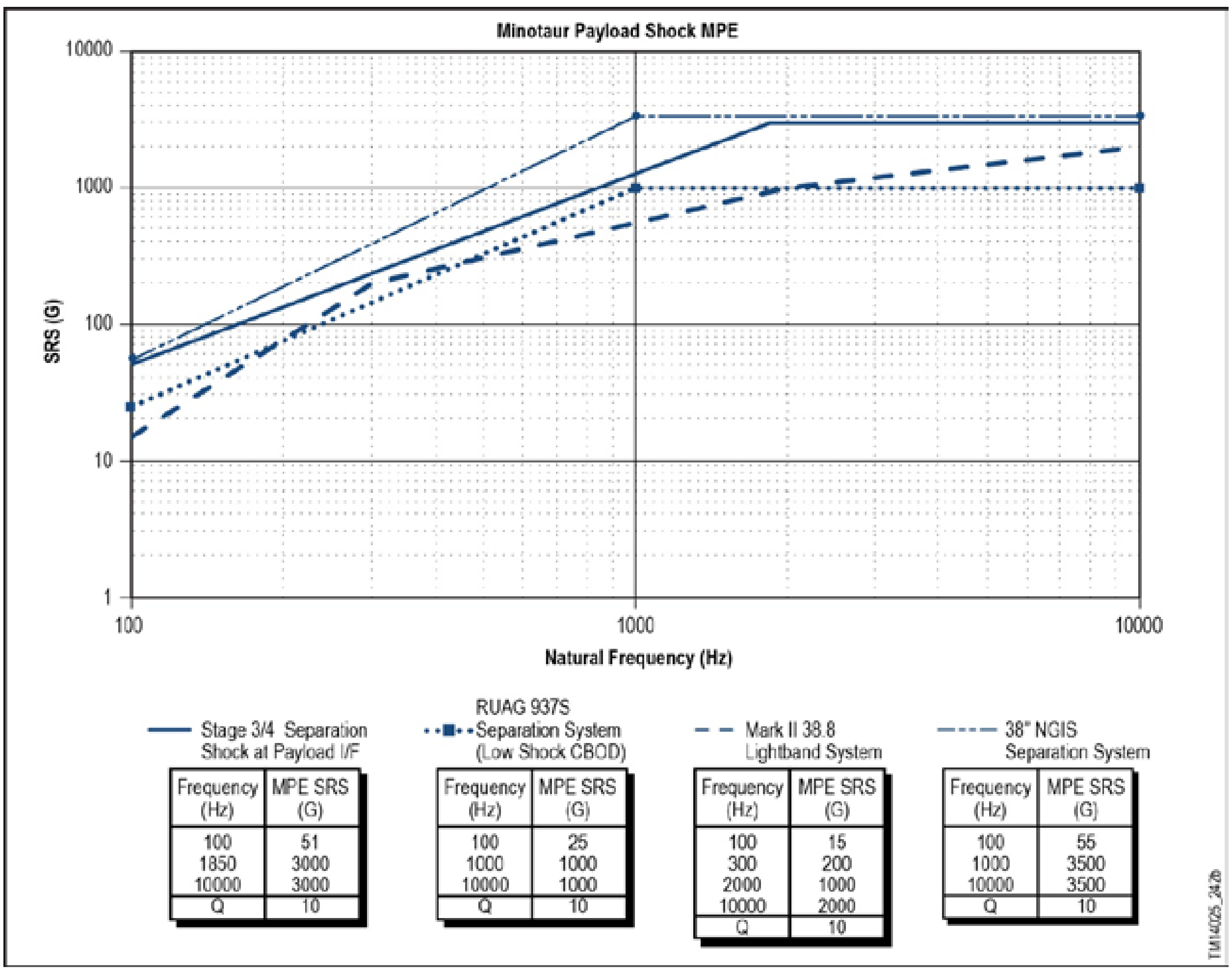


Figure 4.4-1. Maximum Shock Environment – Launch Vehicle to Payload

Processing Facility (PPF) after fairing integration and on the launch pad. For Minotaur I, conditioned air is not provided during transport and lifting operations. The conditioned air enters the fairing at a location forward of the payload, exits aft of the payload and is maintained up to 5 minutes prior to launch (for the 61" fairing, the conditioned air can be maintained until liftoff). A diffuser is designed into the air conditioning inlet to reduce impingement velocities on the payload. Class 10,000 (ISO 7) can be provided inside a clean room and at payload fairing HVAC inlet on a mission-specific basis as an enhanced option (Section 8.6).

Fairing inlet conditions are selected by the customer, and are bounded as follows:

a. Dry Bulb Temperature: 13 to 29 °C (55 to 85 °F) controllable to ±5 °C (±10 °F) of setpoint
b. Temperature environment lower limit is 12.8 °C (55 °F) due to the Orion 38 motor's limit
c. Standard Setpoint: 18.3 °C (65 °F)
d. Dew Point Temperature: 3 to 17 °C (38 to 62 °F)
e. Relative Humidity: determined by drybulb and dew point temperature selections and generally controlled to within ±15%. Relative humidity is bound by the psychrometric chart and will be controlled such that the dew point within the fairing is never reached.
f. Nominal Flow: 11.3 m^3/min (400 cfm)

A diagram of the HVAC system is shown in Figure 4.6.1-1.

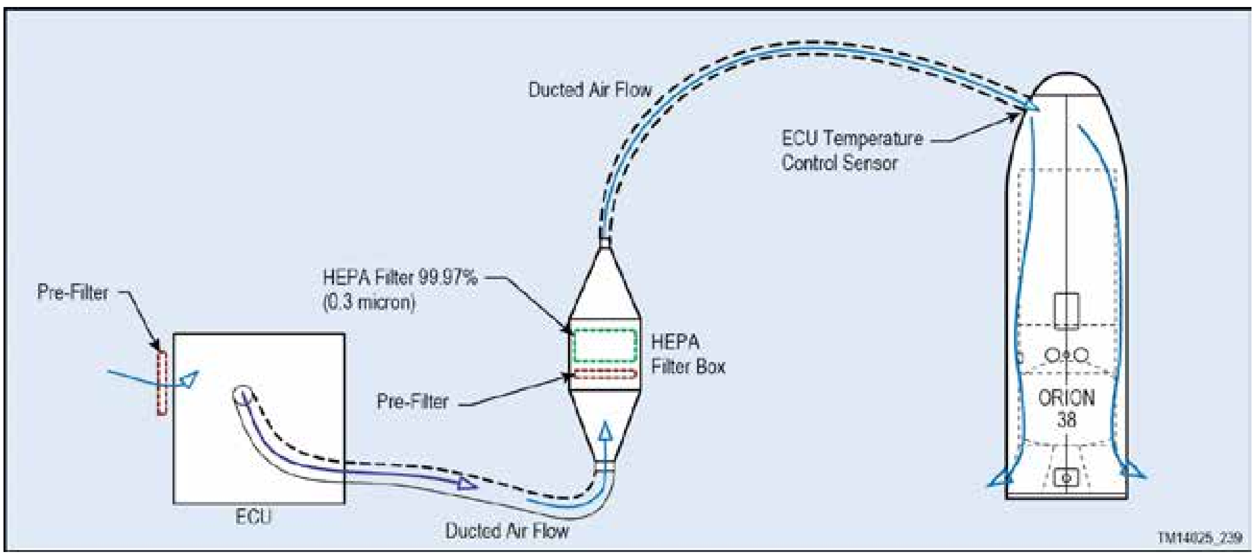


Figure 4.6.1-1. Minotaur I HVAC System Provides Conditioned Air to the Payload

4.6.2. Powered Flight

The maximum fairing inside wall temperature will be maintained at less than 93 °C (200 °F), with an emissivity of 0.92 in the region of the payload. As a non-standard service, a low emissivity coating can be applied to reduce emissivity to less than 0.1. Interior surfaces aft of the payload interface will be maintained at less than 121 °C (250 °F). This temperature limit envelopes the maximum temperature of any component inside the payload fairing with a view factor to the payload with the exception of the Stage 4 motor. The maximum Stage 4 motor surface temperature exposed to the payload will not exceed 177 °C (350 °F), assuming no shielding between the aft end of the payload and the forward dome of the motor assembly. Whether this temperature is attained prior to payload separation is dependent upon mission timeline.

The fairing peak vent rate is typically less than 0.6 psi/sec. Fairing deployment will be initiated at a time in flight that the maximum dynamic pressure is less than 0.01 psf or the maximum free molecular heating rate is less than 1135 W/m^2 (0.1 BTU/ft^2/sec), as required by the payload.

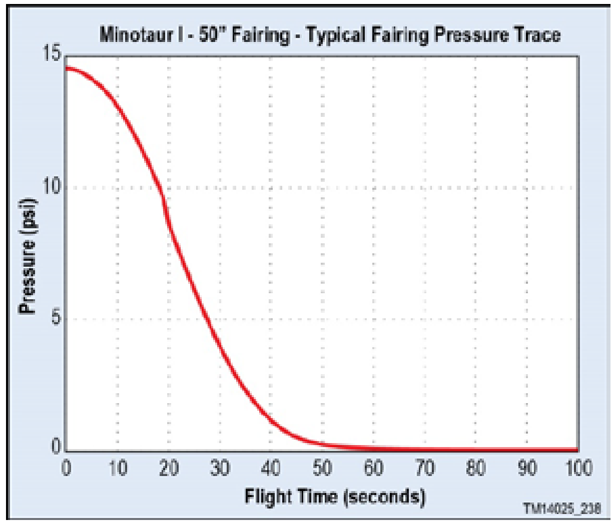


Figure 4.6.2-1. Typical Minotaur I Fairing Pressure Profile

4.6.3. Nitrogen Purge (non-standard service)

If required for spot cooling of a payload component, NGIS will provide GN^2 flow to localized regions in the fairing as a non-standard service. This option is discussed in more detail in Section 8.3.

4.7. Payload Contamination Control

All payload integration procedures, and NGIS' contamination control program have been designed to minimize the payload's exposure to contamination from the time the payload arrives at the payload processing facility through orbit insertion and separation. The payload is fully encapsulated within the fairing at the payload processing facility, assuring the payload environment stays clean in a Class 100,000 environment. Launch vehicle assemblies that affect cleanliness within the encapsulated payload volume include the fairing, avionics assembly, Stage 4 assembly, and 3/4 Interstage. These assemblies are cleaned such that there is no particulate or non-particulate matter visible to the normal unaided eye when inspected from 2 to 4 feet under 50 ft-candle incident light (Visibly Clean Level II). After encapsulation, the fairing envelope is either sealed or maintained with a positive pressure, Class 100,000 (ISO 8) continuous purge of conditioned air.

If required, the payload can be provided with enhanced contamination control as an option, providing a Class 10,000 (ISO 7) environment, low outgassing, and Visibly Clean Plus Ultraviolet cleanliness. With the enhanced contamination control option, the NGIS-supplied elements will be cleaned and controlled to support a Class 10,000 clean room environment, as defined in ISO 14644-1 clean room standards (ISO 7). This includes limiting volatile hydrocarbons to maintain hydrocarbon content at less than 15 ppm.

Also with the enhanced contamination control option, the ECU continuously purges the fairing volume with clean filtered air and maintains humidity between 30 to 60 percent. NGIS' ECU incorporates a HEPA filter unit to provide ISO 7 (Class 10,000) air. NGIS monitors the supply air for particulate matter via a probe installed upstream of the fairing inlet duct prior to connecting the air source to the payload fairing.

4.8. Payload Electromagnetic Environment

The payload Electromagnetic Environment (EME) results from two categories of emitters: Minotaur I onboard antennas and Range radar. All power, control and signal lines inside the payload fairing are shielded and properly terminated to minimize the potential for Electromagnetic Interference (EMI). The Minotaur I payload fairing is Radio Frequency (RF) opaque, which shields the payload from most external RF signals while the payload is encapsulated. Details of the analysis can be provided upon request.

Table 4.8-1 lists the frequencies and maximum radiated signal levels from vehicle antennas that are located near the payload during ground operations and powered flight. Antennas located inside the fairing are inactive until after fairing deployment. The specific EME experienced by the payload during ground processing at the VAB and the launch site will depend somewhat on the specific facilities that are utilized as well as operational details. However, typically the field strengths experienced by the payload during ground processing with the fairing in place are controlled procedurally and will be less than 2 V/m from continuous sources and less than 10 V/m from pulse sources. Range transmitters are typically controlled to provide a field strength of 10 V/m or less. This EME should be compared to the payload's RF susceptibility levels (MIL-STD-461, RS03) to define margin.

Table 4.8-1. Minotaur I Launch Vehicle RF Emitters and Receivers

Source	1	2	3	4	5	6	7
Function	**Command Destruct**	**Tracking Transponder**	**Tracking Transponder**	**Launch Vehicle**	**Enhanced Instrumentation Telemetry (Optional)**	**GPB**	**GPB**
Receive/Transmit	Receive	Transmit	Receive	Transmit	Transmit	Transmit	Receive
Band	UHF	C-band	C-band	S-band	S-band	S-band	L-band (L1/L2)
Frequency (MHz)	421.0	5765	5690	2288.5	2269.5	2241.5	1575.42 / 1227.6
Bandwidth	N/A	14 MHz	14 MHz	1.78 MHz	1.78 MHz	256 kHz	20.46 MHz (P(Y) Code)
Power Output	N/A	400 W (peak)	N/A	10 W	10 W	5 W	N/A
Sensitivity	-107 dBm	-70 dBm	-70 dBm	N/A	N/A	N/A	-123 dB,
Modulation	Tone	Pulse Code	Pulse Code	PCM/FM	PCM/FM	PCM/FM	Spread Spectrum QPSK
Field Strength at PL Interfaces	N/A	3.016 V/m Average 67.436 V/m per 0.5 µsec		<100 V/m		<60 V/m	N/A

5. PAYLOAD INTERFACES

This section describes the available mechanical, electrical and Launch Support Equipment (LSE) interfaces between the Minotaur I launch vehicle and the payload.

5.1. Payload Fairing

5.1.1. 50" Standard Minotaur I Fairing

The standard payload fairing consists of two graphite composite halves, with a nosecap bonded to one of the halves, and a separation system. Each composite half is composed of a cylinder and an ogive section. The two halves are held together by two titanium straps, both of which wrap around the cylinder section, one near its midpoint and one just aft of the ogive section. Additionally, an internal retention bolt secures the two fairing halves together at the surface where the nosecap overlaps the top surface of the other fairing half. The base of the fairing is separated using a frangible joint. During Flight, fairing separation involves first initiating the separation nut which releases the internal retention bolt at the nose of the fairing, then initiating bolt cutters which release the two titanium straps. Next, the frangible joint is severed which allows each half of the fairing to then rotate on hinges mounted on the Stage 3 side of the interface. A contained hot gas generation system is used to drive pistons that force the fairing halves open. All fairing deployment systems are non-contaminating.

5.1.1.1. Payload Dynamic Design Envelope

The fairing drawing in Figure 5.1.1.1-1 shows the maximum dynamic envelopes available for the payload during powered flight. The dynamic envelopes shown account for fairing and vehicle structural deflections only. The payload contractor must take into account deflections due to spacecraft design and manufacturing tolerance stack-up within the dynamic envelope. Proposed payload dynamic envelope violations must be approved by NGIS via the ICD.

No part of the payload may extend aft of the payload interface plane without specific NGIS approval. These areas are considered stay out zones for the payload and are shown in Figure 5.1.1.1-1. Incursions to these zones may be approved on a case-by-case basis after additional verification that the incursions do not cause any detrimental effects. Vertices for payload deflection must be given with the Finite Element Model to evaluate payload dynamic deflection with the CLA. The payload contractor should assume that the interface plane is rigid; NGIS has accounted for deflections of the interface plane. The CLA will provide final verification that the payload does not violate the dynamic envelope.

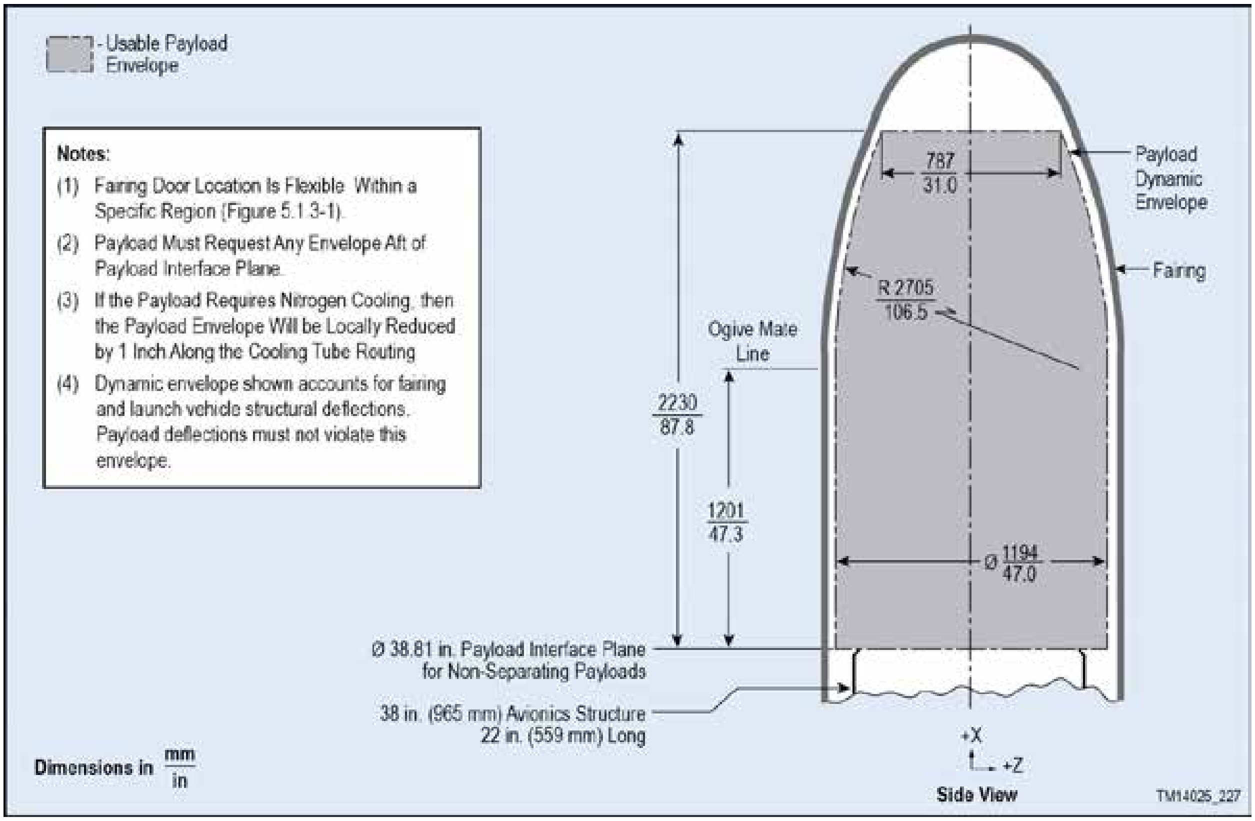


Figure 5.1.1.1-1. 50" Payload Fairing Dynamic Envelope with 38" (97 cm) Diameter Payload Interface

5.1.2. Optional 61" Payload Fairing

To fit payloads larger than those that can be accommodated by the standard 50" diameter fairing, a larger 61" diameter fairing is available as an enhancement. This structure uses an innovative diffusion-bonded titanium sandwich panel composed of titanium facesheets and titanium honeycomb core. The 61" diameter titanium fairing, along with its separation and deployment system, is qualified for flight and has flown successfully on previous Minotaur I missions. Impacts to performance when compared to the 50" fairing are negligible as a result of the more aerodynamic bi-conic nose.

5.1.2.1. Payload Dynamic Design Envelope (61" Payload Fairing)

Figure 5.1.2.1-1 shows the maximum dynamic envelopes available for the payload during powered flight within the optional 61" payload fairing. The dynamic envelopes shown account for fairing and vehicle structural deflections only. The payload contractor must take into account deflections due to spacecraft design and manufacturing tolerance stack-up within the dynamic envelope. Proposed payload dynamic envelope violations must be approved by NGIS via the ICD.

