Antares™

Antares User's Guide

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NORTHROP GRUMMAN

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REVISION SUMMARY

VERSION	DATE	CHANGE	PAGE
1.0	January 2014	Initial Public Release	
2.0	June 2017	Updates associated with additional/new 230 vehicle configurations	All
3.0	August 2018	Updated vehicle configuration and performance capabilities	All
3.1	September 2020	Branding update. Updated contact information.	All

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MEDIUM-CLASS LAUNCH SERVICES FOR THE 21ST CENTURY

Antares® is a flight proven two or three stage launch vehicle designed to provide responsive, cost effective, and reliable access to orbit for Medium-Class payloads. The initial Antares missions demonstrated the Antares launch vehicle performance and capability to provide commercial resupply of the International Space Station (ISS) under NASA's Commercial Orbital Transportation Services (COTS) and Commercial Resupply Services (CRS) contracts. The Antares launch system meets the needs and mission success standards of Medium-Class science and commercial missions. The Antares launch vehicle includes the following features:

- ***Low-Risk Design***: Antares incorporates flight proven components from leading global suppliers, and utilizes subsystem designs successfully employed on other Northrop Grumman launch vehicles.
- ***Flight Proven Technologies****:* The Antares first stage is powered by dual RD-181 engines. These engines draw from an extensive flight proven heritage from the NPO Energomash line of liquid engines, dating back to initial flight in 1985 of the RD-170 engine. The Antares second stage relies on proven CASTOR® solid rocket motors and Modular Avionics Control Hardware (MACH) electronics technology.
- ***Medium-Class Launch Services Gap****:* Antares fills the service gap between Medium Light-Class Minotaur launch vehicles and larger, Intermediate-Class OmegA launch vehicles.

The Antares User's Guide describes the basic elements of the Antares launch system as well as available optional services. In addition, this document provides general vehicle performance, defines payload accommodations and environments, and outlines the Antares mission integration process. The descriptions contained in this Antares User's Guide familiarize potential customers with the Antares launch system, capabilities and associated services. The data presented provides the current capabilities and interfaces of the Antares launch system, with the goal of enabling potential customers to perform mission feasibility trade studies and complete preliminary mission designs. Detailed analyses are performed by the Antares mission team based on the requirements and characteristics of each specific mission.

The information provided in this Antares User's Guide is for initial planning purposes for potential spacecraft customers to utilize Antares Launch Services. Information for development/design of spacecraft and/or launch services are determined through mission specific engineering analyses. The results of these analyses are documented in a mission-specific Interface Control Document (ICD) for the spacecraft organization to use in their development/design process. This document provides an overview of the Antares system design and a description of the services provided to our customers.

For technical information and additional copies of this User's Guide, contact:

Northrop Grumman Space Systems Sector

Sector Headquarters

45101 Warp Drive
Dulles, VA 20166
+1 (703) 406-5000

www.northropgrumman.com

Launch and Missile Defense Systems
Division Headquarters

1575 South Price Road
Chandler, AZ 85286
+1 (480) 899-6000

Warren Frick
Manager, Business Development
(703) 234-3935
Warren.Frick@ngc.com

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GLOSSARY

6DOF	Six Degrees of Freedom
ACS	Attitude Control System
ATP	Authority to Proceed
C&C	Command and Control
CBOD	Clamp Band Opening Devices
CCAM	Collision/Contamination Avoidance Maneuver
CDR	Critical Design Review
CG	Center-of-Gravity
CLA	Coupled Loads Analysis
COTS	Commercial Orbital Transportation Services
CRS	Commercial Resupply Services
CVCM	Collected Volatile Condensable Materials
ECS	Environmental Control System
EDU	Engineering Development Unit
EGSE	Electrical Ground Support Equipment
EICD	Electrical Interface Control Drawing
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FMA	Final Mission Analysis
FTS	Flight Termination System
GNC	Guidance, Navigation, and Control
GSE	Ground Support Equipment
HEPA	High Efficiency Particulate Air
HIF	Horizontal Integration Facility
I/O	Input / Output
IAW	In Accordance With
ICD	Interface Control Document
ILC	Initial Launch Capability
ISS	International Space Station
LC	Launch Conductor
LCC	Launch Control Center
LEO	Low Earth Orbit
LEV	Launch Equipment Vault
LEV	Launch Equipment Vault
LO2	Liquid Oxygen
LV	Launch Vehicle
MACH	Modular Avionics Control Hardware
MARS	Mid-Atlantic Regional Spaceport
Max Q	Maximum Dynamic Pressure
MCC	Mission Control Center
MCD	Mission Constraints Document
MDR	Mission Dress Rehearsal
MECO	Main Engine Cut Off
MICD	Mechanical Interface Control Drawing
MIWG	Mission Integration Working Group
MOCC	Mission Operations Control Center
MSCDR	Mission Specific Critical Design Review
MSPDR	Mission Specific Preliminary Design Review
MSPSP	Missile System Pre-Launch Safety Package
NASA	National Aeronautics and Space Administration
OAM	Orbit Adjust Module
ODM	Ordnance Driver Module
P/L	Payload
PAF	Payload Attach Fitting
PAS	Payload Attach System
PAS	Payload Adapter System
PDR	Preliminary Design Review
PECS	Portable Environmental Control System
PFF	Payload Fueling Facility
PMA	Preliminary Mission Analysis
PMF	Payload Mate Fixture
POC	Point of Contact
PPF	Payload Processing Facility
PTS	Power Transfer Switch
RAAN	Right Ascension of Ascending Node
RCC	Range Control Center
RCC	Range Control Center
REA	Rocket Engine Assembly
RF	Radio Frequency
RH	Relative Humidity
RP	Rocket Propellant
RWG	Range Working Group
SCFM	Standard Cubic Feet per Minute
SRM	Solid Rocket Motor
ST&CICD	Serial Telemetry and Commanding ICD
SV	Space Vehicle
TEL	Transporter/Erector/Launcher
TIM	Technical Interchange Meeting
TML	Total Mass Loss
TVA	Thrust Vector Actuator
TVC	Thrust Vector Control
UDS	Universal Documentation System
UHF	Ultra High Frequency
UV	Ultraviolet
WDR	Wet Dress Rehearsal
WFF	Wallops Flight Facility
psf	per square foot
RAAN	Right Ascension of Ascending Node
RCC	Range Control Center
RF	Radio Frequency
RH	Relative Humidity
RP	Rocket Propellant
rpm	revolutions per minute
RWG	Range Working Group
SAE	Standard measurement (inches)
scfm	standard cubic feet per minute

GLOSSARY (CONTINUED)

sec	second(s)
SL	Sea Level
SRM	Solid Rocket Motor
ST&CICD	Serial Telemetry and Commanding ICD (ST&CICD)
SV	Space Vehicle
TEL	Transporter/Erector/Launcher
TIM	Technical Interchange Meeting
TLM	Telemetry
TML	Total Mass Loss
TVA	Thrust Vector Actuator
TVC	Thrust Vector Control
UDS	Universal Documentation System
UHF	Ultra High Frequency
UV	Ultraviolet
V/m	Volts per meter
Vdc	Volts direct current
WDR	Wet Dress Rehearsal
WFF	Wallops Flight Facility
WP	Work Package

1. INTRODUCTION

The objective of the Antares User's Guide is to familiarize payload mission planners with the Antares launch vehicle and services. This document provides an overview of the Antares system design and a description of the standard launch services provided to our customers. Antares can offer a variety of upgraded services to allow maximum flexibility in satisfying customer requirements.

1.1. Northrop Grumman Innovation Systems History

Northrop Grumman Innovation Systems is a leading developer and manufacturer of small, medium and heavy class space launch systems. Northrop Grumman Innovation Systems has three decades of demonstrated reliable, rapid and affordable development and production experience, serving customers in the commercial, defense and civil government markets. Northrop Grumman Innovation Systems has delivered or is under contract for over 1,000 space products, including satellites and space systems, space and strategic launch vehicles, and sub-orbital target vehicles and sounding rockets.

Northrop Grumman Innovation Systems is a domestic launch service provider and an ISO-9001/2008 certified company. Northrop Grumman Innovation Systems has pioneered new classes of rockets, satellites, and other space-based technologies that help make the benefits of space more affordable and accessible.

1.2. Antares Launch Vehicle

The Antares is a flight proven two or three stage, ground launched vehicle. Conservative design margins, state-of-the-art structural systems, modular avionics architecture, and a simplified integration and test approach yield a robust, reliable launch vehicle design. In addition, Antares payload accommodations and interfaces are flexible and satisfy a wide range of potential customer requirements. Each element of the Antares launch system is designed to maximize payload mass to orbit, streamline the mission design and payload integration process, and provide safe, reliable space launch services.

Antares is launched from the Mid-Atlantic Regional Spaceport (MARS) Pad 0A (Zero A) located on the NASA Wallops Flight Facility (WFF). A cornerstone of the Antares program is the simplified integration and test capabilities that include horizontal integration of the vehicle stages and the payload.