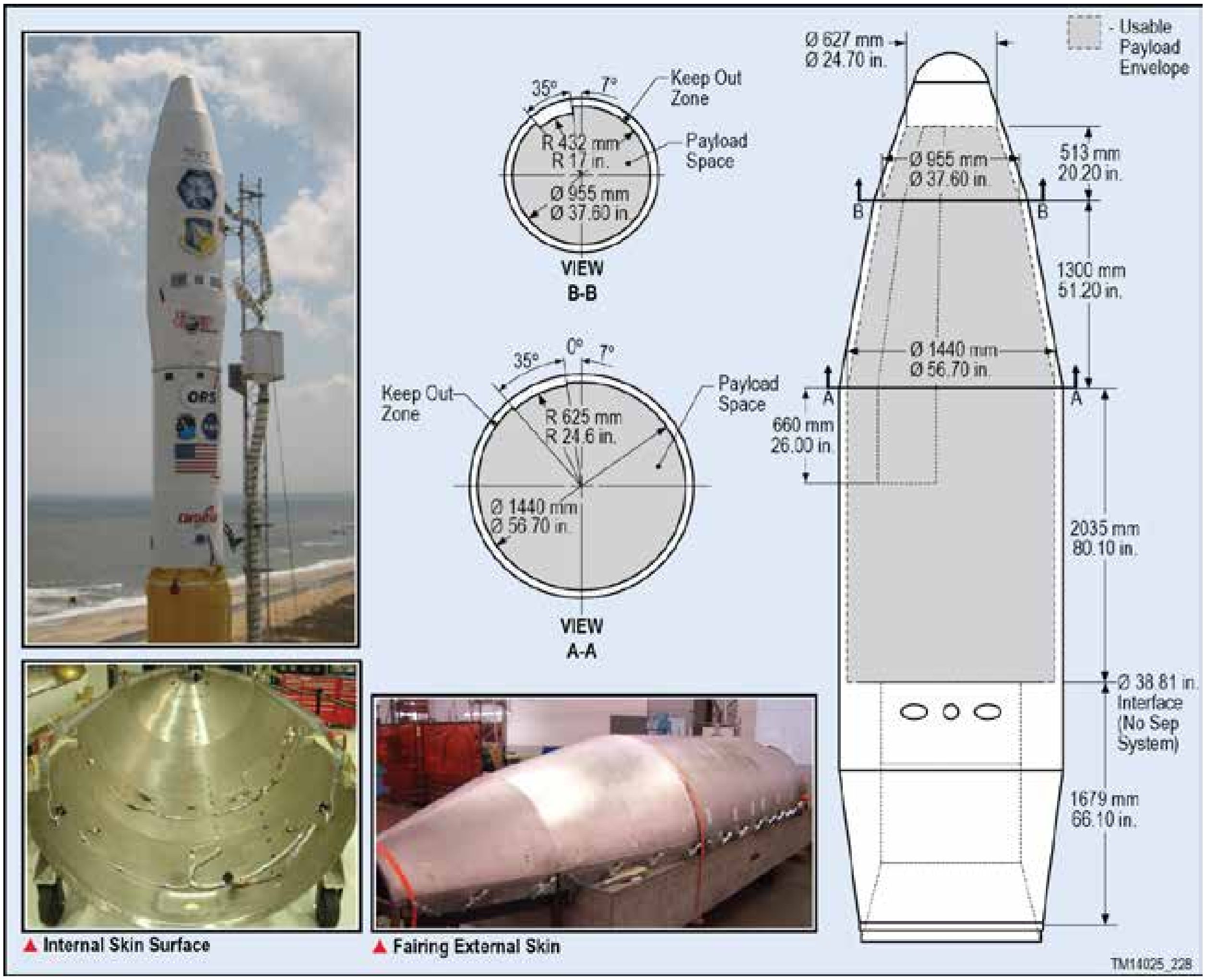


Figure 5.1.2.1-1. 61" Payload Fairing Dynamic Envelope with 38" (97 cm) Diameter Payload Interface

No part of the payload may extend aft of the payload interface plane without specific NGIS approval. Incursions to these zones may be approved on a case-by-case basis after additional verification that the incursions do not cause any detrimental effects. Vertices for payload deflection must be given with the Finite Element Model to evaluate payload dynamic deflection with the CLA. The payload contractor should assume that the interface plane is rigid; NGIS has accounted for deflections of the interface plane. The CLA will provide final verification that the payload does not violate the dynamic envelope.

5.1.3. Payload Access Door

On the standard 50" fairing, NGIS provides one 254 mm by 368 mm (10.00 in. by 14.50 in.) payload fairing access door to provide access to the payload after fairing mate. The door can be positioned according to user requirements within the zone defined in Figure 5.1.3-1. The position of the payload fairing access door must be defined no later than L-8 months. Additional access doors can be provided as a non-standard service (see Section 8.4). Access doors on the optional 61" fairing are limited to 254 mm by 279 mm (10.00 in. by 11.00 in.) and can be positioned within the zone defined in Figure 5.1.3-2.

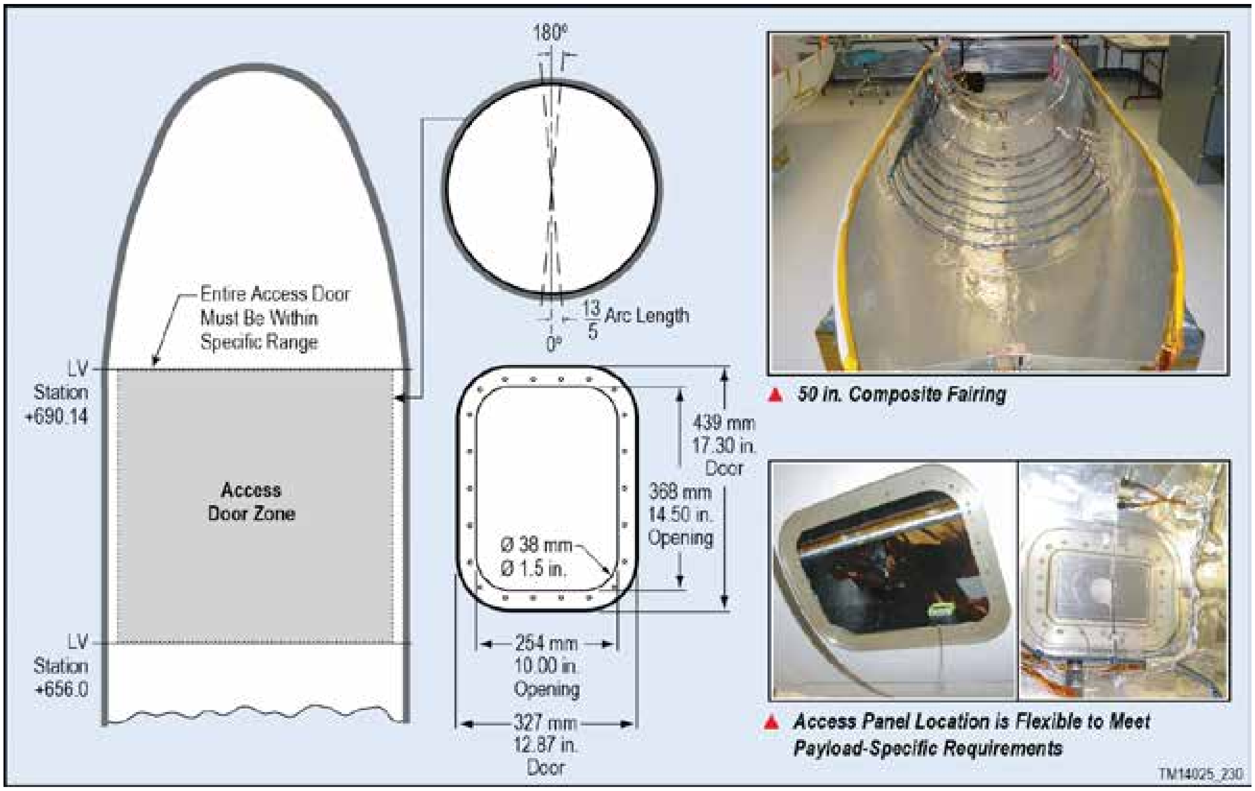


Figure 5.1.3-1. 50" Payload Fairing Access Door Placement Zone

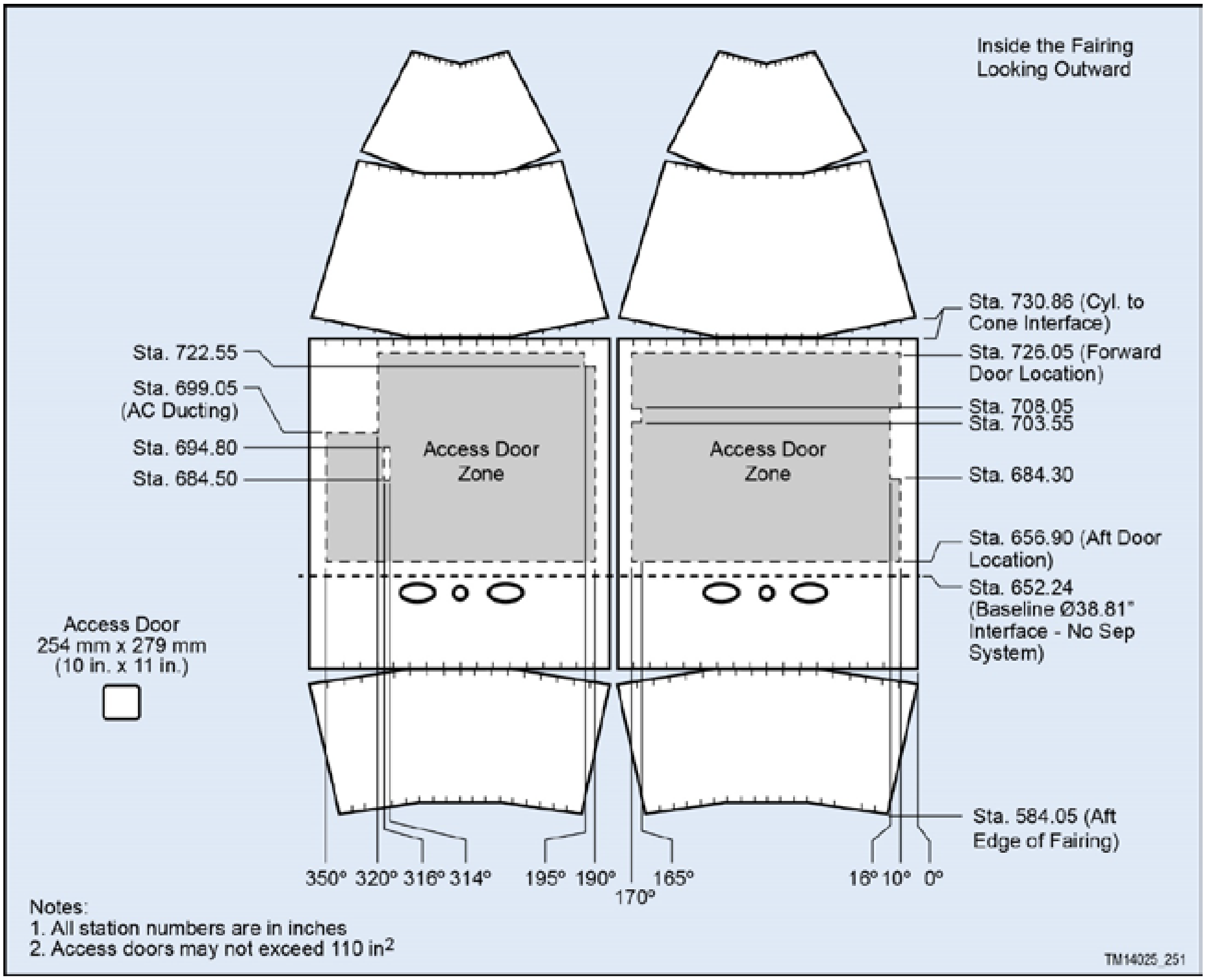


Figure 5.1.3-2. 61" Payload Fairing Access Door Placement Zone

5.2. Payload Mechanical Interface and Separation System

Minotaur I provides for a standard non-separating payload interface and several optional NGIS-provided payload separation systems. NGIS will provide all flight hardware and integration services necessary to attach non-separating and separating payloads to Minotaur I. Ground handling equipment is typically the responsibility of the payload contractor. All attachment hardware, whether NGIS or customer provided, must contain locking features consisting of locking nuts, inserts or fasteners. Additional mechanical interface diameters and configurations can readily be provided as an enhanced option.

5.2.1. Minotaur Coordinate System

The Minotaur I Launch Vehicle coordinate system is defined in Figure 5.2.1-1. For clocking references, degree marks are clockwise when aft looking forward. The positive X-axis is forward along the vehicle longitudinal centerline, the positive Z axis is along the 180 deg angular azimuth, and the positive Y axis is along the 90 deg angular azimuth, and completes the orthogonal system. The origin of the LV coordinate system is centered at the Stage 1 nozzle exit plane of the LV and the vehicle centerline (X = 0.0 in, Y = 0.0 in, Z = 0.0 in).

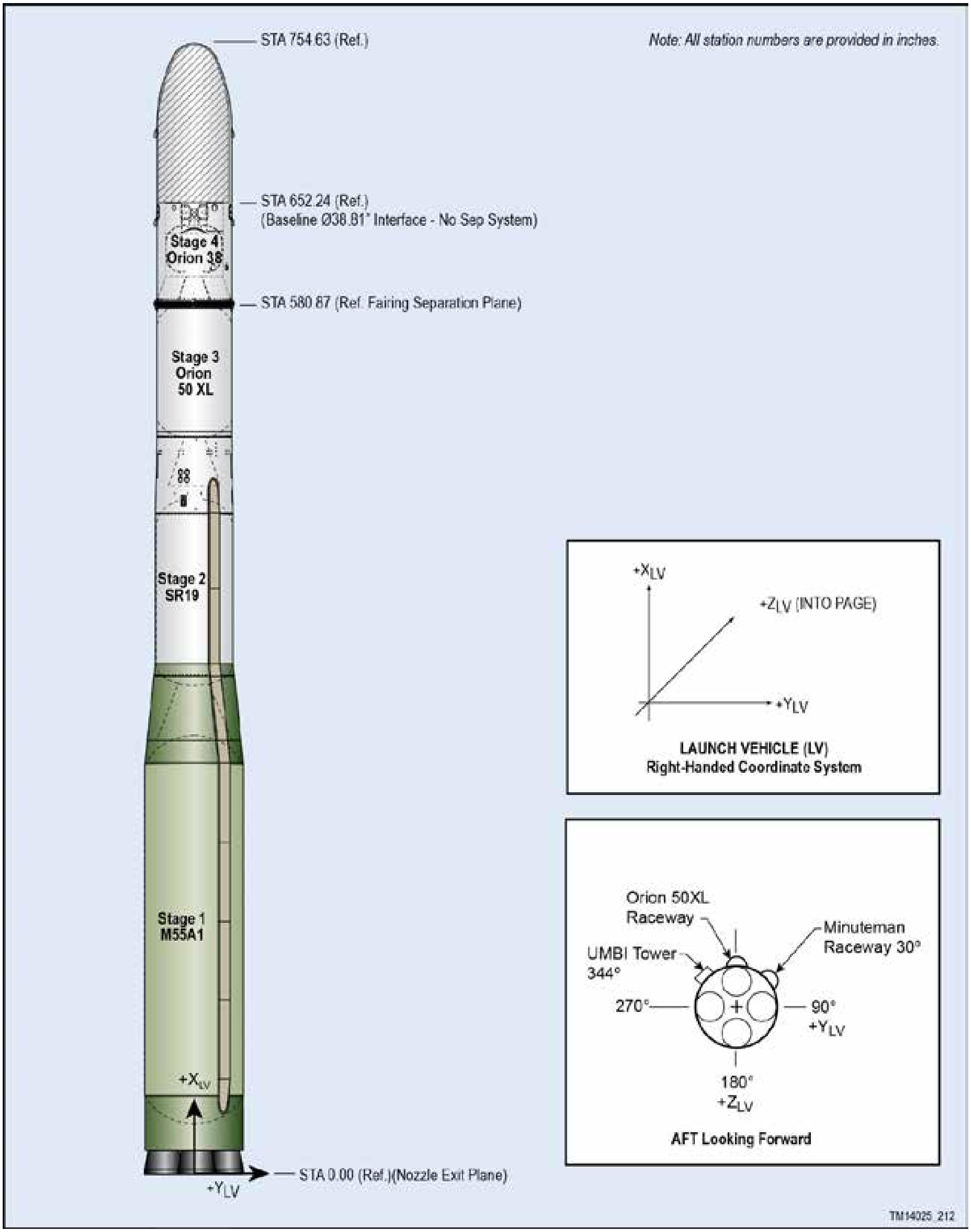


Figure 5.2.1-1. Minotaur Coordinate System

5.2.2. NGIS-Supplied Mechanical Interface Control Drawing

NGIS will provide a toleranced Mechanical Interface Control Drawing (MICD) to the payload contractor to allow accurate machining of the fastener holes. The NGIS provided MICD is the only approved documentation for drilling the payload interface.

5.2.3. Standard Non-Separating Mechanical Interface

NGIS' payload interface design provides a standard interface that will accommodate multiple payload configurations. The Minotaur I baseline is for payloads that provide their own separation system and payloads that will not separate. The standard interface is a 986 mm (38.81 in.) diameter bolted interface. A butt joint with 60 holes (0.281 in. diameter) designed for ¼" fasteners is the payload mounting surface as shown in Figure 5.2.3-1.

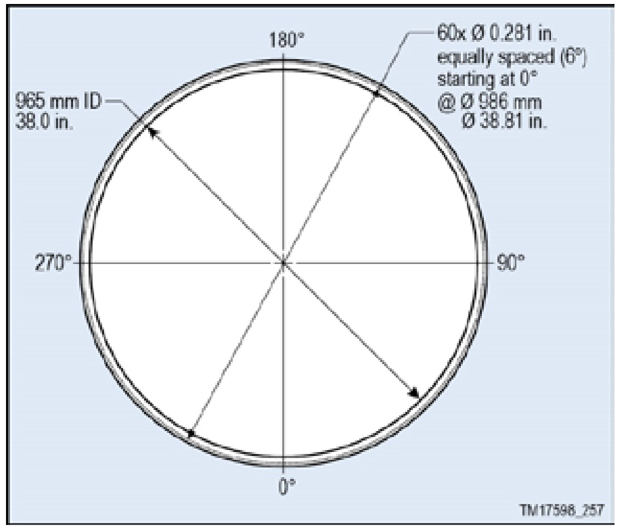


Figure 5.2.3-1. Standard, Non-separating 38.81" Diameter Payload Mechanical Interface

The Minotaur I avionics section is designed to accommodate a 680 kg (1500 lbm) payload with a CG 762 mm (30 in.) above the fixed interface flange. Therefore, as an initial guideline, payload mass times its CG location above this fixed interface needs to be less than or equal to a mass moment of 51,820 kg-cm (45,000 lbm-in.). The payload mass and CG location must include the Payload Attach Fitting (PAF) hardware (adapter cone, separation system, isolation system, etc.), in addition to the actual spacecraft mass properties.

5.2.4. Optional Mechanical Interface

Alternate or multiple payload configurations can be accommodated with the use of a variety of payload adapter fittings. Minotaur I launch vehicles allow flexibility in mounting patterns and configurations.

5.2.4.1. Dual and Multi Payload Adapter Fittings

The Minotaur launch vehicle design flexibility and performance readily accommodates multiple spacecraft that are independently deployed when required as a non-standard service. Minotaur I has demonstrated multiple payload adapter systems, such as the JAWSAT mission, which successfully deployed five satellites and six picosats, as well as load bearing satellites such as the COSMIC mission, which successfully deployed six independent spacecraft.

5.2.4.1.1. Load-Bearing Spacecraft

Use of load-bearing spacecraft maximizes use of available volume and mass. In this case, the aft load-bearing spacecraft interfaces directly to the avionics assembly interface and to the forward spacecraft via pre-determined spacecraft to spacecraft interfaces.

The requirements levied upon spacecraft in this scenario are those involving mechanical and electrical compatibility with the interfacing spacecraft as well as the launch vehicle. Structural loads from forward satellites during all flight events must be transmitted through the aft satellites to the Minotaur I. NGIS will provide LV minimum structural interface design criteria for shear, bending moment, axial and lateral loads, and stiffness.

Another available approach involves the use of a spacecraft design using the NGIS MicroStar bus which was successfully developed and flown for ORBCOMM. The MicroStar bus features a circular design with an innovative, low-shock separation system. The spacecraft bus is designed to allow stacking of co-manifested payloads in "slices" within the fairing. The bus design is compact and provides exceptional lateral stiffness. This approach was flown on the COSMIC mission and is shown in Figure 5.2.4.1.1-1.

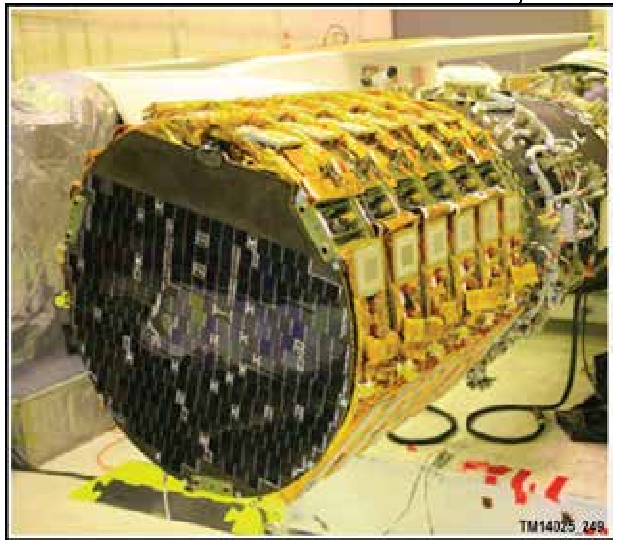


Figure 5.2.4.1.1-1. COSMIC Spacecraft Configuration Utilized the NGIS MicroStar Bus to Fly Six SVs

To avoid the complications involved in spacecraft to spacecraft interfaces and loads, NGIS can provide a mission unique Multi-Payload Adapter (MPA). An example of this approach was flown on the JAWSAT mission, in which the primary payload (JAWSAT) was a Multiple Payload Adapter (MPA) from which four small satellites were separated (Figure 5.2.4.1.1-2). After separating the smaller "piggy-back" satellites, the JAWSAT MPA was also separated as an autonomous satellite by utilizing the NGIS 23" separation system and adapter cone. An updated concept to provide greater payload options and primary payload volume (by mounting directly to the avionics assembly without a separate PAF) is shown in Figure 5.2.4.1.1-3.

Figure 5.2.4.1.1-2. JAWSAT Multiple Payload Adapter Load Bearing Spacecraft

For each of these options, integrated coupled loads analyses will be performed with test verified math models provided by the spacecrafts/payloads. These analyses are required to verify the fundamental frequency and deflections of the stack for compliance with the Minotaur I requirements. Design criteria provided by NGIS will include "stack" margins to minimize interactive effects associated with potential design changes of each spacecraft. NGIS will provide the necessary engineering coordination between the SV and LV.

5.2.4.1.2. Non Load-Bearing Spacecraft – Dual Payload Adapter Fitting (DPAF)

The Minotaur I DPAF option supports delivery of two independent spacecraft to orbit (Figure 5.2.4.1.2-1). The lower payload is encompassed inside the 50" DPAF structure. This configuration assumes use of the Minotaur I 61" fairing that has the available envelope to support a large upper spacecraft and the 50" DPAF structure. The design of the DPAF incorporates a light weight graphite structure which provides independent load paths for each satellite. The upper spacecraft loads are transmitted around the lower spacecraft via the DPAF structure, thus avoiding any structural interface between the two payloads. The structure that supports the dual payload configuration includes a 50" cylindrical section that is configurable in height depending on payload unique requirements. The primary payload is mounted to the top of this DPAF structure using a 38.8" separation system. The lower payload resides within the DPAF structure during flight through primary payload deployment. After the primary payload is deployed, the DPAF structure is released using a separation system that reveals the secondary payload. The secondary payload is released using a 38.8" separation system at the 38.8" interface or via a smaller separation system mounted to a payload adaptor cone. As spacecraft have many options in separation systems that are available to support a given mission, both primary and secondary payload release mechanisms are not included in this enhancement as they are addressed in Section 8.1.

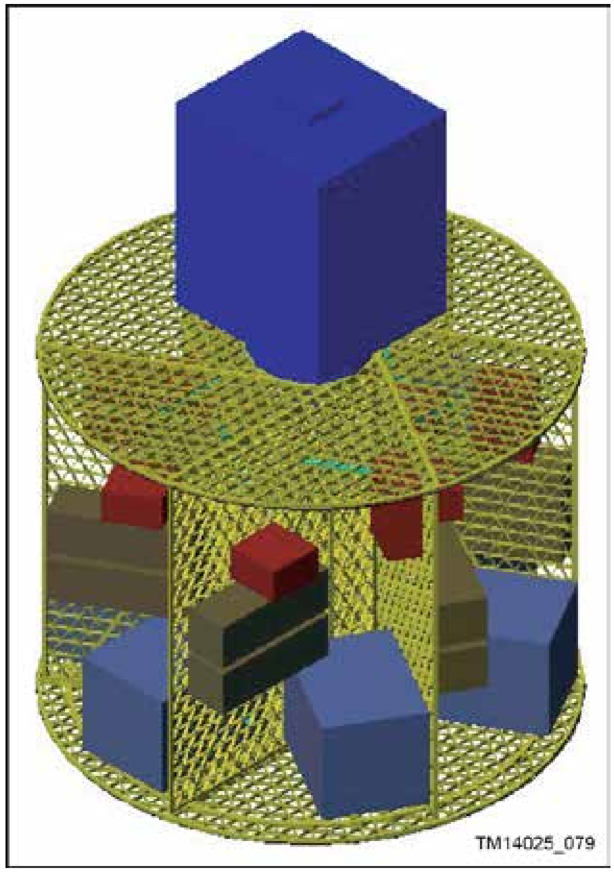


Figure 5.2.4.1.1-3. Five Bay Multiple Payload Adapter Concept

5.2.5. Optional Separation Systems

Three separation system options are offered as flight proven enhancements for Minotaur I. All systems are configurable to various interface diameters and have extensive flight history. These separation systems include the NGIS marmon clamp band system, Planetary Systems Corp. Motorized Lightband (MLB) System, and RUAG low-shock marmon clamp band system. Through this enhancement, NGIS procures the qualified separation system hardware, conducts separation testing and analyses, and integrates the system onto the launch vehicle. The separation system options are summarized in Table 5.2.5-1.

The primary separation parameters associated with a separation system are SV tip-off and overall separation velocity. SV tip-off refers to the angular velocity imparted to the SV upon separation due to SV CG offsets and an uneven distribution of torques and forces. SV tip-off rates induced by the separation systems presented are generally under 1 deg/sec per axis. Entering into the SV separation phase, the launch vehicle reduces vehicle rates. The combined tip-off rate of the separation system and launch vehicle is generally less than 2 deg/sec about each axis when spacecraft mass CG offsets are within specified limits presented in Section 5.4.1. Separation velocities are usually optimized to provide the SV with the lowest separation velocity while ensuring recontact does not occur between the SV and the Minotaur upper stage after separation. The spacecraft is deployed by matched push-

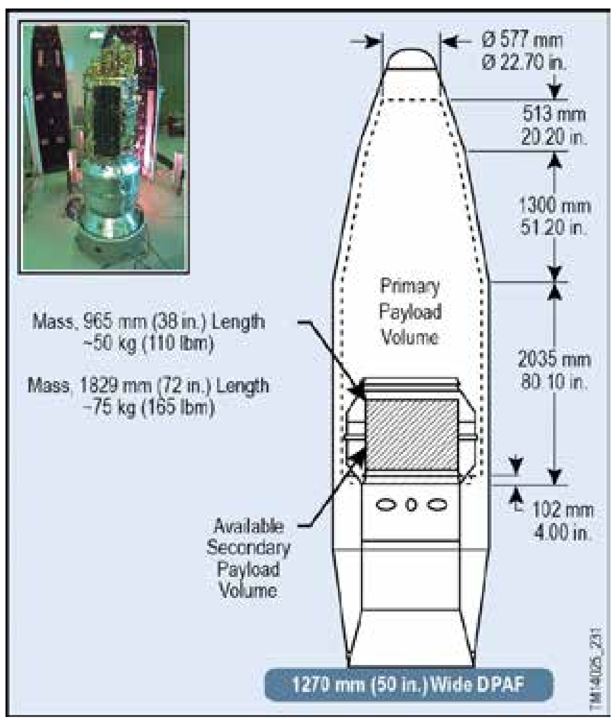
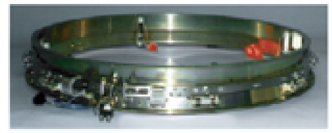
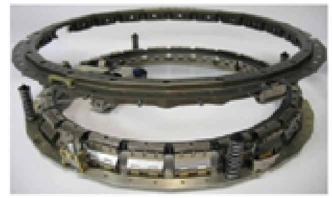


Figure 5.2.4.1.2-1. DPAF Configuration

Table 5.2.5-1. Minotaur I Separation System Options

Separation System	Description	Photo
NGIS 38" Separation System	Height: 100 mm (3.95 in.) SV Interface Diameter: 986 mm (38.81 in.) Total Mass: 12.24 kg (26.95 lbm) Mass Attached to SV Post Sep: 4.0 kg (8.7 lbm) Separation Mechanism: Marmon clamp band with dual redundant bolt cutters	
Planetary Systems Motorized Lightband (MLB)	Height: 53.3 mm (2.10 in.) SV Interface Diameter: 986 mm (38.81 in.) Total Mass: 8.85 kg (19.51 lbm) Mass Attached to SV Post Sep: 2.04 kg (4.50 lbm) Separation Mechanism: Mechanically-actuated hinged leaves with dual redundant release motors	
RUAG 937S Low Shock System	Height: 140.7 mm (5.54 in.) SV Interface Diameter: 986 mm (38.81 in.) Total Mass: 19.89 kg (43.85 lbm) Mass Attached to SV Post Sep: 6.16 kg (13.55 lbm) Separation Mechanism: Clamp band with clamp band opening device (CBOD) that uses redundant ordnance initiated pin puller	 TM14025_246a

off springs with sufficient energy to produce the required relative separation velocity to prevent re-contact with the LV. If non-standard separation velocities are needed, alternative springs may be substituted on a mission-specific basis as a non-standard service. SV separation dynamics are highly dependent on the mass properties of the SV and the particular separation system utilized. Typical separation velocity is 0.6 to 0.9 m/sec (2 to 3 ft/sec). As a standard service, NGIS performs a mission-specific tip-off and separation analyses for each SV.

5.2.5.1. NGIS 38" Separation System

The flight proven NGIS 38" separation system, Figure 5.2.5.1-1, is composed of two rings connected by a marmon clamp band which is separated by redundant bolt cutters. This system has flown successfully on over twenty NGIS launch vehicle missions to date. The weight of hardware separated with the SV is approximately 4.0 kg (8.7 lbm). NGIS-provided attachment bolts to this interface can be inserted from either the launch vehicle or the SV side of the interface via the through-holes in the separation system flange (NAS630xU, fastener length based on SV flange thickness).

In addition to the 38" configuration, NGIS has flight qualified 23" and 17" separation systems. Each of these three systems is based on the marmon clamp band design.

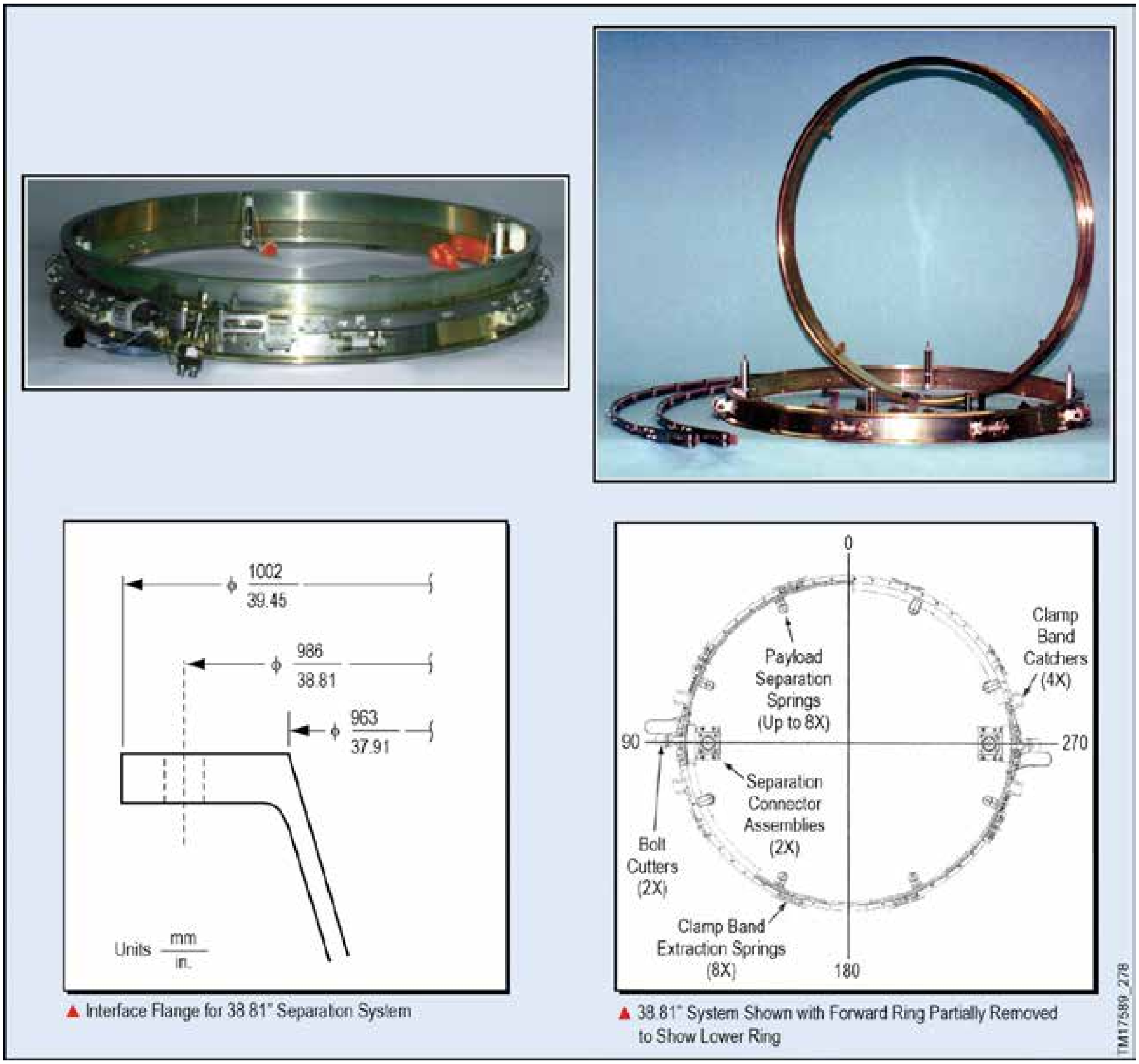


Figure 5.2.5.1-1. NGIS 38" Separation System

5.2.5.2. Planetary Systems Motorized Lightband (MLB)

The Planetary Systems MLB, Figure 5.2.5.2-1, provides a fully qualified and flight proven low shock and lightweight option for use on Minotaur missions. Multiple sizes of MLBs have previously flown on Minotaur vehicles. The MLB uses a system of mechanically-actuated hinged leaves, springs, and a dual redundant release motor to separate the upper ring (mounted to the spacecraft) from the lower ring. The MLB is flexible and configurable to support various separation force requirements and number of required separation connectors. The MLB upper ring interfaces to the spacecraft through holes in the upper ring and remains attached after separation adding approximately 2.04 kg (4.5 lb) of mass. Due to the unique design of the system and space constraints for tooling, NGIS provided socket head cap screw mating hardware must be inserted from the launch vehicle side. The MLB offers the unique ability to perform separation verification tests both at a component and system level.

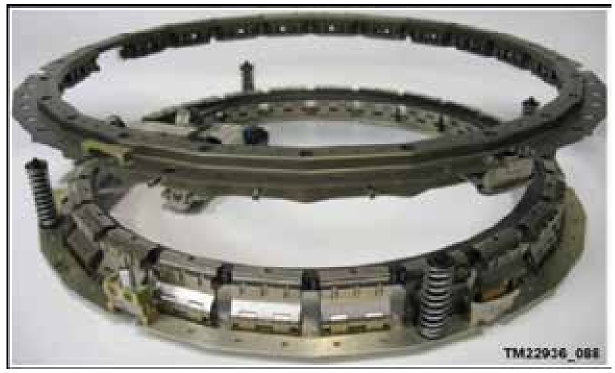


Figure 5.2.5.2-1. 38" Planetary Sciences Motorized Lightband

5.2.5.3. RUAG 937 Separation Systems

The RUAG 937S 38" separation system, Figure 5.2.5.3-1, is a flight proven, low-shock separation system that offers outstanding load capability. This system is composed of two rings and a clamp band separated by a Clamp Band Opening Device (CBOD) rather than traditional bolt cutters. The CBOD uses a redundant, ordnance initiated pin puller device to convert strain energy, created by the clamp band tension, into kinetic energy through a controlled event that greatly reduces separation shock. Hardware separated with the payload is approximately 6.2 kg (13.6 lb) for the 937S. NGIS-provided attachment bolts to this interface can be inserted from either the launch vehicle or the SV side of the interface.

Figure 5.2.5.3-1. RUAG 937S 38" Separation System

5.3. Payload Electrical Interfaces

The payload electrical interface, shown in Figure 5.3-1, supports battery charging, external power, discrete commands, discrete telemetry, analog telemetry, serial communication, SV separation indications, and up to 16 separate ordnance discretes. If an optional NGIS-provided separation system is utilized, NGIS will provide all the wiring through the separable interface plane. If the option is not exercised the spacecraft will be responsible to provide the separation connectors and wiring through the separation plane.

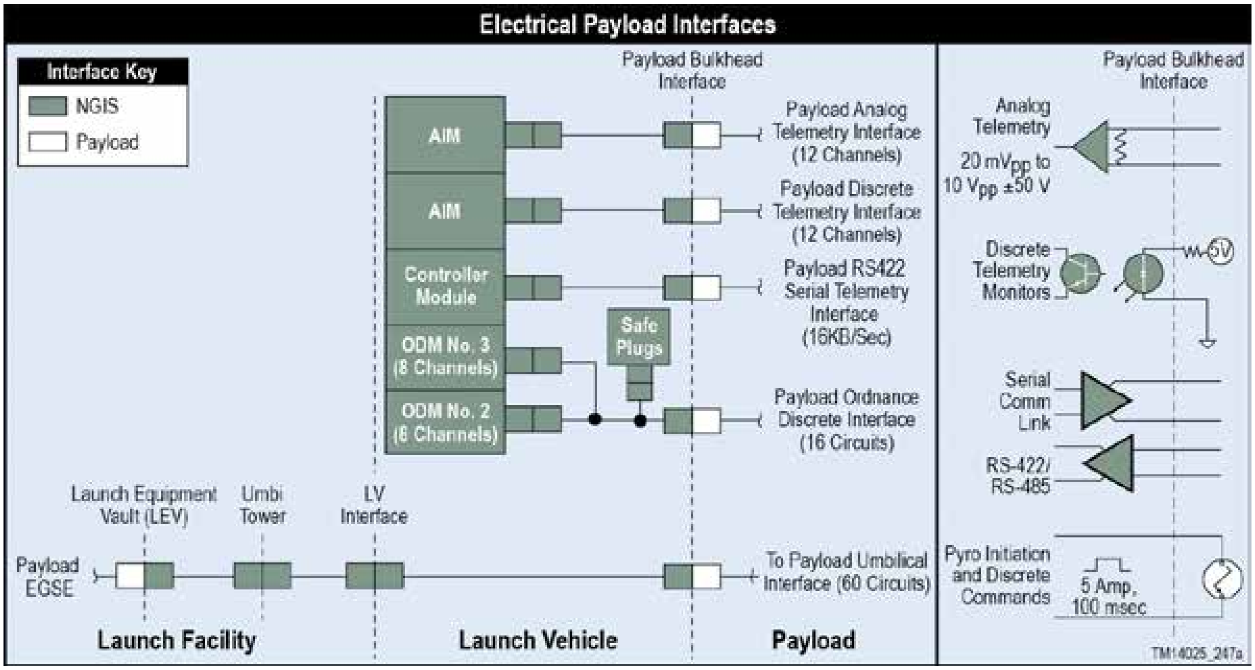


Figure 5.3-1. Payload Electrical Interface Block Diagram Payload Interface Circuitry

5.3.1. Payload Umbilical Interfaces

One dedicated payload umbilical is provided with 60 circuits from the ground to the spacecraft. This umbilical is a dedicated pass through harness for ground processing support. This umbilical allows the SV command, control, monitor, and power to be easily configured per each individual user's requirements. The umbilical wiring is configured as a one-to-one from the Payload/Minotaur interface through to the payload EGSE interface in the Launch Equipment Vault, the closest location for operating customer supplied EGSE equipment. The length of the internal umbilical is approximately 13.7 m (45 ft). The length of the external umbilical from the LEV/SEB to the launch vehicle is approximately 35.1 m (115 ft) to 96.0 m (315 ft) depending on the launch site chosen for the mission.

Figure 5.3.1-1 details the pin outs for the standard interface umbilical. All wires are twisted, shielded pairs, and pass through the entire umbilical system, both vehicle and ground, as one-to-one to simplify and standardize the payload umbilical configuration requirements while providing maximum operational flexibility to the payload provider.