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2. ANTARES LAUNCH SYSTEM OVERVIEW

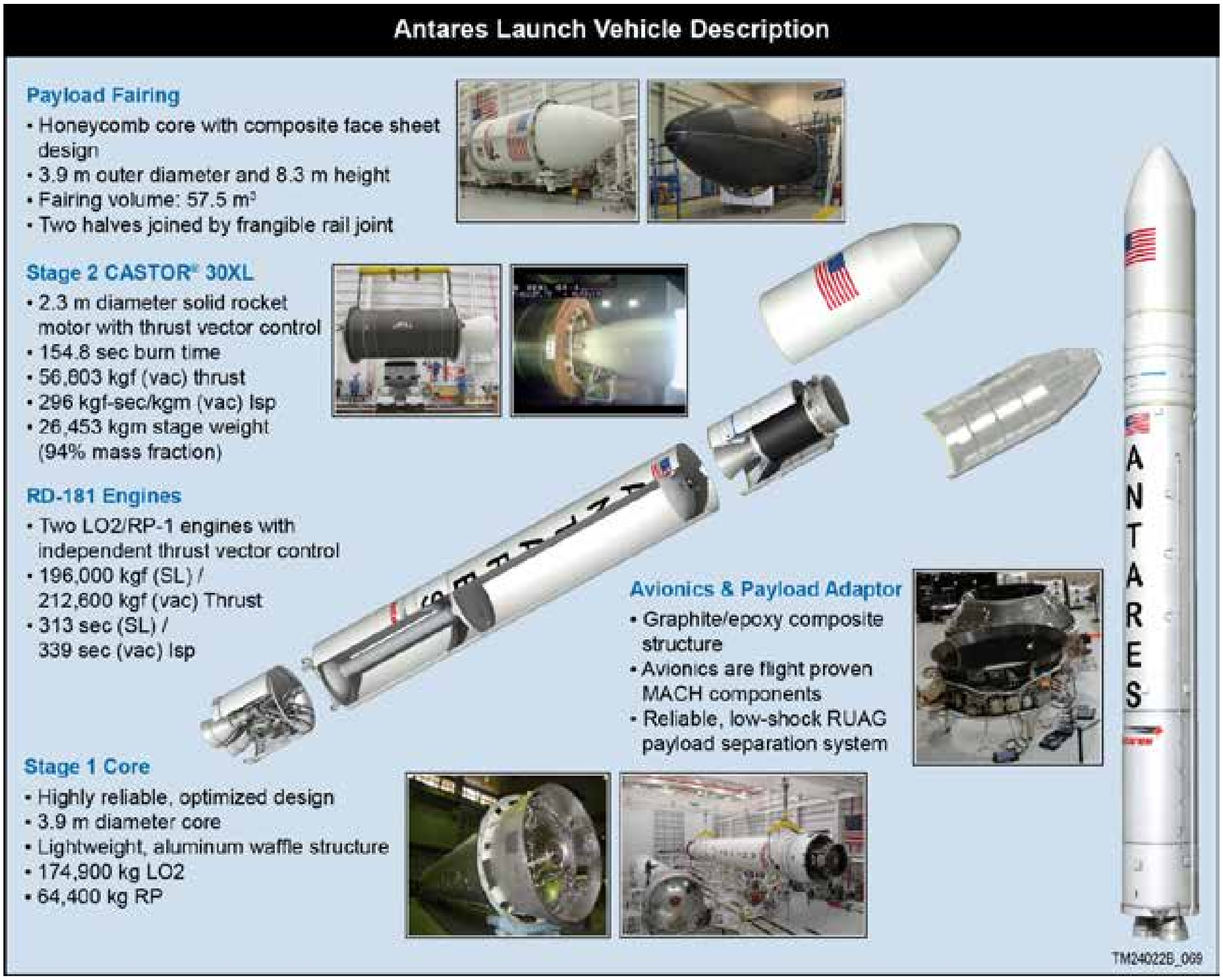
The Antares launch vehicle was developed to serve the Medium-Class space launch market, and to provide a cost effective, reliable and flexible means of placing Medium-Class satellites into orbital and Earth-escape trajectories. The Antares design focuses on system reliability, transportability, and minimum on-pad time.

2.1. Antares Launch Service

The Antares launch service provides all of the necessary hardware, software and services to integrate test and launch a payload into the prescribed orbit. The Antares mission integration process completely identifies, documents, and verifies all spacecraft and mission requirements. In addition, as part of the standard launch services, the Antares mission team will complete all required agreements, licenses, and documentation to conduct Antares launch operations.

2.2. Antares Launch Vehicle Description

Antares features a low-risk design approach by incorporating flight proven components from leading global suppliers, and by utilizing subsystem designs successfully flown on many Northrop Grumman Innovation Systems launch vehicles.



Antares Launch Vehicle Description

Payload Fairing

- Honeycomb core with composite face sheet design
- 3.9 m outer diameter and 8.3 m height
- Fairing volume: 57.5 m^3
- Two halves joined by frangible rail joint

Stage 2 CASTOR® 30XL

- 2.3 m diameter solid rocket motor with thrust vector control
- 154.8 sec burn time
- 56,803 kgf (vac) thrust
- 296 kgf-sec/kgm (vac) Isp
- 26,453 kgm stage weight (94% mass fraction)

RD-181 Engines

- Two LO2/RP-1 engines with independent thrust vector control
- 196,000 kgf (SL) / 212,600 kgf (vac) Thrust
- 313 sec (SL) / 339 sec (vac) Isp

Avionics & Payload Adaptor

- Graphite/epoxy composite structure
- Avionics are flight proven MACH components
- Reliable, low-shock RUAG payload separation system

Stage 1 Core

- Highly reliable, optimized design
- 3.9 m diameter core
- Lightweight, aluminum waffle structure
- 174,900 kg LO2
- 64,400 kg RP

Figure 2.2-1. Antares Launch Vehicle

The Antares configuration numbering convention is shown in Table 2.2-1. The Antares first stage features a Liquid Oxygen/Rocket Propellant (LO2/RP) Stage 1 booster powered by two Energomash RD-181 engines. The second stage utilizes the CASTOR 30XL Solid Rocket Motor (SRM). The two stage configuration is designated Antares 230 (Figure 2.2-2). If a third stage is required to meet mission requirements, three options are available. The Antares 231 configuration features a liquid monopropellant hydrazine Orbit Adjust Module (OAM) stage; the 232 configuration uses a solid STAR 48BV motor for propulsion; the 233 configuration features the Orion 38 solid motor for Stage 3 propulsion. These stages are described in more detail in Section 2.2.3. All Antares configurations utilize a standard 3.9 m payload fairing, as well as common electrical, mechanical, and reaction control systems, ordnance devices, and flight instrumentation.

2.2.1. Stage 1 Assembly

The Stage 1 assembly includes the core, RD-181 main engines, propellant feed system, structure, avionics and harness, ordnance, and other Stage 1 systems. Stage 1 establishes the 3.90 m (154 in) diameter of the Antares launch vehicle and is 27.6 m (90.6 ft.) long.

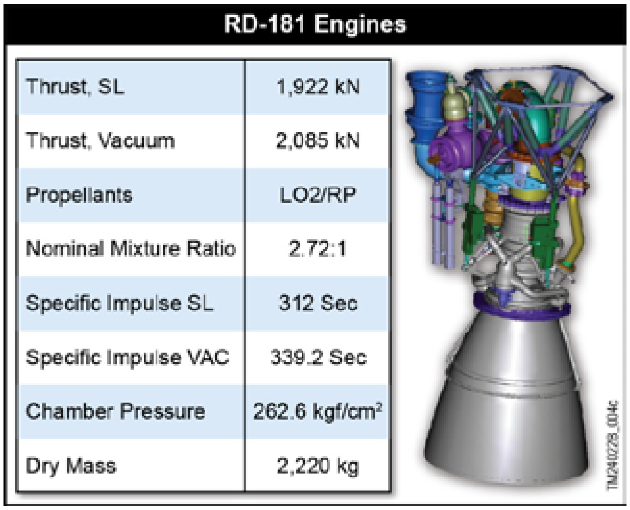
The Stage 1 core facilitates the storage, management, and delivery of propellants (LO2 and kerosene RP) to the main engines at required conditions and flow rates. The Stage 1 core includes propellant tanks, pressurization tanks, valves, sensors, feedlines, tubing, wiring and other associated hardware. Yuzhmash State Enterprise manufactures the Stage 1 core structures and associated propellant systems under the design authority of State Design Office Yuzhnoye, both are prominent Ukraine aerospace organizations. The Stage 1 systems, while specifically designed for the Antares vehicle, are derived from structures and systems used on the Zenit series of launch vehicles, which have extensive flight heritage including more than 70 successful launches.

Table 2.2-1. Antares Numbering Conventions

Vehicle Identifier	Stage 1	Stage 2 (CASTOR)	Stage 3
230	LO2/RP, RD-181	30XL	None
231	LO2/RP, RD-181	30XL	OAM
232	LO2/RP, RD-181	30XL	STAR 48BV
233	LO2/RP, RD-181	30XL	Orion 38

Figure 2.2-2. Antares 230 Configuration

The two RD-181 main engines, shown in Figure 2.2.1-1, generate thrust for launch vehicle propulsion and control during Stage 1 ascent. Each RD-181 rocket engines generates approximately 2,085 kN (468,700 lbf) vacuum thrust at full throttle, for a total Stage 1 thrust of 4,170 kN (937,400 lbf) during ascent. The engines use an oxygen-rich, staged combustion cycle that can be throttled, and have variable mixture ratio valves for controlling relative flow rates of oxidizer and fuel. The engines are Thrust Vector Controlled, to provide vehicle pitch, yaw and roll control during Stage 1 flight. These engines are well characterized and have an extensive test history. Each of the RD-181 engines undergoes hot-fire acceptance testing at Energomash and extensive data review prior to integration onto the vehicle.



RD-181 Engines

Thrust, SL	1,922 kN
Thrust, Vacuum	2,085 kN
Propellants	LO2/RP
Nominal Mixture Ratio	2.72:1
Specific Impulse SL	312 Sec
Specific Impulse VAC	339.2 Sec
Chamber Pressure	262.6 kgf/cm²
Dry Mass	2,220 kg

Figure 2.2.1-1. Antares Main Engine System

2.2.2. Stage 2 Assembly

Antares launch vehicle uses the CASTOR 30XLmotor as the second stage (Figure 2.2.2-1). The CASTOR 30 product line evolved from the heritage CASTOR 120 motor used on the Minotaur-C launch vehicle. The CASTOR 30XL motor includes a composite graphite/epoxy wound case and a flexseal design at the throat to allow for two-axis Thrust Vector Control (TVC) motion during flight.