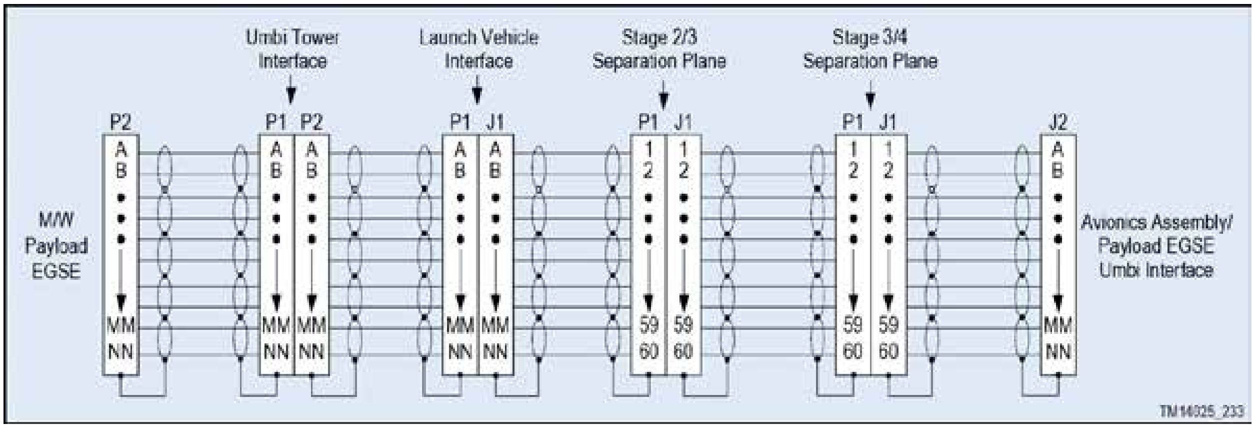


Figure 5.3.1-1. Payload Umbilical 1:1 Pin Outs

5.3.2. Payload Interface Circuitry

Standard interface circuitry passing through the payload-to-launch vehicle electrical connections are shown in Figure 5.3-1. This figure details the interface characteristics for launch vehicle commands, discrete and analog telemetry, separation loopbacks, pyro initiation, and serial communications interfaces with the launch vehicle avionics systems.

5.3.3. Payload Battery Charging

NGIS provides the capability for remote controlled charging of payload batteries, using a customer provided battery charger. This power is routed through the payload umbilical cable. Up to 5.0 amperes per wire pair can be accommodated. The payload battery charger should be sized to withstand the line loss from the LEV to the spacecraft.

5.3.4. Payload Command and Control

The Minotaur standard interface provides discrete sequencing commands generated by the launch vehicle's Ordnance Driver Module (ODM) that are available to the payload as closed circuit opto-isolator command pulses of 5 A in lengths of 35 ms minimum. The total number of ODM discretes is sixteen (16) and can be used for any combination of (redundant) ordnance events and/or discrete commands depending on the SV requirements.

5.3.5. Pyrotechnic Initiation Signals

NGIS provides the capability to directly initiate 16 separate pyrotechnic conductors through two dedicated MACH ODMs. Each ODM provides for up to eight drivers capable of a 5 A, 100 ms, current limited pulse into a 1.5 ohm resistive load. All eight channels can be fired simultaneously with an accuracy of 1 ms between channels. In addition, the ODM channels can be utilized to trigger high impedance discrete events if required. Safing for all SV ordnance events will be accomplished either through an Arm/Disarm (A/D) Switch or Safe Plugs.

5.3.6. Payload Telemetry

The baseline telemetry subsystem capability provides a number of dedicated payload discrete (bi-level) and analog telemetry monitors through dedicated channels in the vehicle encoder. Up to 24 channels will be provided with type and data rate being defined in the mission requirements document. The SV serial and analog data will be embedded in the baseline vehicle telemetry format. For discrete monitors, the SV must provide the 5 Vdc source and the return path. The current at the payload interface must be less than

10 mA. Separation breakwire monitors can be specified if required. The number of analog channels available for payload telemetry monitoring is dependent on the frequency of the data. Payload telemetry requirements and signal characteristics will be specified in the Payload ICD and should not change once the final telemetry format is released at approximately L-6 months. NGIS will record, archive, and reduce the data into a digital format for delivery to the payloaders for review.

Due to the use of strategic assets, Minotaur I telemetry is subject to the provisions of the START treaty. These provisions require that certain Minotaur I telemetry be unencrypted and provided to the START treaty office for dissemination to the signatories of the treaty. The extent to which START applies to the payload telemetry will be determined by SMC/ADSL. Encrypted payload telemetry can be added as a non-standard service pending approval by SMC/ADSL and the START treaty office.

5.3.7. Payload Separation Monitor Loopbacks

Separation breakwire monitors are required on both sides of the payload separation plane. With the NGIS provided separation systems, Minotaur I provides three separation loopbacks on the launch vehicle side of the separation plane for positive payload separation indication.

It is a Launch Vehicle requirement that the payload provide two separation loopback circuits on the payload side of the separation plane. These are typically wired into different separation connectors for redundancy. These breakwires are used for positive separation indication telemetry and initiation of the C/CAM maneuver.

5.3.8. Telemetry Interfaces

The standard Minotaur I payload interface provides a 16Kbps RS-422/RS-485 serial interface for payload use with the flexibility to support a variety of channel/bit rate requirements, and provide signal conditioning, PCM formatting (programmable) and data transmission bit rates. The number of channels, sample rates, etc. will be defined in the Payload ICD.

5.3.9. Non Standard Electrical Interfaces

Non-standard services such as serial command and telemetry interfaces can be negotiated between NGIS and the payload provider on a mission-by-mission basis. The selection of the separation system could also impact the payload interface design and will be defined in the Payload ICD.

5.3.10. Electrical Launch Support Equipment

NGIS will provide space for a rack of customer supplied EGSE in the LCR, and/or the on-pad Launch Equipment Vault (LEV). The equipment will interface with the launch vehicle/spacecraft through either the dedicated payload umbilical interface or directly through the payload access door. The payload customer is responsible for providing cabling from the EGSE location to the launch vehicle/spacecraft.

Separate payload ground processing harnesses that mate directly with the payload can be accommodated through the payload access door(s) as defined in the Payload ICD.

5.4. Payload Design Constraints

The following sections provide design constraints to ensure payload compatibility with the Minotaur I launch vehicle.

5.4.1. Payload Center of Mass Constraints

Along the Y and Z axes, the payload CG must be within 2.54 cm (1.0 in.) of the vehicle centerline and no more than 30 in. (76.2 cm) forward of the payload interface for the standard configuration. Payloads whose CG extend beyond the 2.54 cm (1.0 in.) lateral offset limit will require NGIS to verify the specific offsets that can be accommodated.

5.4.2. Final Mass Properties Accuracy

In general, the final mass properties statement must specify payload weight to an accuracy of at least 0.5%, the CG to an accuracy of at least 6.4 mm (0.25 in.) in each axis, and the products of inertia to an accuracy of at least 2.7 kg-m^2 (2.0 slug-ft^2) as shown in Table 5.4.2-1. However, these accuracies may vary on a mission specific basis. In addition, if the payload uses liquid propellant, the slosh frequency must be provided to an accuracy of 0.2 Hz, along with a summary of the method used to determine slosh frequency.

Table 5.4.2-1. Payload Mass Properties Measurement Tolerance

Measurement	Accuracy
Mass	±0.5%
Principal Moments of Inertia	±5%
Cross Products of Inertia	±2.7 kg – m^2 (±2.0 sl – ft^2)
Center of Gravity X, Y, and Z Axes	±6.4 mm (±0.25 in.)

5.4.3. Pre-Launch Electrical Constraints

Prior to launch, all payload electrical interface circuits are constrained to ensure there is no current flow greater than 10 mA across the payload electrical interface plane. The primary support structure of the spacecraft shall be electrically conductive to establish a single point electrical ground.

5.4.4. Payload EMI/EMC Constraints

The Minotaur I avionics share the payload area inside the fairing such that radiated emissions compatibility is paramount. NGIS places no firm radiated emissions limits on the payload other than the prohibition against RF transmissions within the payload fairing. Prior to launch, NGIS requires review of the payload radiated emission levels (MIL-STD-461, RE02) to verify overall launch vehicle Electromagnetic Interference (EMI) safety margin (emission) in accordance with MIL-E-6051. Payload RF transmissions are not permitted after fairing mate and prior to an ICD specified time after separation of the payload. An EMI/EMC analysis may be required to ensure RF compatibility.

Payload RF transmission frequencies must be coordinated with NGIS and range officials to ensure non-interference with Minotaur I and range transmissions. Additionally, the customer must schedule all RF tests at the integration site with NGIS in order to obtain proper range clearances and protection.

5.4.5. Payload Dynamic Frequencies

Typically, in order to avoid dynamic coupling of the payload modes with the natural frequency of the vehicle, the spacecraft should be designed with a structural stiffness to ensure that the lateral fundamental frequency of the spacecraft, fixed at the spacecraft interface, is greater than 12 Hz. However, this value is affected significantly by other factors such as the coupled dynamics of the spacecraft, isolation system and/or separation system. Therefore, the final determination of compatibility must be made on a mission-specific basis.

5.4.6. Payload Propellant Slosh

A slosh model should be provided to NGIS in either the pendulum or spring-mass format. Data on first sloshing mode are required and data on higher order modes are desirable. Additional critical model parameters will be established during the mission development process. The slosh model should be provided with the payload finite element model submittals.

5.4.7. System Safety Constraints

NGIS considers the safety of personnel and equipment to be of paramount importance. AFSPCM 91-710 outlines the safety design criteria for Minotaur I payloads. These are compliance documents and must be strictly followed. It is the responsibility of the customer to ensure that the payload meets all OSP-3, NGIS, and range imposed safety standards.

Customers designing payloads that employ hazardous subsystems are advised to contact NGIS early in the design process to verify compliance with system safety standards.

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6. MISSION INTEGRATION

6.1. Mission Management Approach

OSP-3 is managed through U.S. Air Force, Space and Missile Systems Center, Advanced Systems and Development Directorate (SMC/AD), Rocket Systems Launch Program (SMC/ADSL). SMC/ADSL serves as the primary point of contact for the payload customers for the Minotaur I launch service. The organizations involved with the mission integration team are shown in Figure 6.1-1. Open communication between NGIS and the customer, with an emphasis on timely data transfer and prudent decision-making, ensures efficient launch vehicle/payload integration operations.

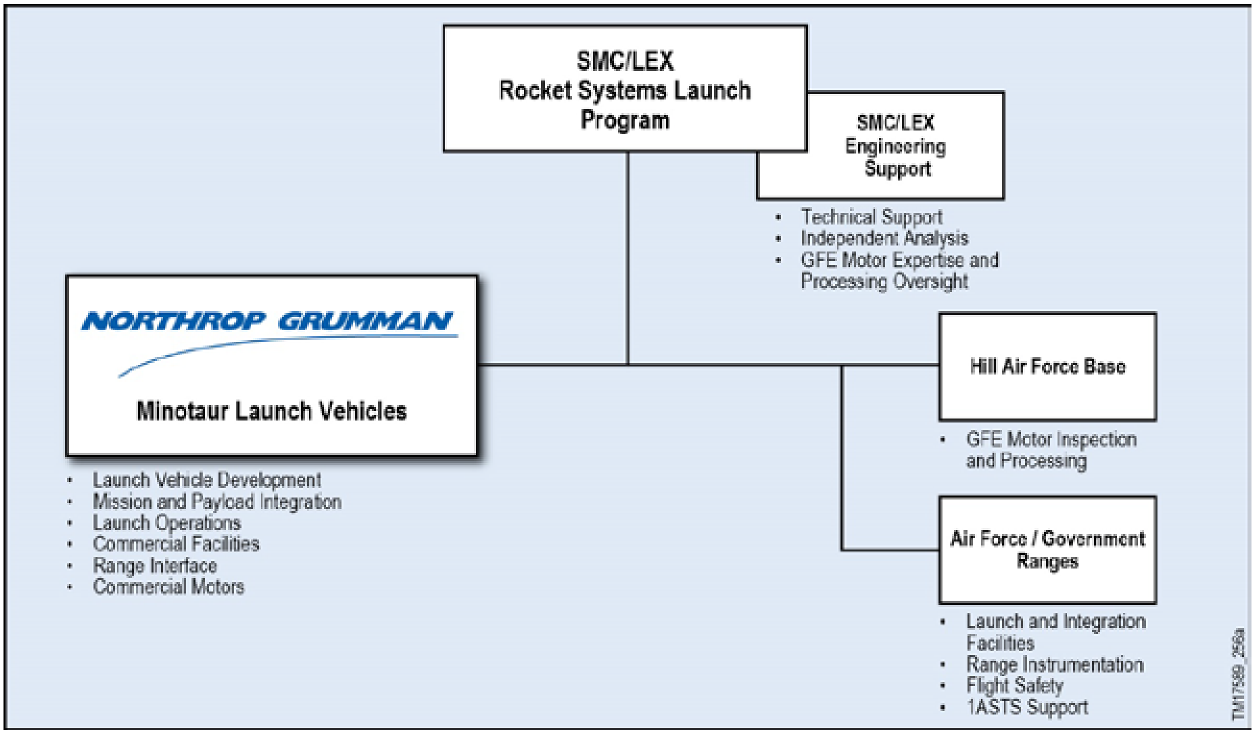

Figure 6.1-1. Mission Integration Team

6.1.1. SMC/ADSL Mission Responsibilities

SMC/ADSL is the primary focal point for all contractual and technical coordination. SMC/ADSL contracts with NGIS to provide the Launch Vehicle, launch integration, and commercial facilities (i.e., spaceports, clean rooms, etc.). Separately, they contract with Government Launch Ranges for launch site facilities and services. Once a mission is identified, SMC/ADSL will assign a government Mission Manager to coordinate all mission planning and contracting activities. SMC/ADSL is supported by associate contractors for both technical and logistical support, capitalizing on their extensive expertise and background knowledge of the Peacekeeper booster and subsystems.

6.1.2. NGIS Mission Responsibilities

As the launch vehicle provider, NGIS' responsibilities fall into four primary areas:

a. Launch Vehicle Program Management
b. Mission Management
c. Engineering
d. Launch Site Operations

The Minotaur organization uses highly skilled personnel with extensive Minotaur experience. The Minotaur program is led by a Program Director who reports directly to NGIS' Launch Systems Group General Manager and has full responsibility for mission success. This direct line to executive management provides high visibility, ensuring access to critical organizational resources. Supporting the Program Director is the Minotaur Chief Engineer, who provides technical direction and oversight to maintain standard practices across NGIS' family of Minotaur launch vehicles.

For new missions, a Program Management team is assigned. Leading this team is the Program Manager, whose primary responsibilities include developing staff requirements, interpreting contract requirements as well as managing schedules and budgets for the mission. A Program Engineering Manager (PEM) is assigned to provide management and technical direction to all engineering department personnel assigned to the mission. The PEM is the single focal point for all engineering activity, and functions as the chief technical lead for the mission and technical advisor to the Program Manager. In addition, the PEM serves as the single point of contact for the OSP-3 Government COR.

NGIS also assigns a Mission Manager that serves as the primary interface to the SMC/ADSL Mission Manager and payload provider. This person has overall mission responsibility to ensure that payload requirements are met and that the appropriate launch vehicle services are provided. They do so via detailed mission planning, payload integration scheduling, systems engineering, mission-peculiar design and analyses coordination, payload interface definition, and launch range coordination. The NGIS Mission Manager will jointly chair Working Group meetings with the SMC/ADSL Mission Manager.

Engineering Leads and their supporting engineers conduct detailed mission design and analyses, perform integration and test activities, and follow hardware to the field site to ensure continuity and maximum experience with that mission's hardware.

Launch Site Operations are carried out by the collective Minotaur team as detailed in Section 7.0. A Launch Site Integration and Operations lead are typically assigned and on-site full-time to manage day-to-day launch site activities.

6.2. Mission Planning and Development

NGIS will assist the customer with mission planning and development associated with Minotaur launch vehicle systems. These services include interface design and configuration control, development of integration processes, launch vehicle analyses and facilities planning. In addition, launch campaign planning that includes range services, integrated schedules and special operations.

The procurement, analysis, integration and test activities required to place a customer's payload into orbit are typically conducted over a 26 month standard sequence of events called the Mission Cycle. This cycle normally begins 24 months before launch, and extends to 8 weeks after launch.

The Mission Cycle is initiated upon receipt of the contract authority to proceed. The contract option designates the payload, launch date, and basic mission parameters. In response, the Minotaur Program Manager designates an NGIS Mission Manager who ensures that the launch service is supplied efficiently, reliably, and on-schedule.

The typical Mission Cycle interweaves the following activities:

a. Mission management, document exchanges, meetings, and formal reviews required to coordinate and manage the launch service.
b. Mission analyses and payload integration, document exchanges, and meetings.
c. Design, review, procurement, testing and integration of all mission-peculiar hardware and software.
d. Range interface, safety, and flight operations activities, document exchanges, meetings and reviews.

Figure 6.2-1 details the typical Mission Cycle and how this cycle folds into the NGIS vehicle production schedule with typical payload activities and milestones. A typical Mission Cycle is based on a 24 month interval between mission authorization and launch. This interval reflects the OSP-3 contractual schedule and has been shown to be an efficient schedule based on NGIS' past program execution experience. OSP-3 does allow flexibility to negotiate either accelerated or extended mission cycles that may be required by unique payload requirements. Payload scenarios that might drive a change in the duration of the mission cycle include those that have funding limitations, rapid response demonstrations, extensive analysis needs or contain highly complex payload-to-launch vehicle integrated designs or tests.

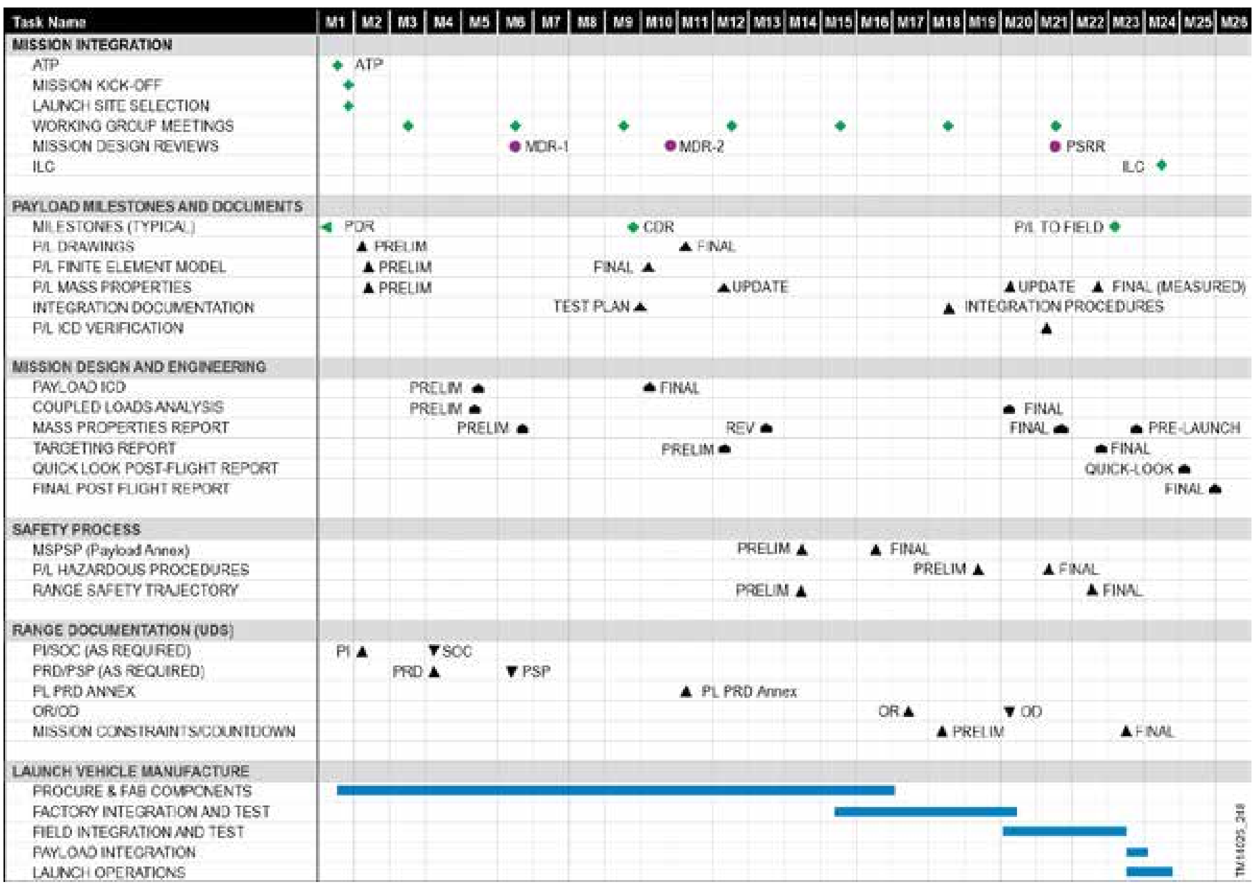

Figure 6.2-1. Typical Minotaur Mission Integration Schedule

A typical mission field integration schedule is provided in Figure 6.2-2. The field integration schedule is adjusted as required based on the mission requirements, launch vehicle configuration and launch site selection.