Figure 2.2.2-1. CASTOR 30XL Motor

2.2.3. Stage 3 Assembly

If a third stage is required to meet mission requirements, Antares features three optional Stage 3 propulsion configurations.

2.2.3.1. 231 Configuration

The 231 configuration features the Orbit Adjust Module (OAM) for third stage propulsion. The OAM is a pressure-regulated monopropellant hydrazine system. This versatile configuration provides increased performance relative to Antares 230 as well as precise orbit injection over a range of Low Earth Orbit (LEO) mission designs. The OAM features up to four spherical propellant tanks with 1200 kg maximum capacity housed inside a payload adapter cone. Thrust is provided by eight 45 lbf Rocket Engine Assemblies (REAs) that are capable of multiple mission burns.

2.2.3.2. 232 Configuration

The 232 configuration features the STAR 48BV solid rocket motor with two-axis thrust vector control for third stage propulsion. The flight-proven STAR 48BV evolved from the STAR 48 family of motors, with over 100 successful flights to-date. This configuration provides a significant performance increase for payloads with high-energy orbit requirements.

2.2.3.3. 233 Configuration

The 233 configuration features the Orion 38 solid rocket motor with two-axis thrust vector control for third stage propulsion. The Orion 38 motor was developed as a low-cost, high-performance third stage for the Pegasus launch vehicle. The Orion 38 is the upper stage motor for Minotaur launch vehicles, and has performed successfully on more than 75 flights over two decades of use. This configuration is used for high-energy orbits and some Low Earth Orbits, depending on mission requirements.

2.2.4. Attitude Control System (ACS)

The Antares Attitude Control System (ACS) employs a heritage cold gas nitrogen system from Northrop Grumman Innovation Systems fleet of space launch vehicles to provide three-axis attitude control during coast phases, roll control during Stage 2 burn, and roll control during Stage 3 burn for the 232 and 233 configurations. The cold-gas control system is used to reorient the vehicle prior to burns, and to orient the payload for separation. Following payload separation, the cold-gas control system is used to orient the upper stage for collision avoidance and prevent payload contamination from residual by-products of the upper stage motors.

2.2.4.1. Avionics Assembly

The Antares avionics design incorporates the company's latest Modular Avionics Control Hardware (MACH) design technology to provide power transfer, data acquisition, booster interfaces, and ordnance initiation. This advanced system supplies the increased capability and flexibility to communicate with vehicle subsystems, Ground Support Equipment (GSE), and the payload utilizing standard Ethernet links and discrete Input / Output (I/O).

2.2.5. Payload Accommodations

2.2.5.1. Payload Fairing

Antares employs a 3.9 m (155 in.) composite bi-sector fairing (Figure 2.2.5.1-1) consisting of two graphite composite shell halves and associated separation systems. The two fairing halves are joined with a frangible rail joint, and the base of the fairing is attached to Stage 2 using a similar ring-shaped frangible joint. Severing the rail/ring frangible joints allows each half of the fairing to rotate on hinges mounted on the Stage 2 fairing cylinder. A cold gas system drives pistons that force the fairing halves open. All fairing deployment systems are contamination-controlled.

Figure 2.2.5.1-1. Antares 3.9 m Fairing Assembly

The payload design envelope for the Antares fairing ensures adequate clearances to the payload assembly during ground operations and ascent. The static payload envelopes provided by Antares fairing are illustrated in Section 5.

2.2.5.2. Payload Interface

All Antares configurations provide a standard 1194 mm (47 in.) Marmon clamp separable interface based on a RUAG 1194VS Payload Attach System (PAS) coming off the intermediate 1575 mm (62 in.) bolted interface.

Optional separating interfaces are available for all configurations. Available interfaces for all configuration include the RUAG 937S, and 1666VS. The RUAG 2624VS is only available for the 230 configuration. Users also have the option to attach directly to the 1575 mm (62 in.) non-separable second stage. Details of the available payload separation systems are in Section 8.

Accommodations for payload electrical interfaces include cable pass-through wires from payload interface connectors to Electrical Ground Support Equipment (EGSE) through umbilical connectors. Details of electrical payload interfaces are included in Section 5.

2.3. Launch Operations

Brief descriptions of the Antares launch operations and fixed launch infrastructure are provided below, with a more detailed discussion in Section 7.

2.3.1. Horizontal Integration

The Antares launch vehicle is designed for horizontal processing. The Antares team performs launch site integration and test activities in a Horizontal Integration Facility (HIF) in preparation for roll-out to the pad for erection, launch vehicle fueling, and launch. The HIF is used to assemble and test the Antares launch vehicle, mate the payload to the launch vehicle, perform launch vehicle to payload checkout, and enclose the payload in the fairing.

2.3.2. Payload Processing and Fueling

Northrop Grumman Innovation Systems' approach to payload processing places few requirements on the customer. Payload processing is conducted near the launch vehicle integration facility in an environmentally controlled Payload Processing Facility (PPF). If required, spacecraft fueling is conducted in an environmentally controlled hazardous operations Payload Fueling Facility (PFF). Once the payload is fully assembled, checked out, and fueled (if required), the payload is transported to the HIF for integration with the launch vehicle.

2.3.3. Mission and Launch Control

The NASA Mission Operations Control Center (MOCC) provides for the conduct and control of the launch countdown as well as the engineering support team. The MOCC provides Antares vehicle Command and Control (C&C), Antares fueling control, payload control, and launch site control (i.e., propellant facilities, Environmental Control System (ECS), and telemetry, power, and network support equipment).

The launch management team is located in the Range Control Center (RCC) and serves as the launch authority center for Antares launches The RCC houses the Range, MARS, Antares and customer launch management teams.

Each control center has hardline and Radio Frequency (RF) telemetry consoles, voice net communications and live video of launch Pad 0A.

2.3.4. Launch Pad

The launch pad for Antares, MARS Pad 0A at WFF, consists of the equipment necessary to support launch vehicle erection, fueling, and launch. These fixed assets include a launch mount with a flame duct, lightning towers, Launch Equipment Vaults (LEVs) to house the launch vehicle and payload EGSE, cabling, fueling trenches, water storage, LO2 and RP fueling system and tanks, and nitrogen and helium tank skids. Antares pad activities include vehicle erection, fueling, final checkout, and launch.

2.3.5. Ground Support Equipment (GSE)

GSE that supports Antares launch operations include the Transporter/Erector/Launcher (TEL), for transporting the vehicle from HIF to pad, erecting vehicle at the pad, and supporting the vehicle during launch operations, Electrical GSE, used for ground commanding, communication, and vehicle external power, and ECS, which provides conditioned air to the payload fairing and vehicle dry bays. This GSE is discussed further in Section 7.

3. PERFORMANCE

This section describes the orbital performance capabilities of the Antares launch vehicle. Antares can deliver payloads to a variety of altitudes and to a range of posigrade and retrograde inclinations. High-energy missions are achieved through the addition of an optional STAR 48BV-based third stage (Antares 232) or the Orion 38 third stage (Antares 233).

3.1. Mission Design

Antares mission team will perform a mission design for each payload optimized to meet critical requirements while satisfying payload, launch vehicle, and Range Safety constraints. Launch site selection, ascent trajectory design, and post-injection deployment design are developed and verified during the Antares mission design process.

3.1.1. Mission Integration

Mission requirements are detailed in the specific mission ICD that is developed as part of the payload/launch vehicle mission integration process. The Antares Mission Manager works with the payload customer to optimize requirements parameters to best suit spacecraft requirements and Antares launch vehicle capabilities. Special mission requirements (e.g. argument of perigee, pointing, etc.) are addressed on a mission-specific basis. Mission requirements drive elements of the trajectory design, including maximum dynamic pressure, launch azimuth constraints, free molecular heating at fairing separation, etc.