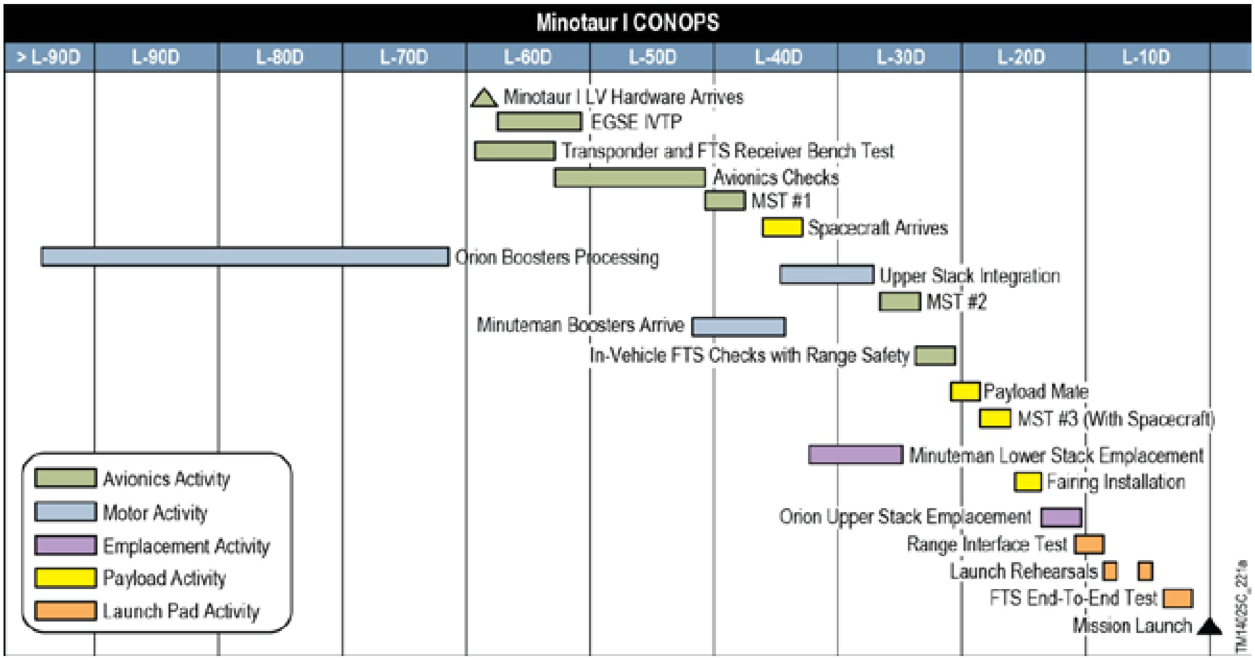

Figure 6.2-2. Typical Mission Field Integration Schedule

6.2.2. Mission Assurance

The OSP-3 contract has three tailored levels of Mission Assurance (MA); Category 1, Category 2 and Category 3. These categories provide progressively increasing levels of government oversight, above and beyond NGIS rigorous internal MA standards.

Category 1 MA is the simplest, relying on NGIS' robust internal MA standards and processes, and does not required SMC flight worthiness certification or Government Independent Verification and Validation (IV&V) oversight. Category 1 missions will be licensed under Federal Aviation Administration (FAA) licensing guidelines.

Category 2 MA builds upon Category 2 and dictates that NGIS provide additional information and support for the government's MA efforts and the government's Independent Readiness Review Team (IRRT). NGIS will provide support for SMC/AD's Spaceflight Worthiness Certification, independent IV&V, requirements decomposition and verification, testing (planning, qualification, design verification), as well as additional reviews and activities both pre and post launch. Category 2 MA represents what has traditionally been the standard level of MA on past Minotaur missions.

Category 3 MA builds upon the requirements of Category 2 and is subject to increased breadth and depth of government IV&V and insight. Up to ten dedicated IRRT reviews may be required, with monthly 1-day Program Management Reviews throughout the period of performance, as well as weekly 2-hour telecons to communicate current status of concerns and action items. Category 3 is intended mainly for high value DoD missions similar to Acquisition Category 1 (ACAT-1).

6.3. Mission Integration Process

6.3.1. Integration Meetings

The core of the mission integration process consists of a series of Mission Integration and Range Working Groups (MIWG and RWG, respectively). The MIWG has responsibility for all physical interfaces between the payload and the launch vehicle. As such, the MIWG develops the Payload-to-Minotaur ICD in addition to all mission-unique analyses, hardware, software, and integrated procedures. The RWG is responsible for items associated with launch site operations. Examples of such items include range interfaces, hazardous procedures, system safety, and trajectory design. Documentation produced by the RWG includes all required range and safety submittals.

Working Group membership consists of the Mission Manager and representatives from Minotaur I engineering and operations organizations, as well as their counterparts from the customer organization. While the number of meetings, both formal and informal, required to develop and implement the mission integration process will vary with the complexity of the spacecraft, quarterly meetings are typical.

6.3.2. Mission Design Reviews (MDR)

Two mission-specific design reviews will be held to determine the status and adequacy of the launch vehicle mission preparations. They are designated MDR-1 and MDR-2 and are typically held 6 months and 13 months, respectively, after authority to proceed. They are each analogous to Preliminary Design Reviews (PDRs) and Critical Design Reviews (CDRs), but focus primarily on mission-specific elements of the launch vehicle effort.

6.3.3. Readiness Reviews

During the integration process, readiness reviews are held to provide the coordination of mission participants and gain approval to proceed to the next phase of activity from senior management. Due to the variability in complexity of different payloads, missions, and mission assurance categories, the content and number of these reviews are tailored to customer requirements. A brief description of each readiness review is provided below:

a. **Pre-Ship Readiness Review** — Conducted prior to committing flight hardware and personnel to the field. The PSRR provides testing results on all formal systems tests and reviews the major mechanical assemblies which are completed and ready for shipping at least T-60 days. Safety status and field operations planning are also provided covering Range flight termination, ground hazards, spaceport coordination status, and facility preparation and readiness.
b. **Incremental Readiness Review (IRR)** – The quantity and timing of IRR(s) depends on the complexity and Mission Assurance Category of the mission. IRRs typically occur 2-12 months prior to the launch date. IRR provides an early assessment of the integrated launch vehicle/payload/facility readiness.
c. **Mission Readiness Review (MRR)** — Conducted within 2 months of launch, the MRR provides a pre-launch assessment of integrated launch vehicle/payload/facility readiness prior to committing significant resources to the launch campaign.
d. **Flight Readiness Review (FRR)** – The FRR is conducted at L-10 days and determines the readiness of the integrated launch vehicle/payload/facility for a safe and successful launch. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.
e. **Launch Readiness Review (LRR)** — The LRR is conducted at L-1 day and serves as the final assessment of mission readiness prior to activation of range resources on the day of launch.

6.4. Documentation

Integration of the payload requires detailed, complete, and timely preparation and submittal of interface documentation. SMC/ADSL is the primary communication path with other U.S. Government agencies, which include—but are not limited to—the various Ranges and their support agencies, the U.S. Department of Transportation, U.S. State Department, and U.S. Department of Defense. The major products and submittal times associated with these organizations are divided into two areas—those products that are provided by the customer, and those produced by NGIS. Customer-provided documents represent the formal communication of requirements, safety data, system descriptions, and mission operations planning.

6.4.1. Customer-Provided Documentation

Documentation produced by the customer is detailed in the following paragraphs.

6.4.1.1. Payload Questionnaire

The Payload Questionnaire is designed to provide the initial definition of payload requirements, interface details, launch site facilities, and preliminary safety data. Prior to the Mission Kickoff Meeting, the customer shall provide the information requested in the Payload Questionnaire form (Appendix A). Preliminary payload drawings, as well as any other pertinent information, should also be included with the response. The customer's responses to the payload questionnaire define the most current payload requirements and interfaces and are instrumental in NGIS' preparation of numerous documents including the ICD, Preliminary Mission Analyses and launch range documentation. NGIS understands that a definitive response to some questions may not be feasible prior to the Mission Kickoff Meeting as they will be defined during the course of the mission integration process.

6.4.1.2. ICD Inputs

The LV-to-payload ICDs (mission, mechanical and electrical) detail all the mission specific requirements agreed upon by NGIS and the customer. These key documents are used to ensure the compatibility of all launch vehicle and payload interfaces, as well as defining all mission-specific and payload- unique requirements. As such, the customer defines and provides to NGIS all the inputs that relate to the payload. These inputs include those required to support flight trajectory development (e.g., orbit requirements, payload mass properties, and payload separation requirements), mechanical and electrical interface definition, payload unique requirements, payload operations, and ground support requirements.

6.4.1.3. Payload Mass Properties

Payload mass properties must be provided in a timely manner in order to support efficient launch vehicle trajectory development and dynamic analyses. Preliminary mass properties should be submitted as part of the MRD at launch vehicle authority to proceed. Updated mass properties shall be provided at predefined intervals identified during the initial mission integration process. Typical timing of these deliveries is included in Figure 6.2-1.

6.4.1.4. Payload Finite Element Model

A payload mathematical model is required for use in NGIS' preliminary coupled loads analyses. Acceptable forms include either a Craig-Bampton model valid to 120 Hz or a NASTRAN finite element model. For the final coupled loads analysis, a test verified mathematical model is desired.

6.4.1.5. Payload Thermal Model for Integrated Thermal Analysis

An integrated thermal analysis can be performed for any payload as a non-standard service. A payload thermal model will be required from the payload organization for use in NGIS' integrated thermal analysis if it is required. The analysis is conducted for three mission phases:

a. Prelaunch ground operations
b. Ascent from lift-off until fairing jettison
c. Fairing jettison through payload deployment

The preferred thermal model format is Thermal Desktop, although FEMAP and SINDA/G can also be provided. There is no limit on model size; however, larger models may increase the turn-around time.

6.4.1.6. Payload Drawings

NGIS prefers electronic versions of payload configuration drawings to be used in the mission specific interface control drawing, if possible. NGIS will work with the customer to define the content and desired format for the drawings.

6.4.1.7. Program Requirements Document (PRD) Mission Specific Annex Inputs

In order to obtain range support, a PRD must be prepared. This document describes requirements needed to generally support the Minotaur launch vehicle. For each launch, an annex is submitted to specify the range support needed to meet the mission's requirements. This annex includes all payload requirements as well as any additional Minotaur I requirements that may arise to support a particular mission. The customer completes all appropriate PRD forms for submittal to NGIS.

6.4.1.7.1. Launch Operations Requirements (OR) Inputs

To obtain range support for the launch operation and associated rehearsals, an OR must be prepared. The customer must provide all payload pre-launch and launch day requirements for incorporation into the mission OR.

6.4.1.8. Payload Launch Site Integration Procedures

For each mission, NGIS requires detailed spacecraft requirements for integrated launch vehicle and payload integration activities. With these requirements, NGIS will produce the integrated procedures for all launch site activities. In addition, all payload procedures that are performed near the LV (either at the integration facility or at the launch site or both) must be presented to NGIS for review prior to first use.

6.4.1.9. ICD Verification Documentation

NGIS conducts a rigorous verification program to ensure all requirements on both sides of the launch vehicle-to-payload interface have been successfully fulfilled. As part of the ICD, NGIS includes a verification matrix that indicates how each ICD requirement will be verified (e.g., test, analysis, demonstration, etc.). As part of the verification process, NGIS will provide the customer with a matrix containing all interface requirements that are the responsibility of the payload to meet. The matrix clearly identifies the documentation to be provided as proof of verification. Likewise, NGIS will ensure that the customer is provided with similar data for all interfaces that are the responsibility of launch vehicle to verify.

6.4.2. NGIS Produced Documentation, Data, and Analyses

Mission documentation produced by NGIS is detailed in the following paragraphs.

6.4.2.1. Launch Vehicle to Payload ICD

The launch vehicle-to-payload ICD details all of the mission-unique requirements agreed upon by NGIS and the customer. The ICD is a critical document used to ensure compatibility of all launch vehicle and payload interfaces, as well as defining all mission-specific and mission-unique requirements. The ICD contains the payload description, electrical and mechanical interfaces, environmental requirements, targeting parameters, mission-peculiar vehicle requirement description, and unique GSE and facilities required. As a critical part of this document, NGIS provides a comprehensive matrix that lists all ICD requirements and the method in which these requirements are verified, as well as who is responsible.

The launch vehicle to payload ICD, as well as the Payload Mechanical ICD and Electrical ICD are configuration controlled documents that are approved by NGIS and the customer. Once released, changes to these documents are formally issued and approved by both parties. The ICDs are reviewed in detail as part of the MIWG process.

6.4.2.2. ICD Verification Documentation

NGIS conducts a rigorous verification program to ensure all requirements on both sides of the launch vehicle-to-payload interface have been successfully fulfilled. Like the customer-provided verification data discussed in Section 6.4.1.9, NGIS will provide the customer with similar data for all interfaces that are the responsibility of launch vehicle to verify. This documentation is used as part of the team effort to show that a thorough verification of all ICD requirements has been completed.

6.4.2.3. Preliminary Mission Analyses

NGIS performs preliminary mission analyses to determine the compatibility of the payload with the Minotaur launch vehicle and to provide succinct, detailed mission requirements such as launch vehicle trajectory information, performance capability, accuracy estimates and preliminary mission sequencing. Much of the data derived from the preliminary mission analyses is used to establish the ICD and to perform initial range coordination.

6.4.2.4. Coupled Loads Analyses (CLA)

NGIS has developed and validated finite element structural models of the Minotaur vehicle for use in CLAs with Minotaur payloads. NGIS will incorporate the customer-provided payload model into the Minotaur finite element model and perform a preliminary CLA to determine the maximum responses of the entire integrated stack under transient loads. Once a test validated spacecraft model has been delivered to NGIS, a final CLA load cycle is completed. Through close coordination between the customer and the NGIS, interim results can be made available to support the customer's schedule critical needs.

6.4.2.5. Integrated Launch Site Procedures

For each mission, NGIS prepares integrated procedures for various operations that involve the payload at the processing facility and launch site. These include, but are not limited to: payload mate to the Minotaur launch vehicle; fairing encapsulation; mission simulations; final vehicle closeouts, and transport of the integrated launch vehicle/payload to the launch pad. Once customer inputs are received, NGIS will develop draft procedures for review and comment. Once concurrence is reached, final procedures will be released prior to use. Draft hazardous procedures must be presented to the appropriate launch site safety organization 90 days prior to use and final hazardous procedures are due 45 days prior to use.

6.4.2.6. Missile System Pre-Launch Safety Package (MSPSP) Annex

The MSPSP Annex documents launch vehicle and payload safety information including an assessment of any hazards which may arise from mission-specific vehicle and/or payload functions, and is provided as an annex to the baseline Minotaur MSPSP. The customer must provide NGIS with all safety information pertaining to the payload. NGIS assesses the combined vehicle and payload for hazards and prepares a report of the findings. NGIS will then forward the integrated assessment to the appropriate launch Range for approval.

6.4.2.7. PRD Mission Specific Annex

Once customer PRD inputs are received, NGIS reviews the inputs and upon resolving any concerns or potential issues, submits the mission specific PRD annex to the range for approval. The range will respond with a Program Support Plan (PSP) indicating their ability to support the stated requirements.

6.4.2.8. Launch Operation Requirements (OR)

NGIS submits the OR to obtain range support for pre-launch and launch operations. Information regarding all aspects of launch day, particularly communication requirements, is detailed in the OR. NGIS generates the document, solicits comments from the customer, and, upon comment resolution, delivers the mission OR to the range. The range generates the Operations Directive (OD) that is used by range support personnel as the instructions for providing the pre-launch and launch day services.

6.4.2.9. Mission Constraints Document (MCD)

This NGIS-produced document summarizes launch day operations for the Minotaur launch vehicle as well as for the payload. Included in this document is a comprehensive definition of the Minotaur and payload launch operations constraints, the established criteria for each constraint, the decision making chain of command, and a summary of personnel, equipment, communications, and facilities that will support the launch.

6.4.2.10. Final Countdown Procedure

NGIS produces the launch countdown procedure that readies the Minotaur launch vehicle and payload for launch. All Minotaur and payload final countdown activities are included in the procedure.

6.4.2.11. Post-Launch Analyses

NGIS provides post-launch analyses to the customer in two forms. The first is a quick-look assessment provided within four days of launch. The quick-look data report includes preliminary trajectory performance data, orbital accuracy estimates, system performance preliminary evaluations, and a preliminary assessment of mission success.

The second post-launch analysis, a more detailed final report of the mission, is provided to the customer within 30 days of launch. Included in the final mission report are the actual mission trajectory, event times, significant events, environments, orbital parameters and other pertinent data from on-board telemetry and Range tracking sensors. Photographic and video documentation, as available, is included as well.

NGIS also analyzes telemetry data from each launch to validate Minotaur performance against the mission ICD requirements. In the case of any mission anomaly, NGIS will conduct an investigation and closeout review.

6.5. Safety

6.5.1. System Safety Requirements

In the initial phases of the mission integration effort, regulations and instructions that apply to spacecraft design and processing are reviewed. Not all safety regulations will apply to a particular mission integration activity. Tailoring the range requirements to the mission unique activities will be the first step in establishing the safety plan.

Before a spacecraft arrives at the processing site, the payload organization must provide the cognizant range safety office with certification that the system has been designed and tested in accordance with applicable safety requirements (e.g. AFSPCM 91-710 for CCAFS and VAFB). Spacecraft must also comply with the specific payload processing facility safety requirements. NGIS will provide the customer assistance and guidance regarding applicable safety requirements.

It cannot be overstressed that the applicable safety requirements should be considered in the earliest stages of spacecraft design. Processing and launch site ranges discourage the use of waivers and variances. Furthermore, approval of such waivers cannot be guaranteed.

6.5.2. System Safety Documentation

For each Minotaur mission, NGIS acts as the interface with Range Safety. In order to fulfill this role, NGIS requires safety information from the payload. For launches from either the Eastern or Western Ranges, AFSPCM 91-710 provides detailed range safety regulations. To obtain approval to use the launch site facilities, specific data must be prepared and submitted to NGIS. This information includes a description of each payload hazardous system and evidence of compliance with safety requirements for each system. Drawings, schematics, and assembly and handling procedures, including proof test data for all lifting equipment, as well as any other information that will aid in assessing the respective systems should be included. Major categories of hazardous systems are ordnance devices, radioactive materials, propellants, pressurized systems, toxic materials, cryogenics, and RF radiation. Procedures relating to these systems as well as any procedures relating to lifting operations or battery operations should be prepared for safety review submittal. NGIS will provide this information to the appropriate safety offices for approval.

7. GROUND AND LAUNCH OPERATIONS

Minotaur ground and launch operations processing minimizes the handling complexity for both launch vehicle and payload. All launch vehicle motors, parts and completed subassemblies are delivered to the Minotaur Processing Facility (MPF) from either NGIS' Chandler production facility, the assembly/motor vendor, or the Government. Ground and launch operations are conducted in three major phases:

a. **Launch Vehicle Integration —** Assembly and test of the Minotaur launch vehicle.
b. **Payload Processing/Integration —** Receipt and checkout of the payload, followed by integration with the Minotaur launch vehicle interface, verification of those interfaces and payload encapsulation.
c. **Launch Operations —** Includes transport of the upper stack to the launch pad, final integration, checkout, arming and launch.

Figure 7-1 depicts the typical flow of hardware from the factory to the launch site.

Figure 7-1. Hardware Flow – Factory to Launch Site

7.1. Launch Vehicle Integration Overview

NGIS utilizes the same fundamental integration and process flow for all launch vehicles in the Minotaur family. A flow chart of the launch vehicle integration at the MPF is shown in Figure 7.1-1 for a VAFB Minotaur I launch. This minimizes the handling complexity for both vehicle and payload. Horizontal integration of the Minotaur I vehicle upper stages simplifies integration procedures, increases safety and provides excellent access for the integration team. In addition, simple mechanical and electrical interfaces reduce vehicle/payload integration times, increase system reliability and minimize vehicle demands on payload availability.