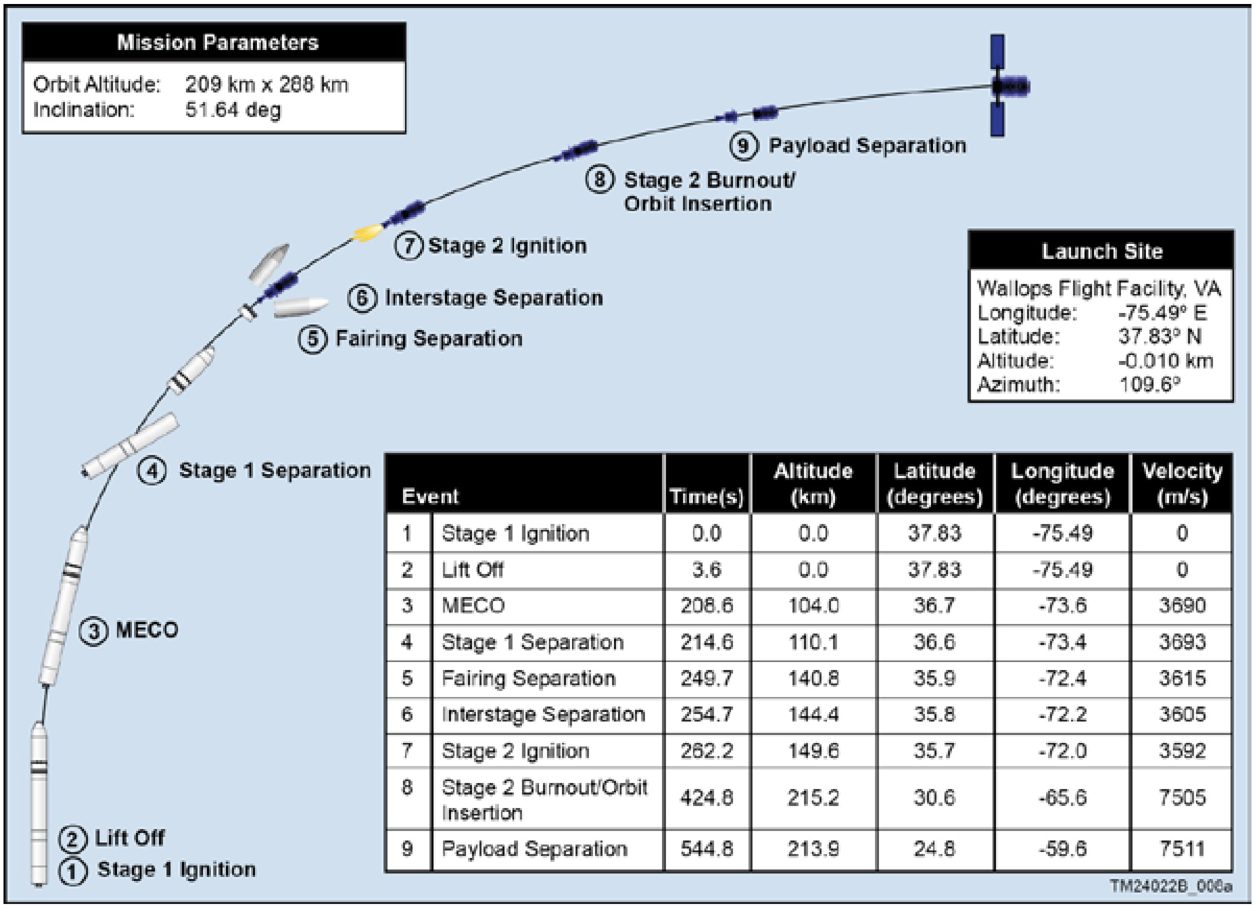
3.1.2. Launch Site

Antares launch operations are conducted from the MARS Spaceport Pad 0A at NASA WFF in Virginia. This launch location supports easterly launch azimuths, some high inclination missions, and high energy launches.

Figure 3.1.2-1. MARS Spaceport at the NASA Wallops Flight Facility

3.2. Mission Profile

A typical mission profile including event timelines for an Antares 230 vehicle from WFF to LEO is shown in Figure 3.2-1. Once the payload has separated, the Stage 2 performs a Collision/Contamination Avoidance Maneuver (CCAM) to ensure no re-contact with the payload.



Mission Parameters	
Orbit Altitude:	209 km x 288 km
Inclination:	51.64 deg

Launch Site	
Wallops Flight Facility, VA	
Longitude:	-75.49° E
Latitude:	37.83° N
Altitude:	-0.010 km
Azimuth:	109.6°

	Event	Time(s)	Altitude (km)	Latitude (degrees)	Longitude (degrees)	Velocity (m/s)
1	Stage 1 Ignition	0.0	0.0	37.83	-75.49	0
2	Lift Off	3.6	0.0	37.83	-75.49	0
3	MECO	208.6	104.0	36.7	-73.6	3690
4	Stage 1 Separation	214.6	110.1	36.6	-73.4	3693
5	Fairing Separation	249.7	140.8	35.9	-72.4	3615
6	Interstage Separation	254.7	144.4	35.8	-72.2	3605
7	Stage 2 Ignition	262.2	149.6	35.7	-72.0	3592
8	Stage 2 Burnout/Orbit Insertion	424.8	215.2	30.6	-65.6	7505
9	Payload Separation	544.8	213.9	24.8	-59.6	7511

Figure 3.2-1. Antares 230 Typical Mission Profile to LEO

3.3. General Performance from WFF

Antares general performance for circular orbits and various configurations, altitudes, and inclinations is provided in Figure 3.3-1 for launches from WFF.

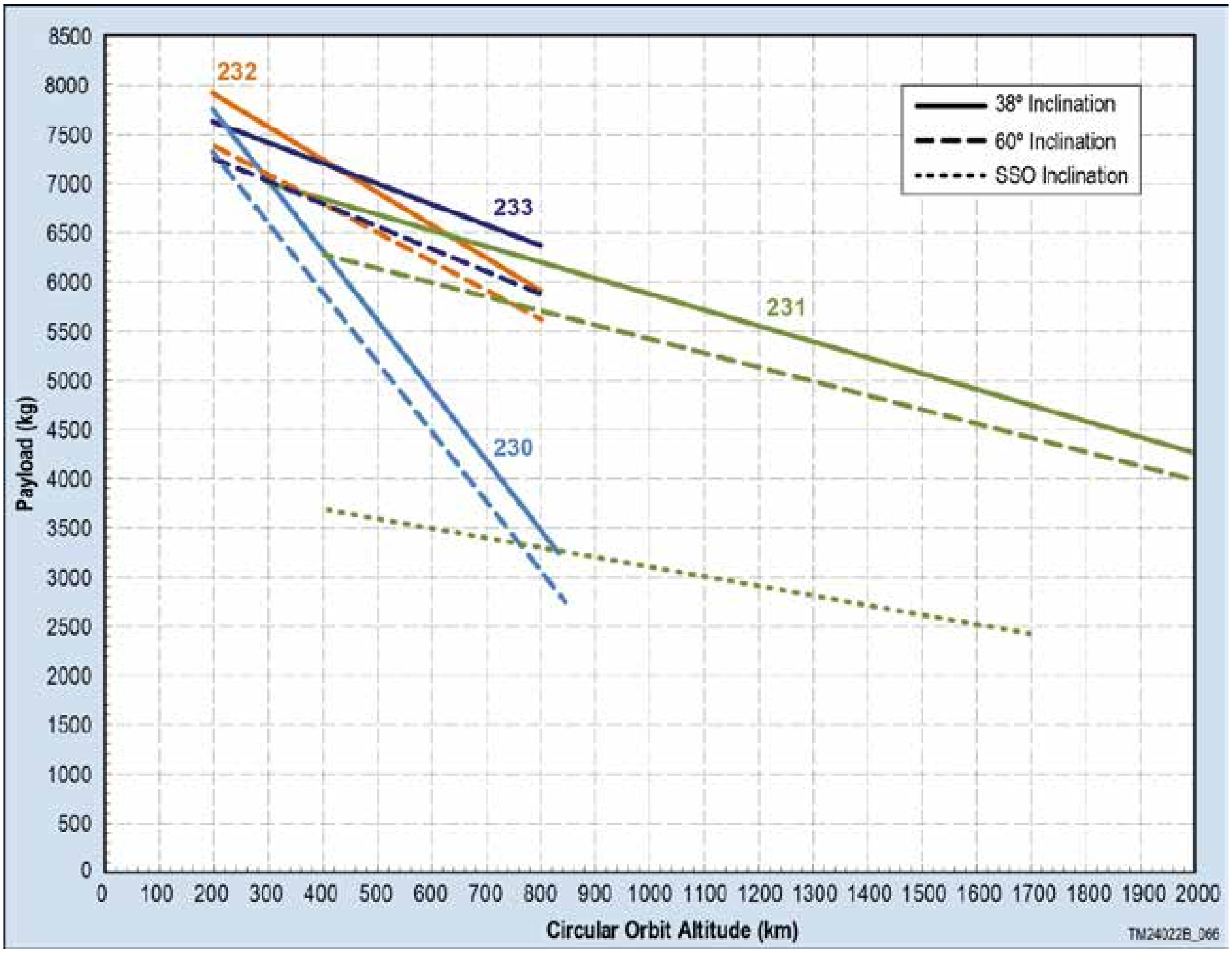


Figure 3.3-1. Antares Launch Capabilities from WFF

Antares performance for high-energy orbits for configurations utilizing 232 and 233 configurations is provided in Figure 3.3-2.

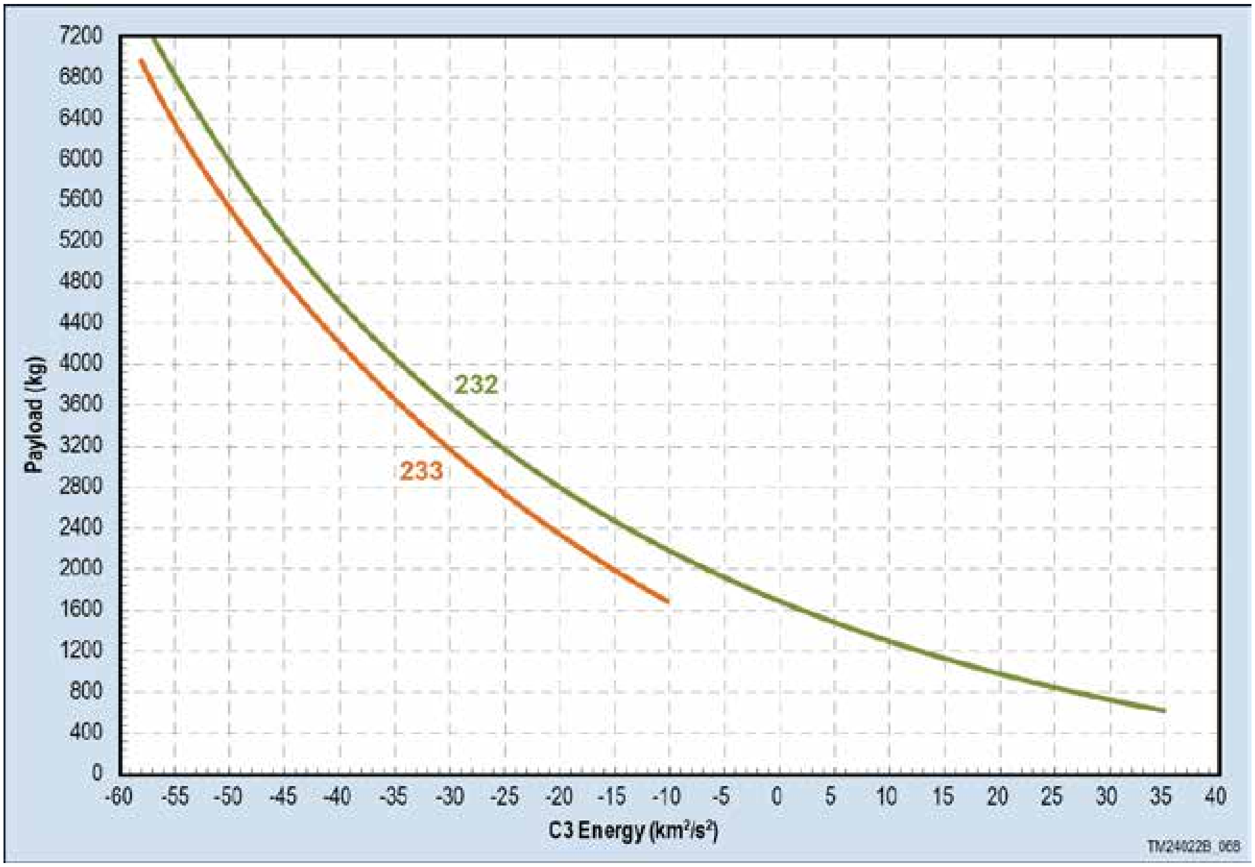


Figure 3.3-2. Antares 232 and 233 High Energy Performance from WFF

Elliptical orbits are also addressed by the Antares 232 or 233 configurations. Figure 3.3-3 provides the performance capabilities of these configurations for 38 degrees inclination targets to various apogee altitudes.