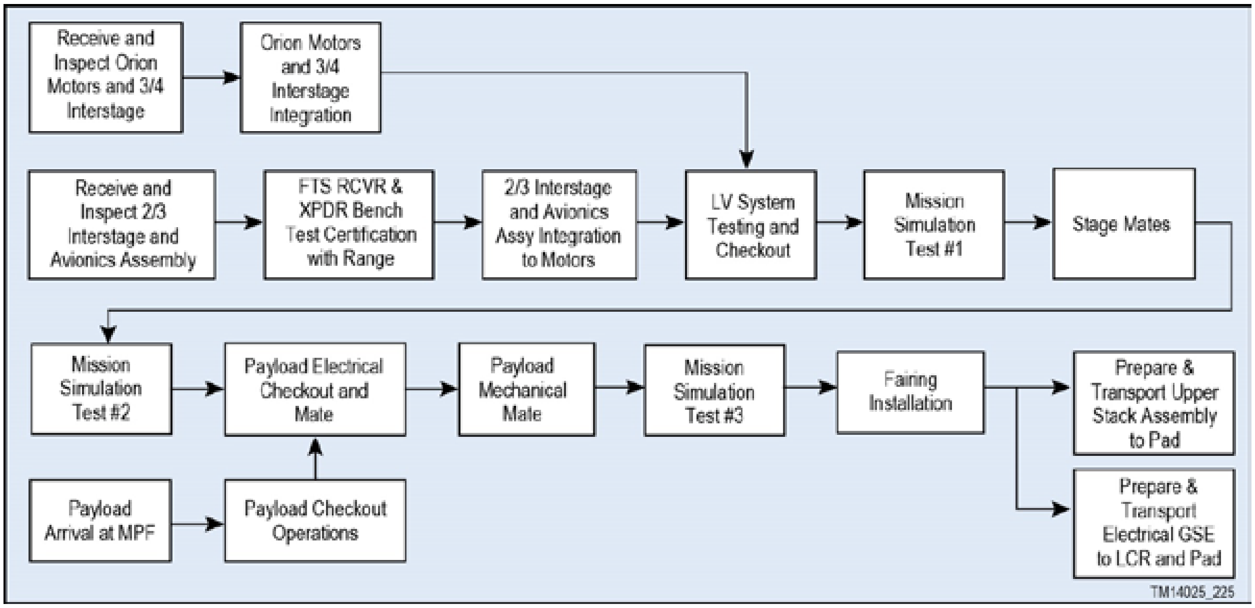

Figure 7.1-1. Launch Vehicle Processing Flow

7.1.1. Planning and Documentation

Minotaur integration and test activities are controlled by a comprehensive set of Work Packages (WPs) that describe and document every aspect of integrating and testing the Minotaur launch vehicle and its payload. All testing and integration activities are scheduled by work package number on an activity schedule that is updated and distributed daily during field operations. This schedule is maintained by NGIS and serves as the master document communicating all activities planned at the field site. The schedule contains notations regarding the status of the work package document and hardware required to begin the operation. Mission-specific work packages are created for mission-unique or payload-specific procedures. Any discrepancies encountered are recorded on a Non-Conformance Report and dispositioned as required. All activities are in accordance with NGIS' ISO 9001 certification.

7.1.2. Upper Stack Assembly Integration and Test Activities

The upper stack assembly will undergo system level testing at NGIS' Chandler facility prior to being shipped to the field. The major vehicle components and subassemblies that comprise the Minotaur I Upper Stack Assembly, including the Stage 3 and Stage 4 Orion motors, are delivered to NGIS' MPF located at VAFB, CA. There, the vehicle is horizontally integrated prior to the arrival of the payload. Integration is performed at a convenient working height, which allows easy access for component installation, inspection and test. The integration and test process ensures that all vehicle components and subsystems are thoroughly tested.

7.1.3. Minuteman Motor Integration and Test Activities

The Minuteman Stage 1 and 2 motors are refurbished at Hill Air Force Base. They also undergo ordnance and raceway installation before being shipped directly to the launch pad for emplacement.

7.1.4. Mission Simulation Tests

NGIS will run three Mission Simulation Tests (MST) to verify the functionality of launch vehicle hardware and software (i.e., MST #1, MST #2, and MST #3). The Mission Simulation Tests use the actual flight software and simulate a "fly to orbit" scenario using simulated Inertial Navigation System (INS) data. This allows the test to proceed throughout all mission phases and capture vehicle performance data. The data will be compared to previous MSTs performed in the factory using the same flight software and hardware. Since the Minuteman motors are not available at the MPF, a high fidelity simulator consisting of actual Minuteman components is used. These components provide a realistic assessment of booster performance during the testing operations. After a thorough data review of all telemetry parameters, the test configuration is disassembled and prepared for payload integration.

The Mission Simulation is repeated after each major change in vehicle configuration (i.e., Mission Simulation #2 after stage mate and Mission Simulation #3 after the payload is mechanically integrated). After each test, a complete review of the data is undertaken prior to proceeding. The payload nominally participates in Mission Simulation #3.

7.1.5. Launch Vehicle Processing Facilities

The Minotaur Processing Facility (MPF), Building 1900, at VAFB is a 48,000 sq. ft facility used primarily for LV processing prior to transporting the LV to the appropriate launch site or range for that mission. For missions out of VAFB, the MPF has adequate floor space and infrastructure to support concurrent launch vehicle and payload processing. An exterior view of the MPF is shown in Figure 7.1.5-1. Should the MPF be utilized for payload processing, it is expected that the payload and Minotaur launch vehicle would be processed in separate sections of the High Bay area.

The MPF has infrastructure capability to support payload processing requirements in terms of security, electrical and communications service, overhead crane, and a temperature and humidity controlled environment. High Cleanliness operations are discussed further in Section 8.2.3.1 as required per the mission and particle containment requirements.

7.2. Payload Processing/Integration

Payloads typically undergo initial checkout and preparation for launch at a Payload Processing Facility, which can be either a government provided or commercial facility. The payload is then sent to the MPF for integration with the Minotaur I upper stack. After arrival at the MPF, the payload completes its own independent verification and checkout prior to beginning the integration process with Minotaur I. Following completion of Minotaur I and payload testing, the payload will be enclosed inside the fairing. The required payload environments are then maintained inside the fairing until launch.

Figure 7.1.5-1. Minotaur I Processing Is Performed at the MPF at VAFB

7.2.1. Payload to Minotaur I Integration

The integrated launch processing activities are designed to simplify final launch processing while providing a comprehensive verification of the payload interface. The systems integration and test sequence is engineered to ensure all interfaces are verified.

7.2.2. Pre-Mate Interface Testing

If required, the electrical interface between Minotaur I and the payload is verified using a mission unique Interface Verification Test (IVT) to jointly verify that the proper function of the electrical connections and commands. These tests, customized for each mission, typically check bonding, electrical compatibility, communications, discrete commands and any off nominal modes of the payload. For pre-mate verification of the mechanical interface, the separation system can also be made available before final payload preparations.

7.2.3. Payload Mating and Verification

Once the payload aft end closeouts are completed, the payload will be both mechanically and electrically mated to the Minotaur I. Following mate, the flight vehicle is ready for the final integrated systems test, Mission Simulation #3.

7.2.4. Final Processing and Fairing Closeout

After successful completion of Mission Simulation #3, all consumables are topped off and ordnance is connected. Similar payload operations may occur at this time. Once consumables are topped off, final vehicle / payload closeout is performed and the fairing is installed. The payload will coordinate with NGIS access to the payload from payload mate until final closeout before launch.

7.2.5. Payload Propellant Loading

Payloads utilizing integral propulsion systems with propellants such as hydrazine can be loaded and secured through coordinated OSP arrangements. This is a non-standard service.

7.3. Launch Operations

At the completion of activities at the MPF and PPF, the final phase of the Launch campaign is entered. This begins with the stacking of the booster stages and culminates with the launch of the Minotaur I and payload. A notional launch operations flow chart is shown in Figure 7.3-1. The L-minus dates may vary from mission to mission depending on vehicle configuration and other range commitments. Launch operations activities are described in more detail in the subsections to follow.

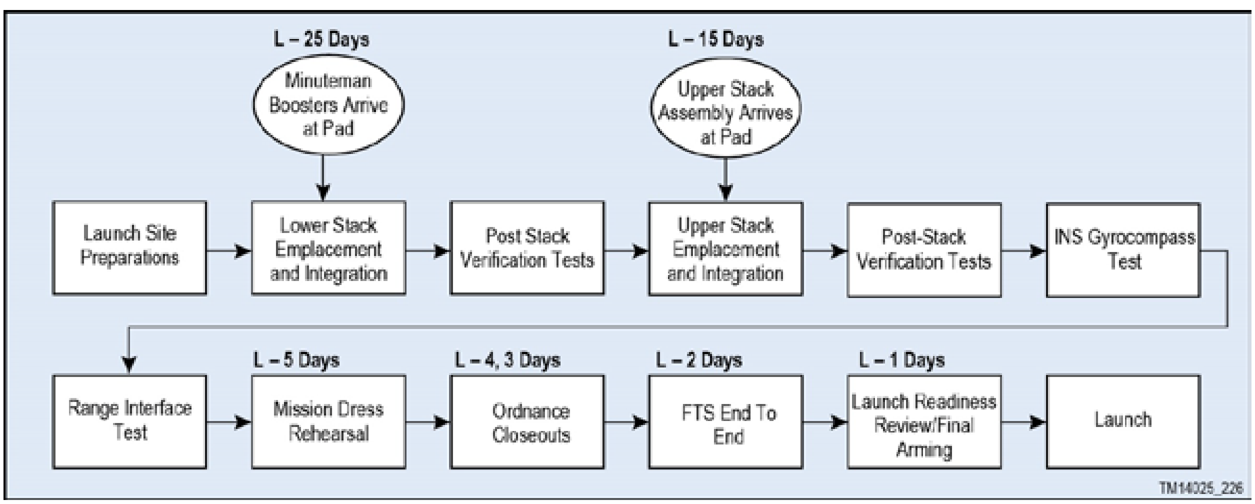

Figure 7.3-1. Minotaur I Launch Site Operations

7.3.1. Booster Assembly Stacking/Launch Site Preparation

Prior to the arrival of the Minuteman boosters, the site is prepared for launch operations with the installation of the launch stand adapter. The Lower Stack Assembly, consisting of the Minuteman motors, is delivered directly to the launch pad from Hill Air Force Base. Following emplacement, the Upper Stack Assembly is horizontally transported from the MPF to the pad and emplaced, as shown in Figure 7.3.1-1 as performed at VAFB SLC-8.

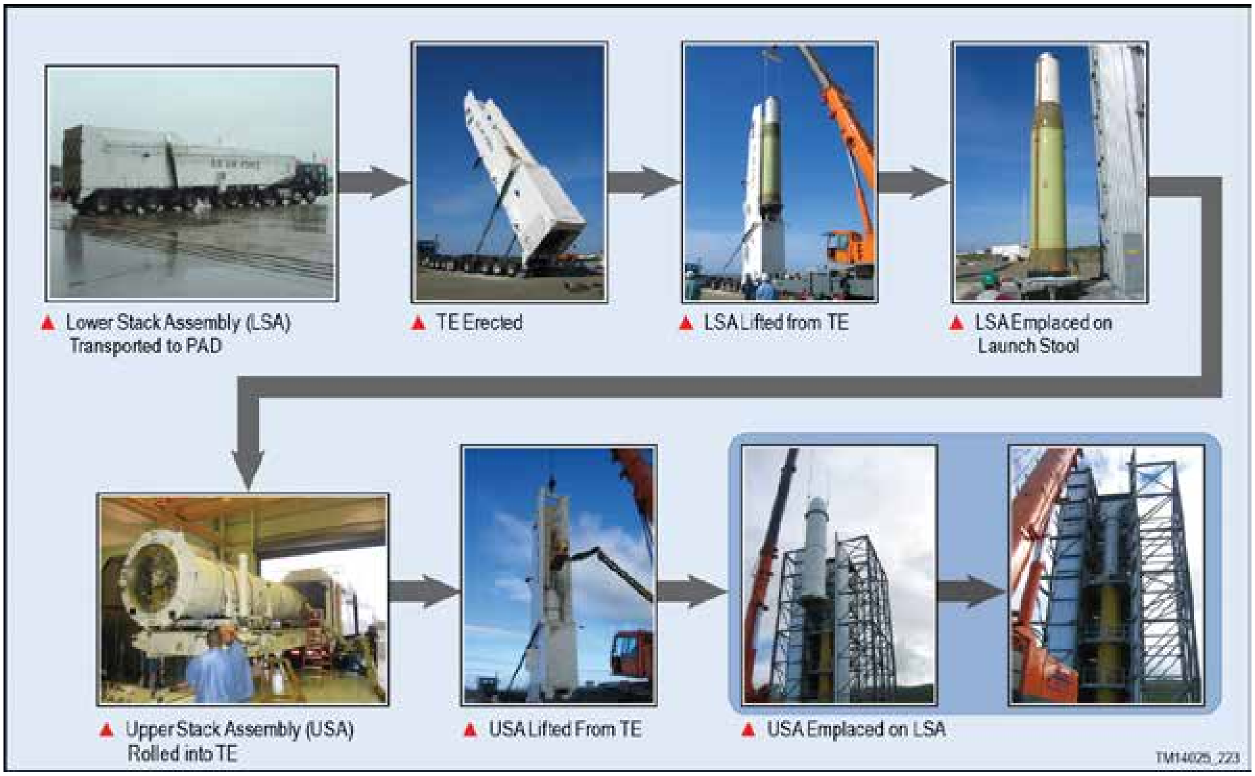

Figure 7.3.1-1. Minotaur I Uses Vertical Integration for Each Booster Stage, the Guidance Control Assembly, and the Encapsulated Payload Assembly

7.3.2. Final Vehicle Integration and Test

After the vehicle is fully stacked at the pad, final tests are completed to verify vehicle integrity and all interfaces to the range are exercised. A range interface test is performed to verify all the RF systems, and an end-to-end FTS test is performed to certify the FTS system. The ACS and separation systems are pressurized to final flight pressure, and final vehicle preparations are accomplished. The vehicle and launch team are then ready for the final countdown and launch.

7.3.3. Launch Vehicle Arming

Following final vehicle testing, the launch vehicle is armed and the pad is cleared for launch. The majority of these arming activities occurs at L-1 day and brings the Minotaur launch vehicle nearly to its launch day configuration. L-1 day is also typically the last opportunity for payload access. The remaining arming steps (final arming) take place mid-way during the countdown on launch day.

7.3.4. Launch

The typical Minotaur final countdown procedure commences at 5 hours prior to the required launch time. Figure 7.3.4-1 describes the nominal Minotaur I launch day flow. These activities methodically transition the vehicle from a safe state to that of launch readiness. Payload tasks, as necessary, are included in the countdown procedure and are coordinated by the Minotaur I Launch Conductor. The Minotaur I is shown ready for launch in Figure 7.3.4-2.

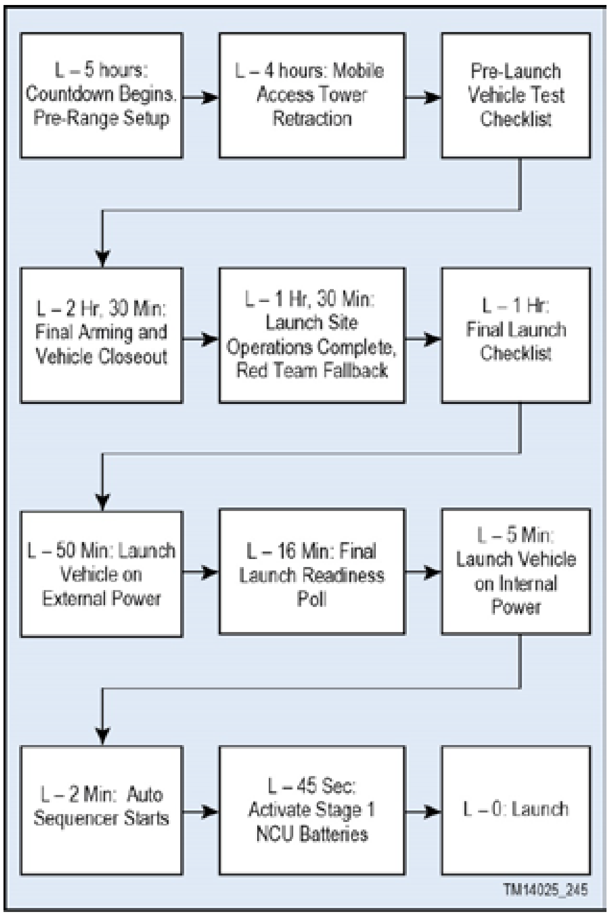

Figure 7.3.4-1. Notional Minotaur Countdown Timeline

Figure 7.3.4-2. Minotaur I Prepared for Launch

7.3.5. Launch Control Organization

The Launch Control Organization is split into two groups: the Management group and the Technical group. The Management group consists of senior range personnel and Mission Directors/Managers for the launch vehicle and payload who provide authority to proceed at selected points in the countdown. The Technical Group consists of the Launch Vehicle, Payload and Range personnel responsible for execution of the launch operation, to include data review and launch readiness assessment. The Payload's members of the technical group are engineers who provide technical representation in the control center. The Launch Vehicle's members of the technical group are engineers who prepare the Minotaur for flight, review and assess data that is displayed in the Launch Control Room (LCR) and provide technical representation in the LCR and in the Launch Operations Control Center (LOCC). The Range's members of the technical group are personnel that maintain and monitor the voice and data equipment, tracking facilities and all assets involved with RF communications with the launch vehicle. In addition, the Range provides personnel responsible for the Flight Termination System monitoring and commanding.

7.3.6. Launch Rehearsals

Two rehearsals are conducted prior to each launch. The first is conducted at approximately L-10 days and is used to acquaint the launch team with the communications systems, reporting, problem solving, launch procedures and constraints, and the decision making process. The first rehearsal is communications only (i.e., the Minotaur launch vehicle and payload are not powered on and range assets are not active). It is typically a full day in duration and consists of a number of countdowns performed using abbreviated time-lines, clock jumps, and off-nominal situations. All aspects of the team's performance are exercised, as well as hold, scrub, and recycle procedures. The operations are critiqued and the lessons learned are incorporated prior to the Mission Dress Rehearsal (MDR) at L-5 days (typical). The MDR is the final rehearsal prior to the actual launch day operation. It will ensure that problems encountered during the first rehearsal have been resolved. The MDR exercises the entire 5 hour Minotaur I countdown procedure and simulated post launch events. The Launch Vehicle is powered for this rehearsal and range assets perform operations as they would on launch day. There are no planned off-nominal events; however, the team will react to real world anomalies as they would on launch day. MDR ends with successful completion of the countdown procedure.

All Customer personnel involved with launch day activities participate in both rehearsals.

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8. OPTIONAL ENHANCED CAPABILITIES

The Minotaur launch service is structured to provide a baseline vehicle configuration which is then augmented with optional enhancements to meet the unique needs of individual payloads. The baseline vehicle capabilities are defined in the previous sections and the optional enhanced capabilities are defined below. The enhanced options allow customization of launch support and accommodations to the Minotaur I designs on an efficient, "as needed" basis.

8.1. Separation System

Several different types of optional separation systems and mechanical interfaces are available through NGIS. Further details can be found in Sections 5.2.4 and 5.2.5.

8.2. Conditioned Air

Conditioned air is included in the baseline vehicle cost and was described previously in Section 4.6.1. The Nitrogen Purge and Enhanced Contamination Control enhancements complement this capability as described in the Sections 8.3 and 8.6. For Minotaur I, conditioned air is not provided during transport or lifting operations.

8.3. Nitrogen Purge

Clean, dry gaseous nitrogen (GN_2) purge meeting Grade B specifications as defined in MIL-P-27401C can be provided to the payload in a Class 10,000 environment for continuous purge of the payload after fairing encapsulation until final payload closeouts (non-fly away) or lift-off (flyaway configuration shown in Figure 8.3-1). This enhancement uses a flow regulated nitrogen ground supply connected to the fairing. The nitrogen flow control regulator ensures the purge is supplied at a minimum flow rate of 5 standard cubic feet per minute with a capability of up to 8 standard cubic feet per minute. A manifold mounted to the inside of the fairing wall feeds lines up the fairing wall to purge points of interest on the payload. Purge nozzles can be positioned on the fairing wall and pointed at the payload instrument. Alternatively, a fly away configuration can be used where the purge line connects to a manifold on the payload and is pulled free during fairing separation. This continuous purge can be supplied from payload encapsulation through launch, including during transport to the pad, as demonstrated on past Minotaur I missions.

Figure 8.3-1. GN_2 Purge Interface To Minotaur Fairing (Flyaway at Liftoff)

8.4. Additional Access Panel

As already discussed in Section 5.1.3, additional doors of the same size and configuration as the standard single access door can be provided. The location of the fairing access door is documented within the mission-specific ICD. Figure 8.4-1 shows multiple access panels used on the Minotaur I ORS-1 mission as located on the optional Minotaur 61" fairing. Figures 5.1.3-1 and 5.1.3-2 define the allowable access door envelopes. Typical missions have included two access doors, at various locations on

Figure 8.4-1. Multiple Access Doors Were Demonstrated on the Optional Minotaur I Large Fairing

the fairing. Required door locations outside the allowable envelope are evaluated on a mission-specific basis. Other fairing access configurations, such as small circular access panels, can be provided as non-standard, mission-specific enhancements. Additional mission-specific effort can be minimized if a previously flown access door configuration is chosen.

8.5. Enhanced Telemetry

Enhanced telemetry provides for mission specific instrumentation and telemetry components to support additional payload, LV, or experiment data acquisition requirements. This enhancement provides a dedicated telemetry link with a baseline data rate of 2 Mbps. Additional instrumentation or signals such as strain gauges, temperature sensors, accelerometers, analog and digital data can be configured to meet mission specific requirements. This capability was successfully demonstrated on the first five Minotaur IV launches. Non-recurring efforts are required to offer enhanced telemetry on Minotaur I. These efforts include modifications to the vehicle telemetry encoder, cabling, and software. Typical enhanced telemetry instrumentation includes accelerometers and microphones intended to capture high frequency transients such as shock and random vibration.

8.6. Enhanced Contamination Control

To meet the requirement for a low contamination environment, NGIS uses existing processes developed and demonstrated on the Minotaur and Pegasus programs. These processes are designed to minimize out-gassing, supply a Class 10,000 clean room environment, assure a high cleanliness payload envelope, and provide a HEPA-filtered, controlled humidity environment after fairing encapsulation. NGIS leverages extensive payload processing experience to provide flexible, responsive solutions to mission-specific payload requirements (Figure 8.6-1).

Figure 8.6-1. Minotaur Team Has Extensive Experience in a Payload Processing Clean Room Environment

8.6.1. Low Outgassing Materials

NGIS' existing high cleanliness design and integration processes ensure that all materials used within the encapsulated volume have outgassing characteristics of less than 1.0% Total Mass Loss (TML) and less than 0.1% Collected Volatile Condensable Mass (CVCM) in accordance with ASTM E59. If materials within the encapsulated volume cannot meet low outgassing characteristics because of unique mission requirements, a contamination control plan is developed to ensure controls are in place to eliminate any significant effect on the payload.

8.6.2. High Cleanliness Integration Environment

With the enhanced contamination control option, the encapsulated payload element of the vehicle is processed in an ISO Standard 14644-1 Class 10,000 environment during all payload processing activities up to fairing encapsulation (ISO 7). The PPF clean room utilizes HEPA filtration units to filter the air and ensure hydrocarbon content is maintained at ≤15 ppm, with humidity maintained at 30-60% relative humidity. Depending on payload requirements, the clean room can also be certified as Class 100,000 (ISO 8) while still providing tighter environmental control than the standard high-bay environment, thereby streamlining access and payload processing.

8.6.3. HEPA-Filtered Fairing Air Supply

With the enhanced contamination control option, the ECU continuously purges the fairing volume with clean filtered air while maintaining temperature, humidity, and cleanliness. NGIS' ECU incorporates a HEPA filtration unit along with a hydrocarbon filter adaptor to provide Class 10,000 (ISO 7) air and ensure hydrocarbon content is maintained at ≤15 ppm, with humidity maintained as stated in section 4.6.1. NGIS monitors the supply air for particulate matter via a probe installed upstream of the fairing inlet duct prior to connecting the air source to the payload fairing.

8.6.4. Fairing Surface Cleanliness

The inner surface of the fairing and exposed launch vehicle assemblies are cleaned to Visibly Clean Plus Ultraviolet cleanliness criteria which ensures no particulate matter visible with normal vision when inspected from 6 to 18 inches under 100 foot candle incident light, as well as when the surface is illuminated by black light at 3200 to 3800 Angstroms. Process and procedures for inspection and the bagging of material to preclude contamination during shipment to the field are in place.

8.7. Secure FTS

The Secure FTS (Figure 8.7-1) is achieved with the L-3 Cincinnati Electronics Model CRD-120/205 Launch Vehicle Command Receiver/Decoder that is compatible with the "High-Alphabet" range safety modulation format. The receiver uses a pre-stored code unique to each specific vehicle to issue configuration and termination commands. This provides an increased level of security over the standard FTS systems that use a basic 4 tone combination for receiver command and control.

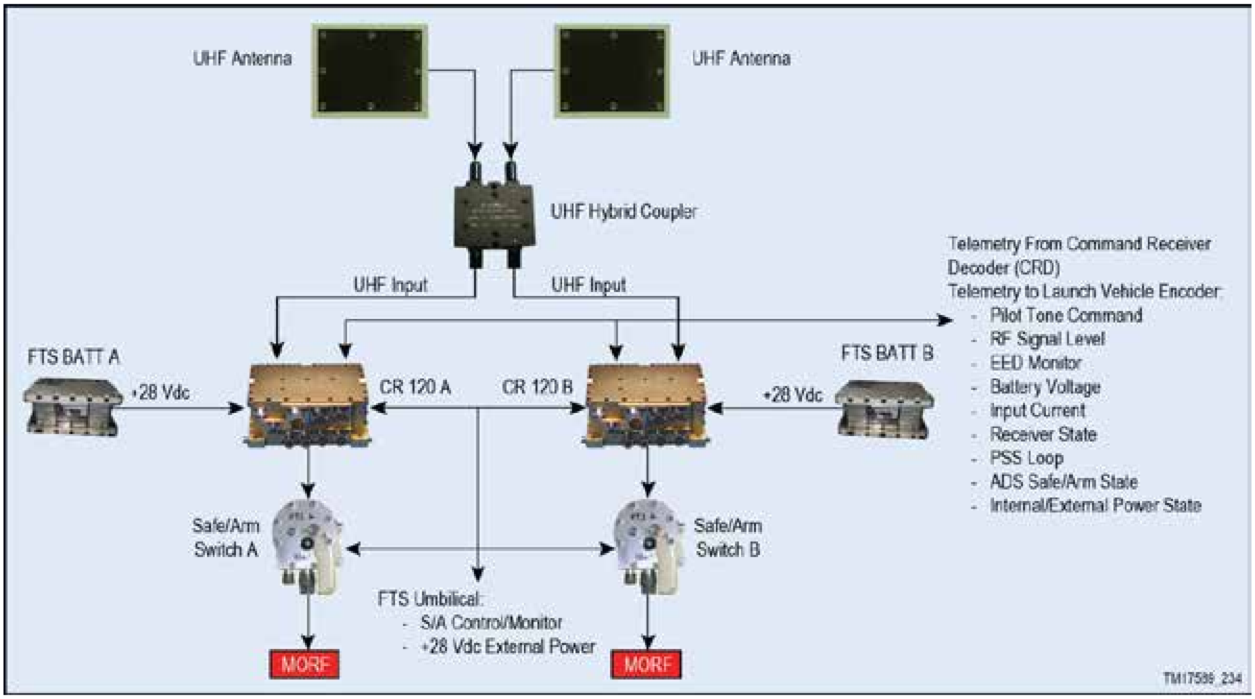

Figure 8.7-1. NGIS' Secure FTS System Block Diagram

The CRD-120/205 Launch Vehicle Command Receiver/Decoder was designed specifically to operate on the Delta expendable space launch vehicles for range safety flight termination. This design incorporates redundancy in both hardware and software and High Reliability piece-parts (in accordance with ELV-JC-002D) to ensure reliable, fail-safe operation.

8.8. Over Horizon Telemetry

A Telemetry Data Relay Satellite System (TDRSS) interface can be added as an enhancement to provide real-time telemetry coverage during blackout periods with ground based telemetry receiving sites. TDRSS was successfully demonstrated on past Minotaur missions. The TDRSS telemetry system enhancement consists of a LCT2 TDRSS transmitter, an antenna (Figure 8.8-1), an RF switch, and associated ground test equipment. The RF switch is used during ground testing to allow for a test antenna to be used in lieu of the flight antennas. Near the time when telemetry coverage is lost by ground based telemetry receiving sites, the LV switches telemetry output to the TDRSS antenna and points the antenna towards a TDRSS satellite. The TDRSS relays the telemetry to the ground where it is then routed to the launch control room (Figure 8.8-2). A cavity backed or phased array antenna can be used depending on data rate requirements.

The TDRSS system proposed includes the launch vehicle design, analysis, hardware and launch vehicle testing. For this option, arrangements need to be made with NASA for system support and planning, management, scheduling, satellite usage, ground operations, and data processing.

Figure 8.8-1. TDRSS 20W LCT2 Transmitter and Cavity Backed S-band Antenna

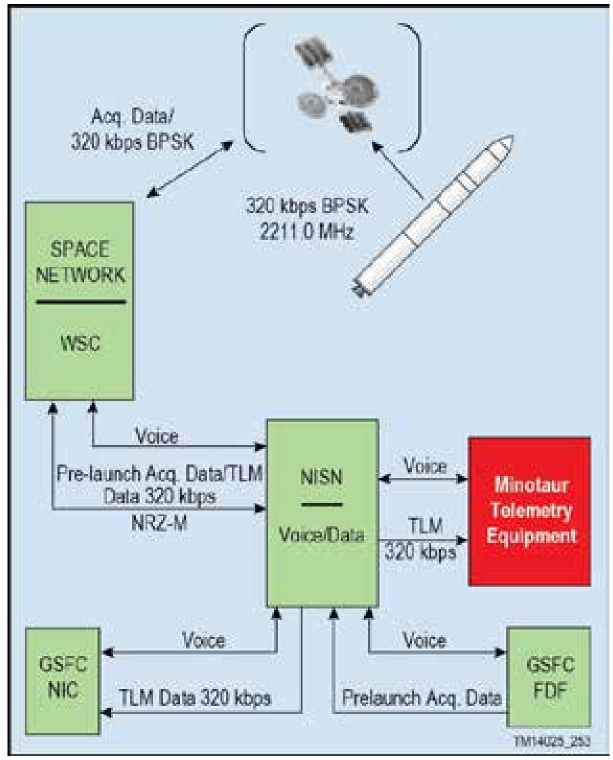

Figure 8.8-2. TDRSS Notional Telemetry Flow

8.9. Increased Insertion Accuracy

Enhanced insertion accuracy can be provided through the use of a Hydrazine Auxiliary Propulsion System (HAPS). 6DOF analyses show the HAPS system provides a controlled impulse to achieve the accuracies shown in Table 8.9-1 (Insertion is for both apse and non-apse).

The HAPS propulsion system consists of a centrally mounted tank containing approximately 100 lbm of hydrazine and three fixed axial thrusters. The hydrazine tank contains an integral propellant management device which supports several zero gravity restarts. The system is integrated inside of a dedicated HAPS stage avionics structure that separates from the Stage 4 assembly. After Stage 4 burnout and separation from the Stage 4 assembly, the HAPS hydrazine thrusters provide additional velocity for improved performance and precise orbit insertion. On the Minotaur I vehicle, the HAPS is integrated into the Pegasus-developed extended avionics cylinder which is used in lieu of the standard Minotaur avionics structure.

Table 8.9-1. Enhanced Insertion Accuracies

Error Type	Tolerance
Insertion	<18.5 km (10 nmi) (3-s)
Inclination	<0.05° (3-s)

8.10. Payload Isolation System

NGIS offers a flight proven payload isolation system as a non-standard service. The Softride for Small Satellites (SRSS) was developed by Air Force Research Laboratory (AFRL) and CSA Engineering. It has successfully flown on numerous Minotaur missions. The typical configuration is shown in Figure 8.10-1. This mechanical isolation system has demonstrated the capability to significantly alleviate the transient dynamic loads that occur during flight. The isolation system can provide relief to both the overall payload center of gravity loads and component or subsystem responses. Typically the system will reduce transient loads to approximately 25% of the level they would be without the system. The exact results will vary for each particular spacecraft and with location on the spacecraft. Generally, a beneficial reduction in shock and vibration will also be provided. The isolation system does impact overall vehicle performance by approximately 9 to 18 kg (20 to 40 lb) and the available payload dynamic envelope by up to 5.08 cm (2.0") axially and up to 2.54 cm (1.0") laterally.

8.11. Orbital Debris Mitigation

For each mission, NGIS evaluates the orbit lifetime of all stages and hardware that reach Earth orbit. In the event that Minotaur hardware is left in an orbit that lasts for 25 years or longer, this enhancement is required to properly dispose and mitigate causality expectations of the hardware in accordance with AFI 91-217. Figure 8.11-1 shows the altitudes where Low Earth Orbits last for more than 25 years. For this enhancement, NGIS optimizes the orbital debris mitigation system to the specific mission requirements. For example, in some cases it might be more efficient to raise the final stage to an orbit in the LEO Disposal region. In other cases it would be best to lower the final stage to an orbit where natural forces can return the hardware to the Earth's atmosphere within 25 years. In some cases, deployment of a solar sail or tether may be required. NGIS will determine the optimal solution on a mission-specific basis.

8.12. Dual and Multi Payload Adapter Fittings

Detailed in Section 5.2.4.2.

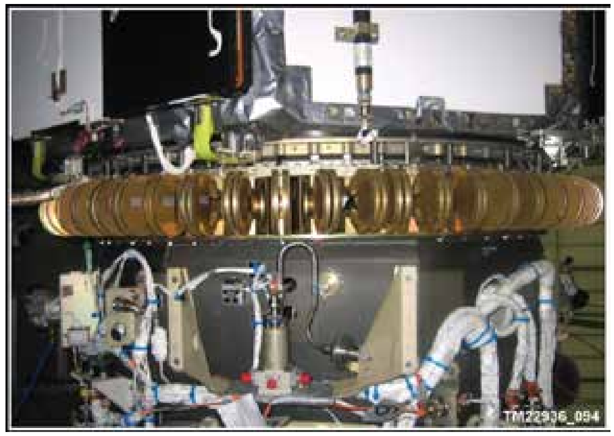

Figure 8.10-1. Minotaur I SRSS Significantly Attenuates Peak LV Dynamic Environments

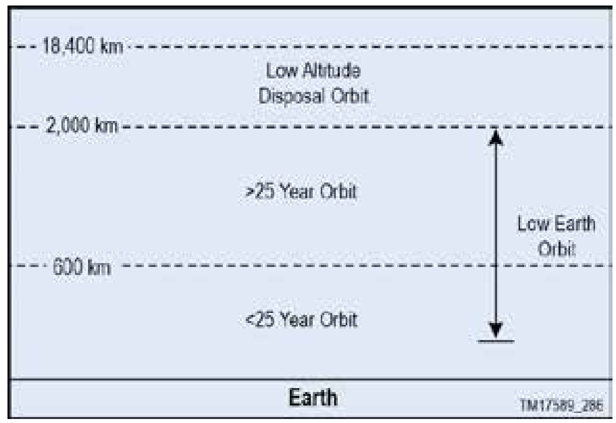

Figure 8.11-1. Operational and Disposal LEOs

8.13. Minotaur I Launch Vehicle Enhanced Performance Configuration

8.13.1. Minotaur I Commercial

The Minotaur I Commercial space launch vehicle represents a substantial (over 25%) increase in performance with minimal vehicle changes, shown in Figure 8.13.1-1. The configuration was established for payloads that do not have government sponsorship but require the highly reliable Minotaur I capability. The Minotaur I Commercial vehicle utilizes the identical flight proven third and fourth stages, mechanical structures, avionics, pneumatics, and ordnance subsystems as the base Minotaur I vehicle. The Minotaur I Commercial vehicle replaces the GFE Stage 1 and Stage 2 boosters with commercially available Castor 120 and Orion 50S XLT boosters, respectively. The S1/2 interstage is flight proven and is vented to minimize vehicle loads during the hot separation event by jettisoning vent panels just prior to Stage 2 ignition. This vehicle configuration can place a 1050 kg payload into a 740 km by 740 km sun-synchronous orbit when launched from VAFB and 390 kg to GTO from CCAFS.

8.14. Large Fairing

Details are in Section 5.1.2.

8.15. Hydrazine Servicing

Under this enhancement, NGIS provides hydrazine fueling service for the SV though a contract to United Paradyne Corporation (UPC). Previous 30SW rules placed restrictions on UPC's ability to use GFE equipment to provide hydrazine servicing to non-Government entities. This led UPC to develop and manufacture their own GSE and they now possess the ability to contract directly with NGIS. A typical propellant loading schematic is shown in Figure 8.15-1.

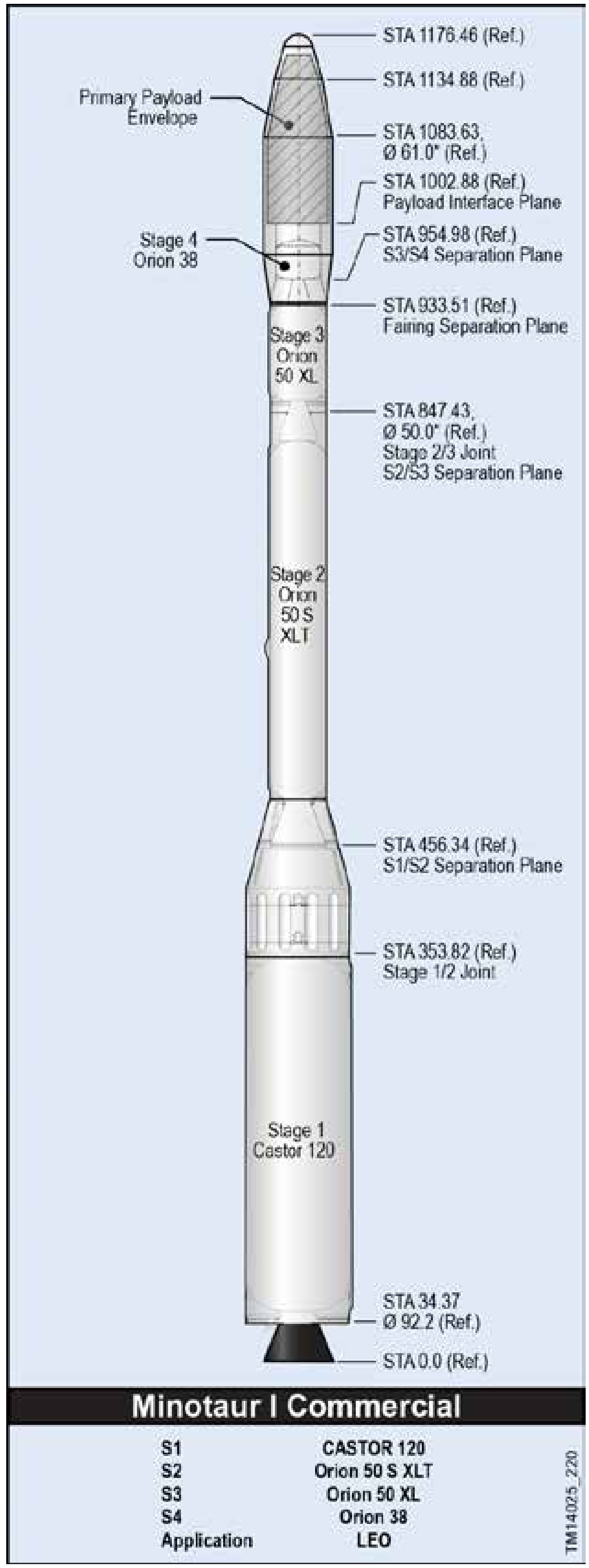

Figure 8.13.1-1. Minotaur I Commercial Offers Exceptional Performance with Proven Reliability

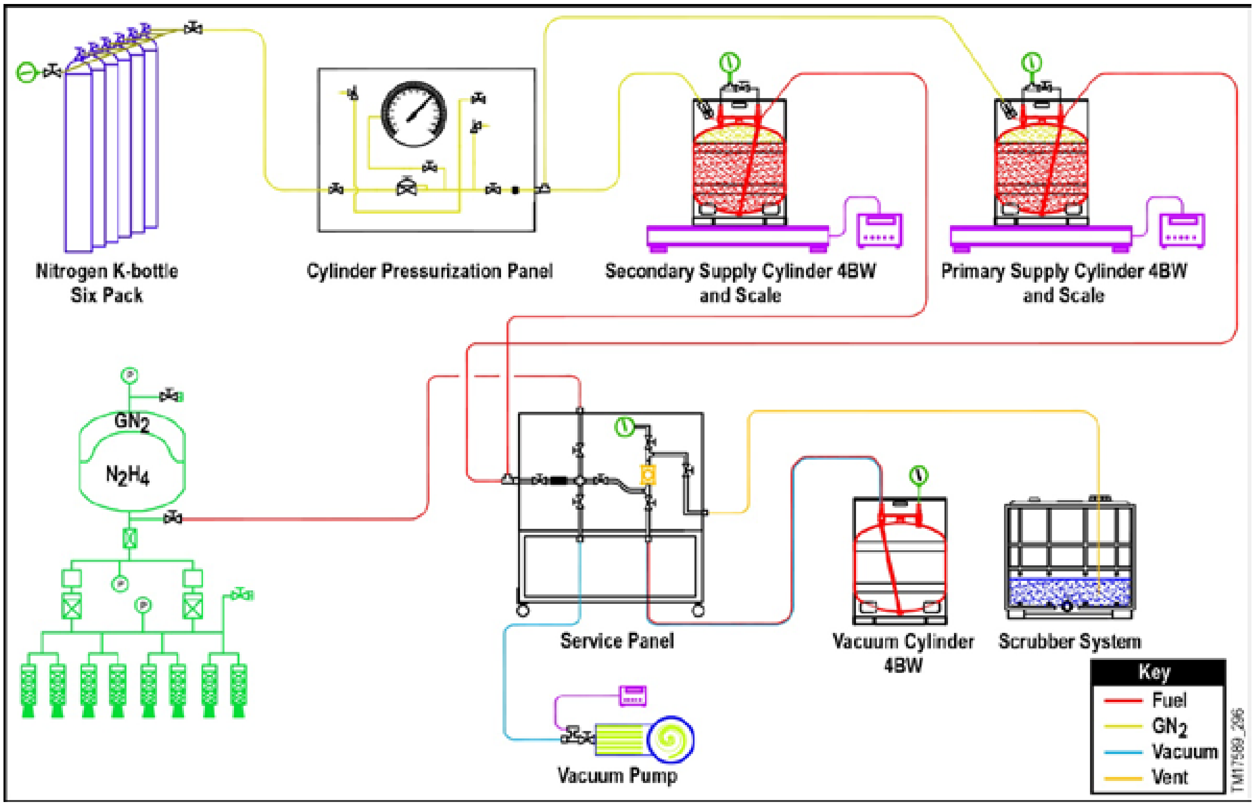

Figure 8.15-1. Typical Propellant Loading Schematic

The scope of this enhancement includes the procurement of hydrazine fuel, the preparation of documentation for fueling operations, the support of safety and integrated operations meetings, the provision of equipment needed for SCAPE operation, including personal protection equipment (if necessary) and fuel transfer cart, and all personnel required to conduct fuel loading operations. Emergency unloading operations can also be supported if desired. Figure 8.15-2 shows hardware used by UPC for hydrazine servicing. The recurring price includes costs for de-fueling operations that would not be required in nominal launch processing.