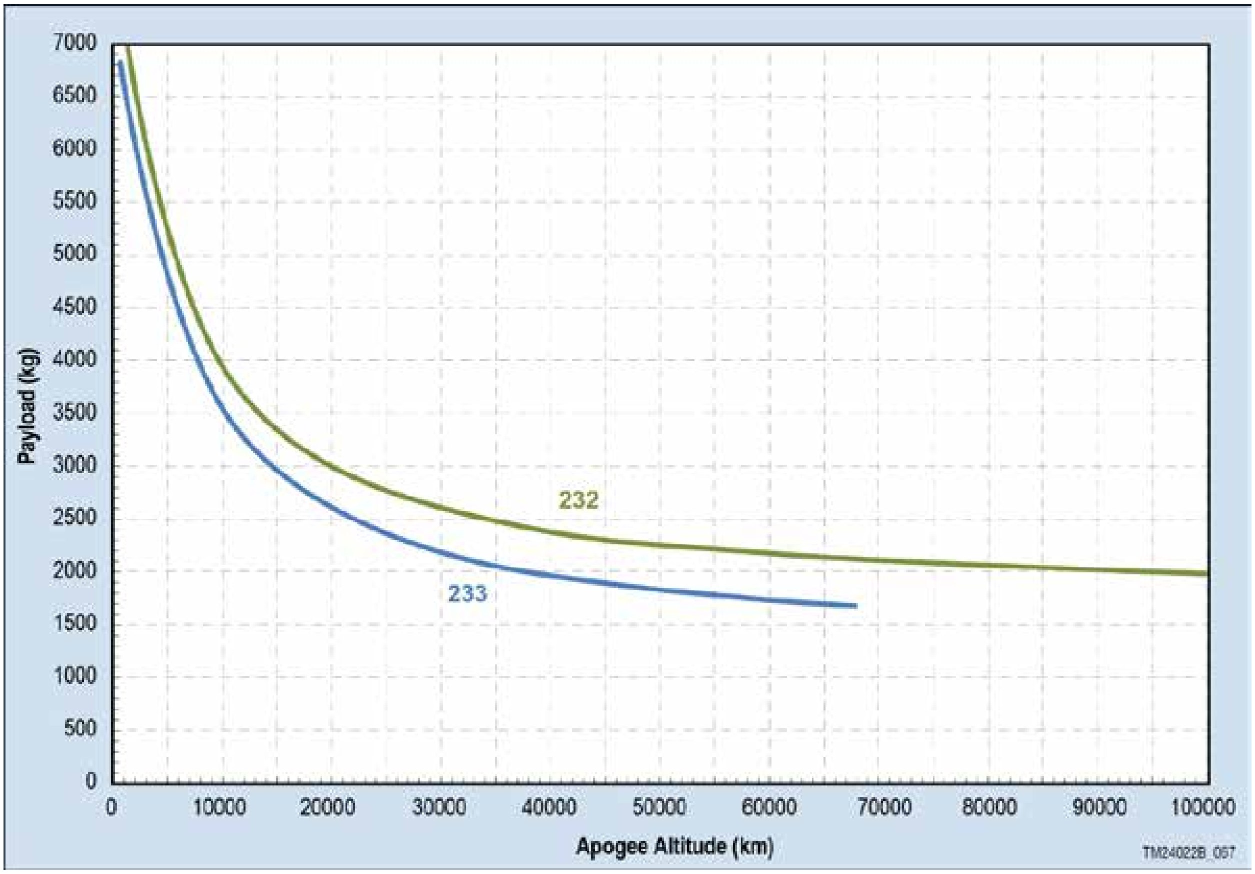


Figure 3.3-3. Antares 232 and 233 Performance to Elliptical Orbits from WFF

3.4. Orbit Insertion Accuracy

Orbit insertion errors are primarily driven by impulse errors from terminal stage propulsion, payload mass, guidance scheme used, and navigational errors. The Antares mission team will characterize apse errors in terms of altitude errors at the insertion and non-insertion apses. The insertion apse is less dependent on impulse errors and payload mass and typically has a tighter dispersion than the non-insertion apse. Errors in the non-insertion apse are caused by velocity errors at insertion, and, as a result, are driven more strongly by impulse errors and payload mass. The distribution of errors between the two apses, as well as to other orbital parameters, can be greatly affected by the guidance scheme, which can be adjusted to place more or less priority on any one of the insertion parameters.

3.4.1. Insertion Accuracies for the Antares 230 Configuration

Orbit injection errors for the Antares 230 are driven by total impulse errors from the CASTOR 30XL motor. The actual insertion errors are dependent on the payload mass and the guidance algorithm. However, insertion apse errors are typically within ±5 to 25 km and non-insertion apse errors are typically within ±60 to 80 km. Lighter payloads going to high altitudes will experience greater dispersions, particularly on the non-insertion apse.

Inclination dispersions are less than ±0.1 to 0.2 degrees. When made a targeting priority, Right Ascension of Ascending Node (RAAN) dispersions are also less than ±0.1 to -0.2 degrees.

3.4.2. Insertion Accuracies for the Antares 231 Configuration

The upgraded Antares 231 configuration includes the OAM, a restartable monopropellant third stage. This stage has sufficient propulsive capability to both improve performance to higher altitude LEO missions as well as significantly reduce apse altitude errors to within ±15 km on both apses. Inclination errors are also improved to within ±0.08 degrees. When made a targeting priority, RAAN errors are similar to the other configurations at less than ±0.1 to 0.2 degrees. Furthermore, this stage allows the explicit targeting of argument of perigee to within ±0.5 degrees.

3.4.3. Insertion Accuracies for the Antares 232 and 233 Configurations

The upgraded Antares 232 and 233 configurations with STAR 48BV or ORION 38 motors as a third stage are used primarily for missions where high energy is required such as high apogee altitude or escape missions. Payload insertion accuracies vary widely depending on the specific requirements and will be provided on a mission-specific basis.

3.5. Payload Deployment

Following orbit insertion, the Antares avionics subsystem executes a series of ACS maneuvers to provide the desired initial payload attitude prior to separation. Multiple ACS maneuvers may be used for the deployment of multiple spacecraft with independent attitude requirements. Antares is capable of orienting to a wide range of deployment attitudes including inertial, orbit track relative, and sun pointing. The customer may specify an inertial-fixed or spin-stabilized attitude. Typical accuracies are shown in Table 3.5-1.

Table 3.5-1. Antares Payload Deployment Pointing and Rate Accuracies

Error Type		Angle	Rate
3-Axis	Pitch	±1.0°	±0.5 °/sec
	Yaw	±1.0°	±0.5 °/sec
	Roll	±1.0°	±0.5 °/sec
Spinning	Spin Axis	±1.0°	-
	Spin Rate	-	±3 °/sec

The maximum spin rate for a specific mission depends upon the spin axis moment of inertia of the payload and the ACS propellant budget but cannot nominally exceed 30 degrees per second. Greater spin rates are possible as a mission unique service.

As part of the Standard Launch Service, Antares mission team will perform a mission-specific payload separation tip-off analysis to determine the expected maximum payload attitude rates immediately following payload separation. The post separation rates are a function of pre-deployment rates, separation system performance, and payload mass properties.

3.5.1. 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. For the standard Marmon Clamp-band separation system, payload tip-off rates are generally under 1°/sec per axis. Separation system options are discussed further in Section 8.1. Antares mission team will perform a mission-specific tip-off analysis for each payload.

Separation velocities are driven by the need to prevent recontact between the payload and the Antares upper stage after separation. Typical separation velocities are between 0.6 to 0.9 m/sec (2 to 3 ft. /sec).

3.5.2. Collision/Contamination Avoidance Maneuver (CCAM)

Following orbit insertion and payload separation, the Antares Stage 2 performs a CCAM. The CCAM minimizes both payload contamination and the potential for recontact between Antares hardware and the separated payload. Antares mission team will perform a recontact analysis for post-separation events.

A typical CCAM begins soon after payload separation. The launch vehicle performs a 90° yaw maneuver designed to direct any remaining Stage 2 motor impulse in a direction which increases the separation distance between the two bodies. After a delay to allow the distance between the spacecraft and Stage 2 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 Antares stage.

Following the completion of the CCAM maneuver as described above, any remaining maneuvers, the ACS valves are opened, and the remaining ACS nitrogen propellant is expelled.

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4. PAYLOAD ENVIRONMENTS

This section provides details of the predicted environmental conditions that the payload experiences during Antares ground operations, powered flight, and post-boost operations. The environmental conditions presented in this section are representative of a typical mission and are applicable to the baseline Antares 230 configuration unless specifically noted. The mission team will perform a mission-specific analysis as part of the standard Antares launch service to determine payload environments for a specific mission.

4.1. Design Limit Load Factors

Design limit load factors due to the combined effects of steady state and low frequency transient accelerations are defined in Table 4.1-1. These values apply to the payload CG, account for maximum ground and flight loads, and include uncertainty margins.

Antares 230 is the single exception to the axial acceleration limit shown in Table 4.1-1. For this configuration, the axial design limit load factor of +8.0g may be reached during second stage operation, dependent on payload mass.

To minimize loads and deflections as well as the potential for coupling with the launch vehicle guidance system, the first bending frequency of the payload assuming a fixed base must be maintained above 8 Hz. Dynamic response is largely governed by payload characteristics, so mission-specific coupled loads analyses must be performed to provide precise load predictions.

Table 4.1-1. Design Limit Load Factors

Axis	Maximum Acceleration (g)
Axial	-1.0/+6.5
Lateral	±1.5

Notes:
1) Sign Convention: Positive Axial Acceleration Produces Compression.
2) Axial and Lateral Accelerations Are Simultaneous.
3) Maximum axial acceleration is based on a minimum payload mass of 3000 kg (6,614 lb.)

4.1.1. Time-Phased Acceleration Loads

Dynamic loading events that occur throughout various portions of the ground operations and flight include steady state acceleration, transient low frequency acceleration, acoustic impingement, random vibration, and pyroshock events. Table 4.1.1-1 shows an example of typical load factors at the payload interface for ground and flight operations. It should be noted these accelerations might vary as a function of payload mass. The payload specific accelerations are provided in the Coupled Loads Analyses (CLAs) that are performed for each mission to define maximum predicted acceleration for a specific payload.

Table 4.1.1-1. Typical Antares 230 Ground and Flight Acceleration Loads at the Payload Interface

		Axial		Lateral	
Load Case		Static	Transient	Static	Transient
Ground	**Payload Vertical**	-1.0	±0.5	±0.1	±0.5
Ground	**Payload Horizontal**	0.1	±0.2	-1.0	±0.1
Flight	**Liftoff**	1.0	±0.15	±0.1	±0.4
Flight	**Transonic**	2.1	±0.3	±0.2	±0.5
Flight	**Stage 1 Maximum**	4.4	±0.3	±0.1	±0.2
Flight	**Stage 2 Ignition**	0.1	-0.8/ +1.5	±0.1	±0.3
Flight	**Stage 2 Maximum**	4.3	±0.3	±0.1	±0.3

Table 4.1.1-2 provides the primary dynamic loading events and the time phasing of these events during Antares flight. Pyroshock events are not indicated, as they do not occur simultaneously with any other significant dynamic loading events.

Table 4.1.1-2. Phasing of Dynamic Loading Events

Item	Liftoff	Transonic	Supersonic/ Max Q	S2 Ignition
Typical Flight Time	2 sec	65-80 sec	80-90 sec	~330 sec
Steady State Loads	Yes	Yes	Yes	No
Transient Loads	Yes	Yes	Yes	Yes
Acoustics	Yes	Yes	Yes	No
Random Vibration	Yes	Yes	Yes	No

As dynamic response is largely governed by payload characteristics, multiple mission-specific Coupled Loads Analyses (CLAs) are performed with customer-provided finite element models of the payload at different states of definition. Flight events analyzed by the CLA include liftoff, the transonic portion of flight, supersonic flight or Maximum Dynamic Pressure (Max Q), Main Engine Cut Off (MECO), and Stage 2 ignition.

Northrop Grumman Innovation Systems performs two CLAs for each mission. The preliminary CLA is based on the analytical payload models. The final CLA is based on the test-verified payload model.

4.1.2. Payload Acceleration as a Function of Mass

Payload mass affects the maximum axial quasi-static acceleration a specific payload experiences. Figures 4.1.2-1 through 4.1.2-3 provides the vehicle quasi-static acceleration as a function of payload mass.