Figure 8.15-2. UPC Provides Reliable and Demonstrated Hydrazine Servicing for Minotaur

8.16. Nitrogen Tetroxide Service

Under this enhancement, NGIS provides Nitrogen Tetroxide (NTO) loading service for the SV though a contract to UPC. The scope of this enhancement includes the procurement of NTO, the preparation of documentation for loading operations, the support of safety and integrated operations meetings, the provision of equipment needed for SCAPE operation, including personal protection equipment (if necessary) and NTO transfer cart, and all personnel required to conduct fuel loading operations. Emergency unloading operations can also be supported if desired.

8.17. Poly-Pico Orbital Deployer (P-POD)

When there is excess performance available on a Minotaur mission, there is an opportunity to fly one or more P-PODS. Small CubeSats deployed from customer provided P-PODs were successfully flown on multiple Minotaur missions. A single P-POD can deploy up to 3 CubeSats.

The P-PODs are mounted on shock isolated plates located on the Orion 38 motor case (Figure 8.17-1) and are deployed in the aft direction following Stage 4 burnout. A standard pyro pulse from the launch vehicle is used to deploy the P-PODs. The Minotaur I launch vehicle is capable of deploying up to two P-PODs per mission, assuming the use of the Large Fairing (61") Enhancement. Due to their mounting location, P-PODs can be easily integrated to the launch vehicle on a fully non-interference basis from the primary spacecraft, thus minimizing impacts to the primary mission spacecraft integration operations. This enhancement assumes the P-PODs are added to the manifest early enough in the contract that extensive rework is not required.

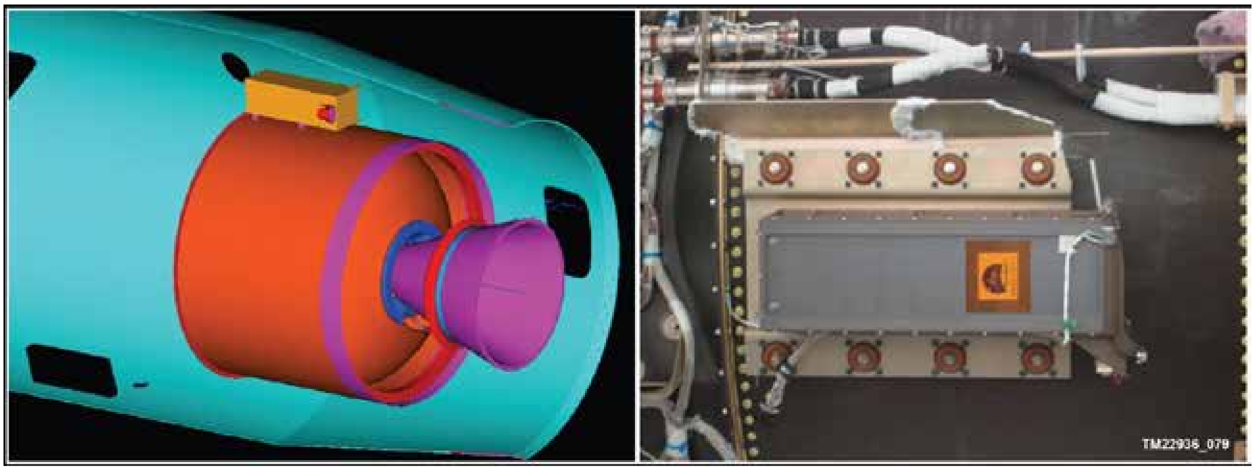

Figure 8.17-1. P-PODs Have Successfully Flown On Multiple Minotaur Missions

8.18. Suborbital Performance

The flight proven Minotaur I provides the basis for an enhanced configuration, Minotaur I Lite, to meet various suborbital mission demands. Minotaur I Lite maintains the existing Minotaur I vehicle systems and simply removes the 4th stage to provide a reliable, proven, and robustly performing suborbital vehicle (see Figure 8.18-1 for performance). In addition to providing significant downrange performance, NGIS draws from many existing, proven, successful guidance schemes to meet the unique targeting needs of the suborbital customer including the highly accurate Pierce Point algorithm proven on Minotaur II and Minotaur IV.

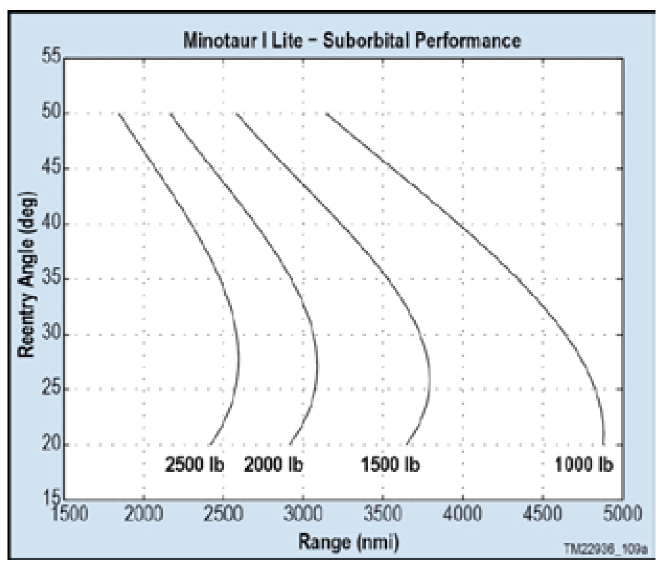

Figure 8.18-1. Minotaur I Lite Ballistic Performance

Under the Suborbital Performance Modification for Minotaur I, the Orion 38 4th stage solid rocket motor and associated components are removed from the

Minotaur I orbital configuration (Figure 8.18-2). Minotaur I Lite provides a larger volume and greater stack height to the suborbital payload. For clearances to fairing deployment components and to maintain proven fairing deployment dynamics, a simple aluminum adapter cylinder is used between the 3/4 interstage and the avionics section. The adapter cylinder is the only new structure; the electrical and ordnance designs above and below remain unchanged from the standard Minotaur I. Payload and launch vehicle environments remain enveloped by previously established and well defined Minotaur I levels. Minotaur I Lite maintains the same high level of payload access, power, discrete, and communication interfaces as the standard Minotaur I LV. Relatively minor design, model, analysis, and procedure updates ensure Minotaur I Lite maintains the high standards of the Minotaur family of vehicles.

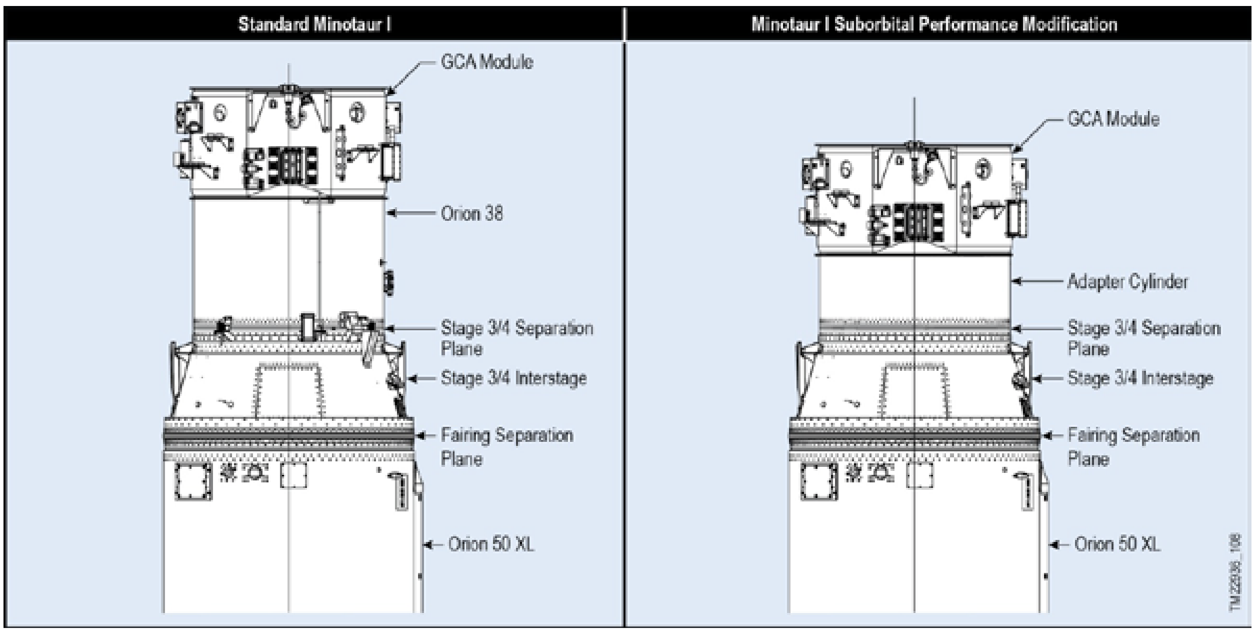

Figure 8.18-2. Minotaur I-Lite Replaces the Orion 38 with a Low Cost and Risk Simple Aluminum Cylinder

8.19. Alternate Launch Location

NGIS has extensive experience processing and launching out of multiple Government and commercial launch sites. Minotaur systems are designed to accommodate missions from multiple ranges with minimal dedicated infrastructure. The Minotaur flight safety systems and Range interface requirements are well documented and approved by multiple safety organizations. NGIS has experience working closely with various ranges to address the ground and flight safety requirements to ensure a safe and successful launch.

While VAFB is home to the Minotaur Processing Facility, the Minotaur system was designed from the beginning to launch from all four of the existing commercial spaceports: Spaceport Systems International's SLC-8 at VAFB, AAC's Kodiak Launch Complex in Alaska (Figure 8.19-1), Space Florida's LC-46 at CCAFS (Figure 8.19-2), and Mid-Atlantic Regional Spaceport's Pad 0B at Wallops Island, Virginia (Figure 8.19-3). Minotaur can also support other ranges and austere sites as a non-standard service on a case-by-case basis.

Figure 8.19-1. Minotaur IV Vehicles Have Successfully Launched From KLC

Figure 8.19-3. Minotaur I Vehicles Have Successfully Launched Multiple Times From Wallops

Figure 8.19-2. Launch Complex 46 at CCAFS Supports All Minotaur Configurations

APPENDIX A

PAYLOAD QUESTIONNAIRE

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SATELLITE IDENTIFICATION	
FULL NAME:	
ACRONYM:	
OWNER/OPERATOR:	
INTEGRATOR(s):	
SPACE CRAFT AND MISSION DESCRIPTION	

ORBIT INSERTION REQUIREMENTS*		
SPHEROID	q Standard (WGS-84, R_e = 6378.137 km) q Other:	
ALTITUDE	Insertion Apse: ________ ± ________ q nmi q km	Opposite Apse: ________ ± ________ q nmi q km
or...	Semi-Major Axis: ________ ± ________ q nmi q km	Eccentricity: ________ £ e £ ________
INCLINATION	________ ± ________ deg	
ORIENTATION	Argument of Perigee: ________ ± ________ deg	Longitude of Ascending Node (LAN): ________ ± ________ deg
	Right Ascension of Ascending Node (RAAN): ________ ± ________ deg	For Launch Date: ________

* Note: Mean orbital elements

LAUNCH WINDOW REQUIREMENTS	
NOMINAL LAUNCH DATE:	LAUNCH SITE:
OTHER CONSTRAINTS (if not already implicit from LAN or RAAN requirements, e.g., solar beta angle, eclipse time constraints, early on-orbit ops, etc):	

EARLY ON-ORBIT OPERATIONS
Briefly describe the satellite early on-orbit operations, e.g., event triggers (separation sense, sun acquisition, etc), array deployment(s), spin ups/downs, etc:

SATELLITE SEPARATION REQUIREMENTS	
ACCELERATION	Longitudinal: ≤ _________ g's Lateral: ≤ _________ g's
VELOCITY	Relative Separation Velocity Constraints:
ANGULAR RATES (pre-separation)	Longitudinal: Pitch: _________ ± deg/sec _________ ± _________ deg/sec Yaw: _________ ± ______ deg/sec
ANGULAR RATES (post-separation)	Longitudinal: Pitch: _________ ± deg/sec _________ ± _________ deg/sec Yaw: _________ ± ______ deg/sec
ATTITUDE (at deployment)	Describe Pointing Requirements Including Tolerances: (Space Craft X,Y,Z)
SPIN UP	Longitudinal Spin Rate: ___________ ± ___________ deg/sec
OTHER	Describe Any Other Separation Requirements:

SPACECRAFT COORDINATE SYSTEM
Describe the Origin and Orientation of the spacecraft reference coordinate system, including its orientation with respect to the launch vehicle (provide illustration if available):

SPACECRAFT PHYSICAL DIMENSIONS	
STOWED CONFIGURATION	Length/Height: ______________ q in q cm Diameter: ______________ q in q cm Other Pertinent Dimension(s):
	Describe any appendages/antennas/etc which extend beyond the basic satellite envelope:
ON-ORBIT CONFIGURATION	Describe size and shape:

If available, provide dimensioned drawings for both stowed and on-orbit configurations.

SPACECRAFT MASS PROPERTIES*	
PRE-SEPARATION	Inertia units: q lb_m-in^2 q kg-m^2 Mass: __________ q lb_m q kg Ixx: __________ Xcg: __________ q in q cm Iyy: __________ Izz: __________ Ycg: __________ q in q cm Ixy: __________ Iyz: __________ Zcg: __________ q in q cm Ixz: __________
POST-SEPARATION (non-separating adapter remaining with launch vehicle)	Inertia units: q lb_m-in^2 q kg-m^2 Mass: __________ q lb_m q kg Ixx: __________ Xcg: __________ q in q cm Iyy: __________ Izz: __________ Ycg: __________ q in q cm Ixy: __________ Iyz: __________ Zcg: __________ q in q cm Ixz: __________

* Stowed configuration, spacecraft coordinate frame

SPACECRAFT SLOSH MODEL*		
SLOSH MODEL UNDER 0 g	Pendulum Mass: ______	□ lbm □ kg
	Pendulum Length: ______	□ ft □ m
	Pendulum Xs: ______	□ in □ cm
	Attachment Ys: ______	□ in □ cm
	Point Zs: ______	□ in □ cm
	Natural Frequency of Fundamental Sloshing Mode (Hz): ______	
SLOSH MODEL UNDER 1 g	Pendulum Mass: ______	□ lbm □ kg
	Pendulum Length: ______	□ ft □ m
	Pendulum Xs: ______	q in q cm
	Attachment Ys: ______	q in q cm
	Point Zs: ______	q in q cm
	Natural Frequency of Fundamental Sloshing Mode (Hz): ______	

ASCENT TRAJECTORY REQUIREMENTS	
Free Molecular Heating at Fairing Separation: (Standard Service: = 360 Btu/ft²/hr)	q Btu/ft²/hr FMH ≤ ______ q W/m²
Fairing Internal Wall Temperature (Standard Service: = 200°F)	q deg F T ≤ ______ q deg C
Dynamic Pressure at Fairing Separation: (Standard Service: = 0.01 lb_f/ft^2)	q lb_f/ft^2 q ≤ ______ q N/m2
Ambient Pressure at Fairing Separation: (Standard Service: = 0.3 psia)	q lb_f/in^2 P ≤ ______ q N/m2
Maximum Pressure Decay During Ascent: (Standard Service: = 0.6 psia)	q $lb_f/in^2/sec$ Δ P ≤ ______ q N/m2/sec
Thermal Maneuvers During Coast Periods: (Standard Service: none)	

SPACECRAFT ENVIRONMENTS	
THERMAL DISSIPATION	Spacecraft Thermal Dissipation, Pre-Launch Encapsulated: ________ Watts Approximate Location of Heat Source: Thermal Control Provisions: (Paint, Tape, etc.):
TEMPERATURE	Temperature Limits During Ground/Launch Operations: Max ___________ q deg F q deg C Min ___________ q deg F q deg C (Standard Service is 55°F to 80°F)
	Component(s) Driving Temperature Constraint: Approximate Location(s):
HUMIDITY	Relative Humidity: ***or***, Dew Point: Max ________ % Max ___________ q deg F q deg C Min ________ % Min ___________ q deg F q deg C (Standard Service is 37 deg F)
NITROGEN PURGE	Specify Any Nitrogen Purge Requirements, Including Component Description, Location, and Required Flow Rate: (Nitrogen Purge is a Non-Standard Service)
CLEANLINESS	Volumetric Requirements (e.g. Class 100,000): ____________________ Surface Cleanliness (e.g. Visually Clean): ____________________ Other: ____
LOAD LIMITS	Ground Transportation Load Limits Axial ≤ _______ g'sLateral ≤ _______ g's

ELECTRICAL INTERFACE
Bonding Requirements:
Are Launch Vehicle Supplied Pyro Commands Required? Yes / No If Yes, magnitude: ________ amps for _______ msec (Standard Service is 10 amps for 100 msec)
Are Launch Vehicles Supplied? Yes / No If Yes, describe: Discrete Commands Required? Yes / No
Is Electrical Access to the Satellite Required... After Encapsulation?Yes / No at Launch SiteYes / No
Is Satellite Battery Charging Required... After Encapsulation?Yes / No at Launch Site? Yes / No
Is a Telemetry Interface with the Launch Vehicle Flight Computer Required? Yes / No If Yes, describe:
Other Electrical Requirements:

Please complete attached sheet of required pass-through signals.

RF RADIATION
Time After Separation Until RF Devices Are Activated: (Note: Typically, no spacecraft radiation is allowed from encapsulation until 30 minutes after liftoff.)
Frequency: ________________ MHz Power: ______________ Watts
Location(s) on Satellite (spacecraft coordinate frame): Longitudinal __________ q in q cm Clocking (deg), Describe: Longitudinal __________ q in q cm Clocking (deg), Describe:

REQUIRED PASS-THROUGH SIGNALS							
Item #	**Pin**	**Signal Name**	**From LEV**	**To Satellite**	**Shielding**	**Max Current (amps)**	**Total Line Resistance (ohms)**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
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MECHANICAL INTERFACE	
DIAMETER	Describe Diameter of Interface (e.g. Bolt Circle, etc):
SEPARATION SYSTEM	Will Launch Vehicle Supply the Separation System? Yes / No If Yes, approximate location of electrical connectors: special thermal finishes (tape, paint, MLI) needed: If No, provide a brief description of the proposed system:
SURFACE FLATNESS	Flatness Requirements for Sep System or Mating Surface of Launch Vehicle:
FAIRING ACCESS	Payload Fairing Access Doors (spacecraft coordinate frame): Longitudinal __________ q in q cm Clocking (deg), Describe: Longitudinal __________ q in q cm Clocking (deg), Describe: Note: Standard Service is one door
DYNAMICS	Spacecraft Natural Frequency: Axial ____________ Hz Lateral ____________ Hz Recommended: > 35 Hz > 12 Hz
OTHER	Other Mechanical Interface Requirements:

GROUND SUPPORT EQUIPMENT

Describe any additional control facilities (other than the baseline Support Equipment Building (SEB) and Launch Equipment Vault (LEV)) which the satellite intends to use:

SEB

Describe (in the table below) Satellite EGSE to be located in the LSV.

[Notes: Space limitations exist in the SEB. 110 m (360 ft) umbilical cable length to spacecraft typical]

Equipment Name / Type	Approximate Size (LxWxH)	Power Requirements

Is UPS required for equipment in the SEB? Yes / No

Is Phone/Fax connection required in the SEB? Yes / NoCircle: Phone / FAX

GROUND SUPPORT EQUIPMENT (CONTINUED)			
LEV	Describe (in the table below) Satellite EGSE to be located in the LEV. [Notes: Space limitations exist in the LEV. 49 m (160 ft) umbilical cable length to spacecraft typical]		
	Equipment Name / Type	**Approximate Size (LxWxH)**	**Power Requirements**
	Is UPS required for equipment in the LEV? Yes / No Is Phone/Fax connection required in the LEV? Yes / NoCircle: Phone / FAX		