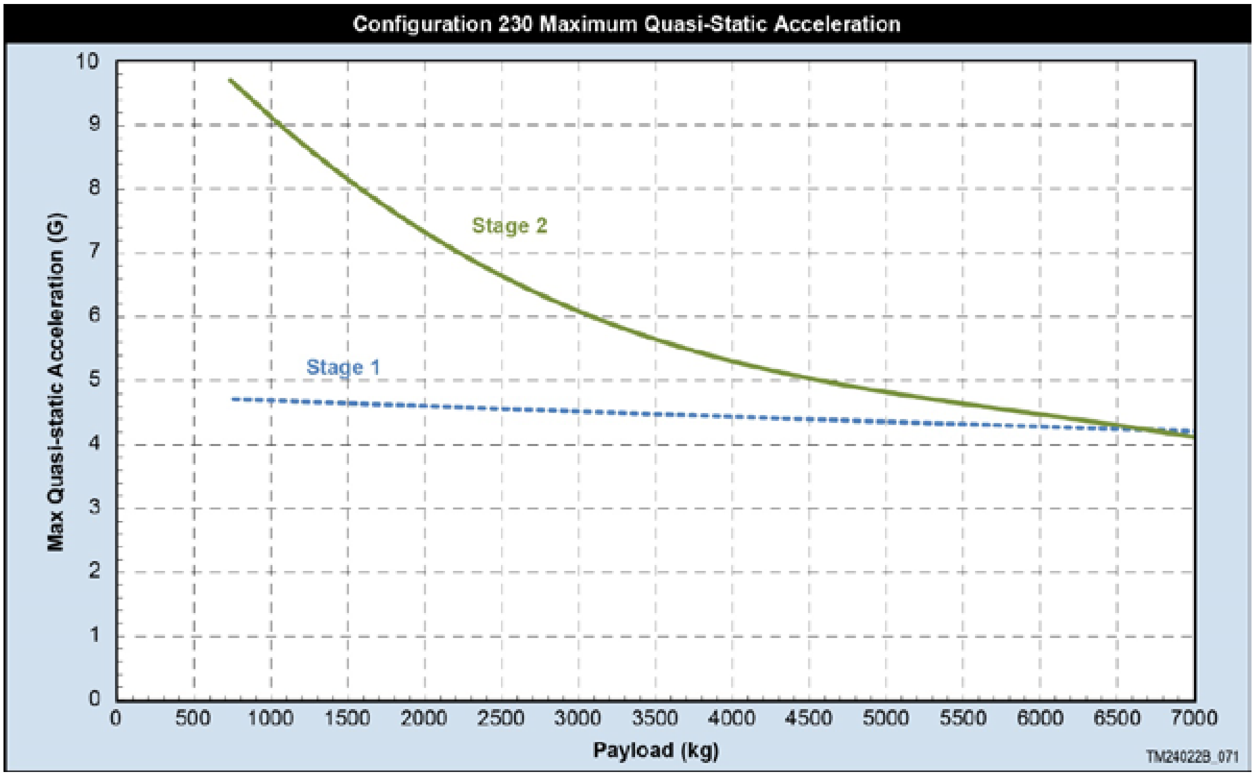


Figure 4.1.2-1. Antares 230 Nominal Payload Acceleration as a Function of Mass

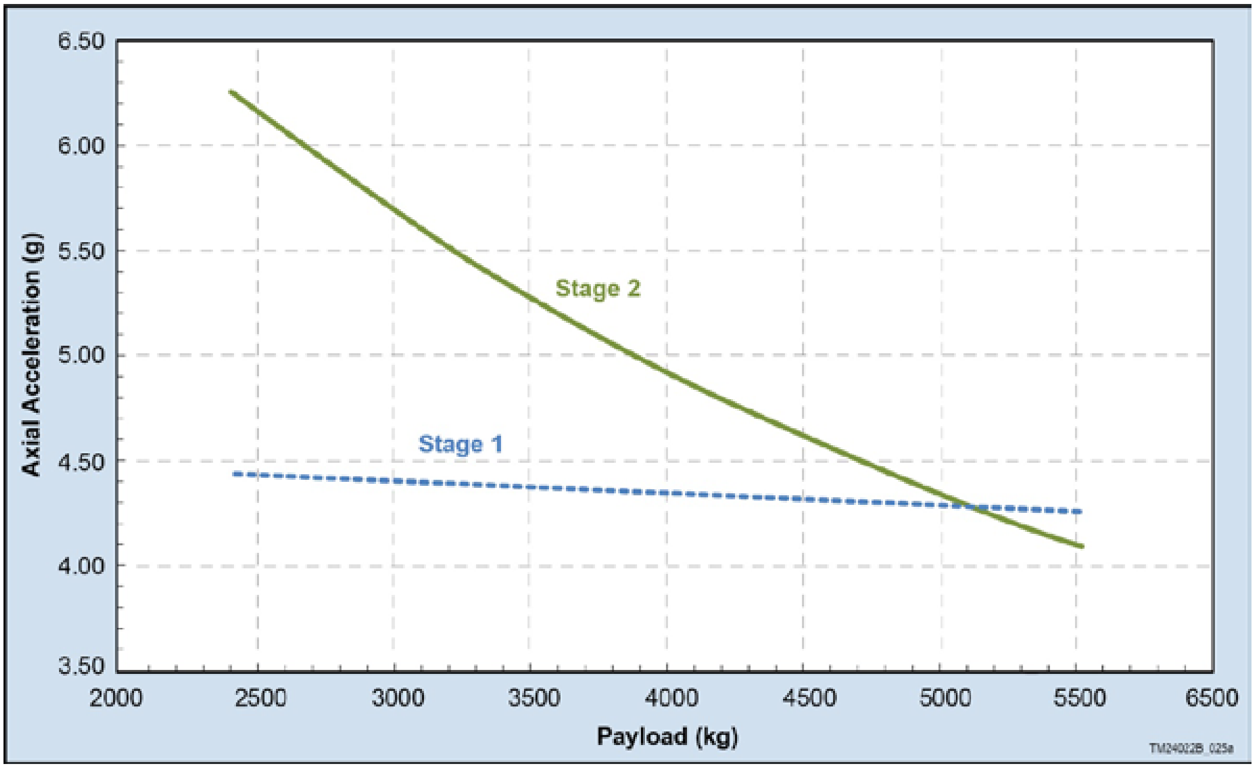


Figure 4.1.2-2. Antares 231 Nominal Payload Acceleration as a Function of Mass

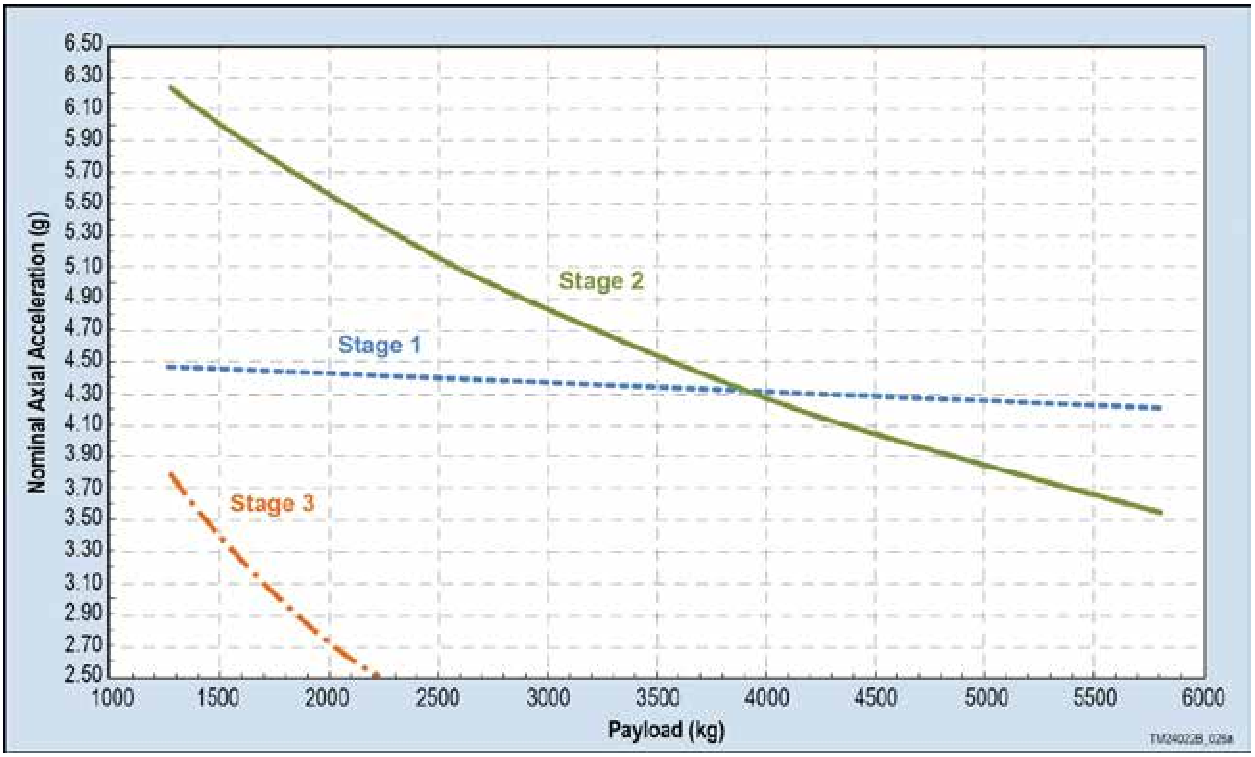


Figure 4.1.2-3. Antares 232 Nominal Payload Acceleration as a Function of Mass

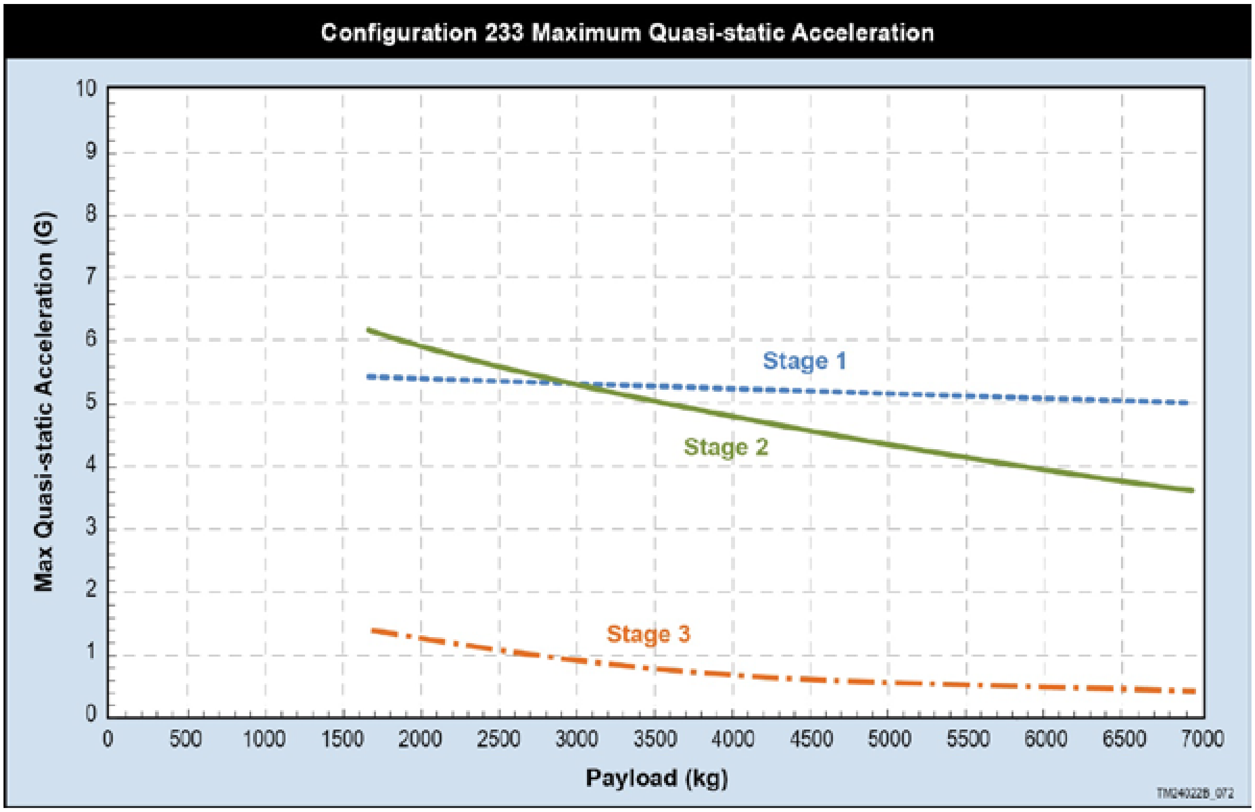


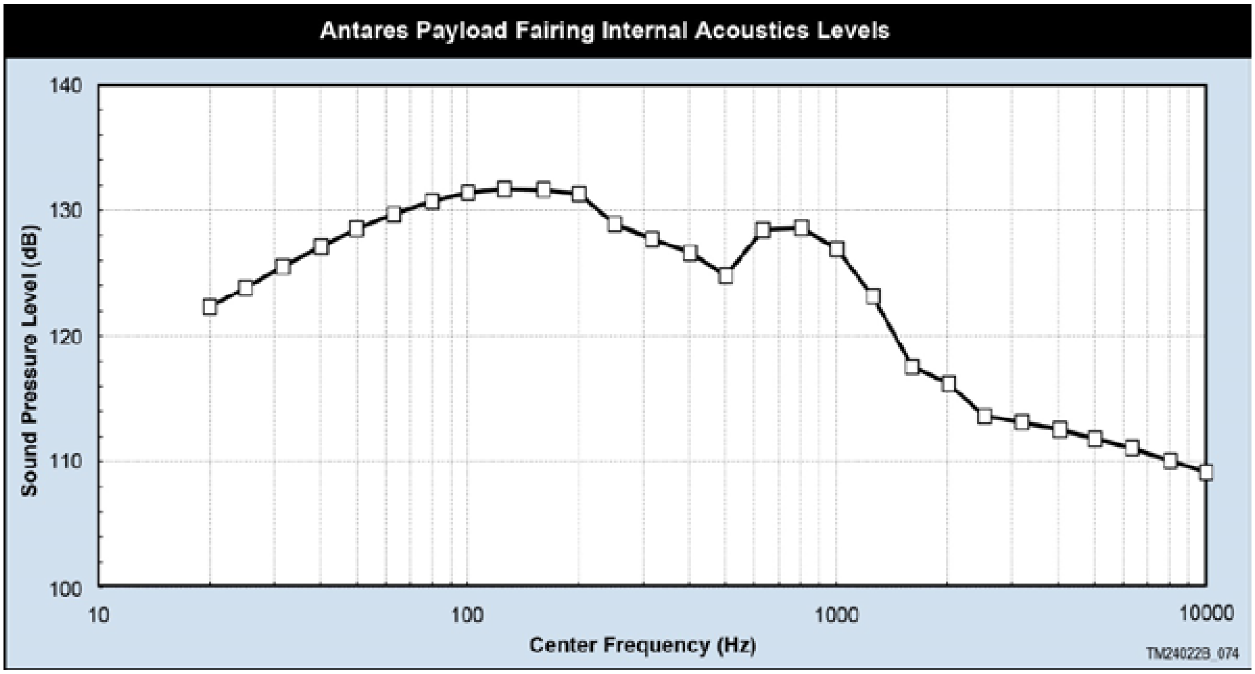
Figure 4.1.2-4. Antares 233 Nominal Payload Acceleration as a Function of Mass

4.2. Payload Vibration Environment

The random vibration environment at the payload interface is encompassed by acoustics and coupled loads analysis results. Antares does not have a specific random vibration environment for the payload.

4.2.1. Payload Acoustic Environment

The maximum expected acoustic levels within the Antares fairing are shown in Figure 4.2-1. Antares peak acoustic environments occur at lift-off and near the point of maximum dynamic pressure. Acoustic levels are sensitive to spacecraft geometry (fill factor), so payload specific adjustments may be necessary.



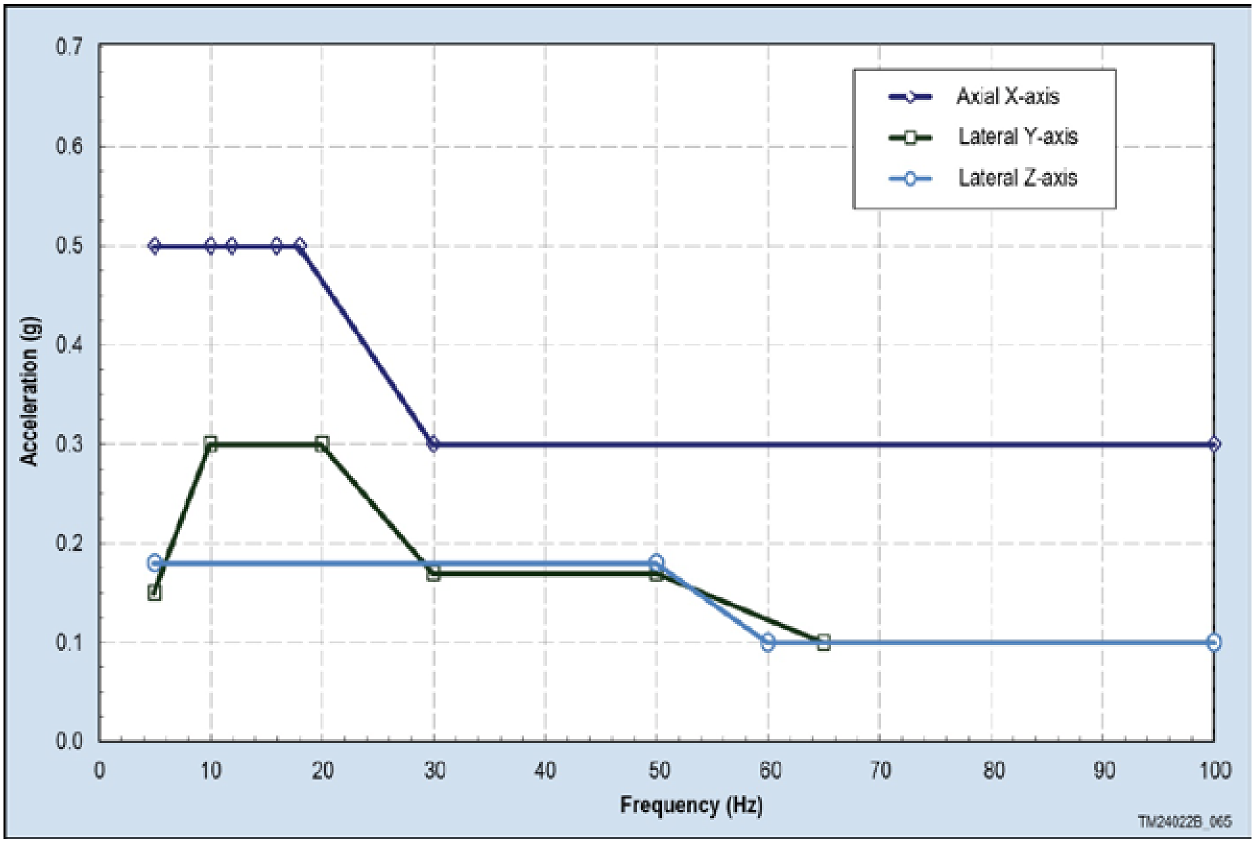
Center Frequency (Hz)	Sound Pressure Level (dB)	Center Frequency (Hz)	Sound Pressure Level (dB)
20	122.3	630	128.4
25	123.8	800	128.6
31.5	125.5	1000	126.9
40	127.1	1250	123.1
50	128.5	1600	117.5
63	129.7	2000	116.2
80	130.7	2500	113.6
100	131.4	3150	113.1
125	131.7	4000	112.5
160	131.6	5000	111.8
200	131.3	6300	111.0
250	128.9	8000	110.0
315	127.7	10000	109.1
400	126.6	OASPL	141.5
500	124.8		

Includes Fill Factor calculated per NASA-STD-7001 with the following parameters:
Average Gap – 17 inches
Volume Ratio – 0.62

Figure 4.2-1. Antares Fairing Internal Maximum Flight Level Payload Acoustic Environment

4.2.2. Sine Vibration

Figure 4.2.2-1 defines the maximum flight level payload interface sinusoidal vibration levels for a fixed base payload test, which may be used for preliminary design. The spectrum defined in this figure is provided for reference only. Northrop Grumman Innovation Systems develops a mission-specific sine spectrum for each mission using the results from CLA.

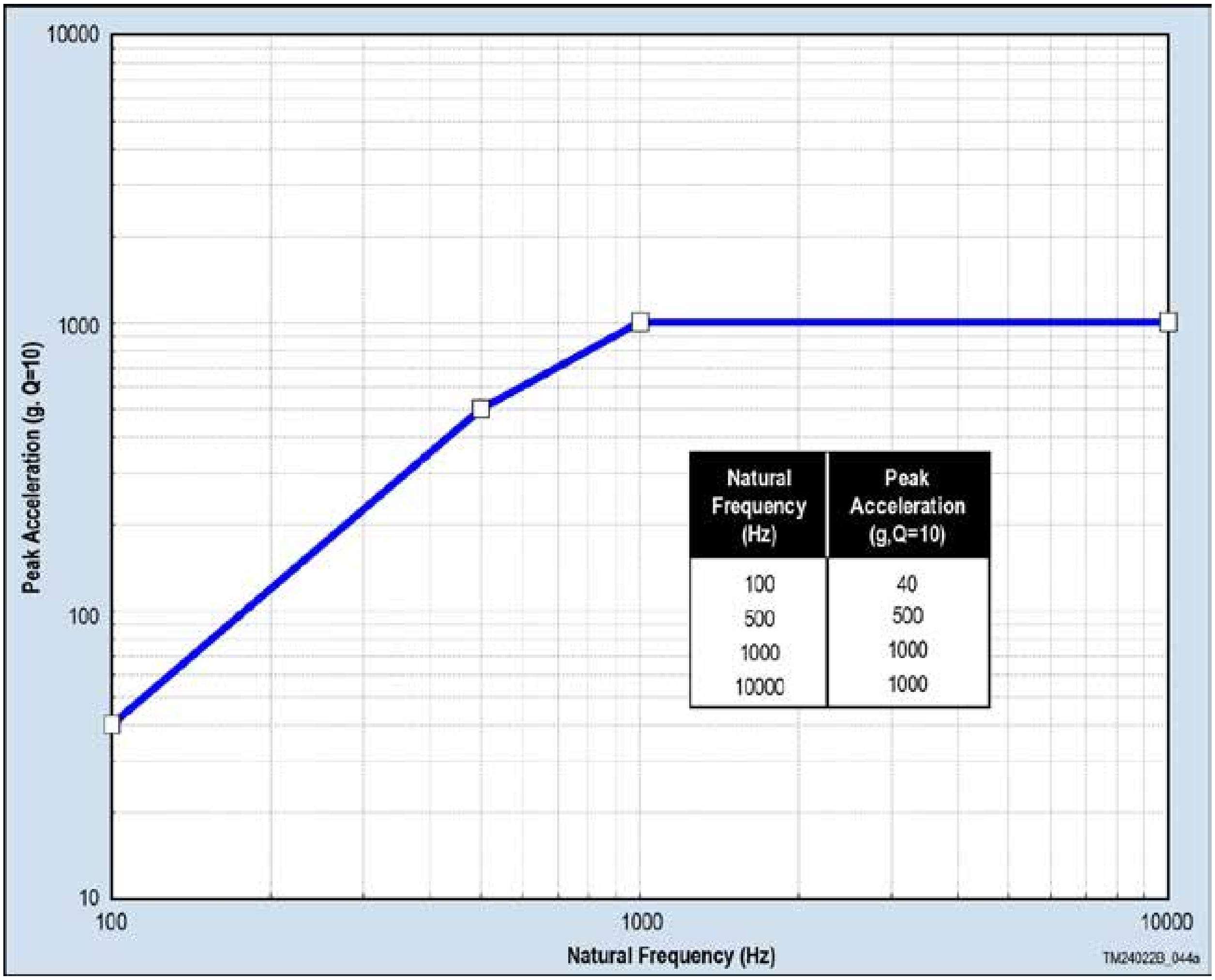


Axial (X-axis)		Lateral (Y-axis)		Lateral (Z-axis)	
Frequency (Hz)	Acceleration (g)	Frequency (Hz)	Acceleration (g)	Frequency (Hz)	Acceleration (g)
5	0.50	5	0.15	5	0.18
10	0.50	10	0.30	50	0.18
12	0.50	20	0.30	60	0.10
16	0.50	30	0.17	100	0.10
18	0.50	50	0.17		
30	0.30	65	0.10		
100	0.30	100	0.10		

Figure 4.2.2-1. Antares Payload Interface Sine Vibration Levels

4.3. Payload Shock Environment

The maximum shock response spectrum at the base of the payload from all launch vehicle events does not exceed the flight limit levels provided in Figure 4.3-1. The flight limit levels are derived from ground separation test data and analytical predictions for the vehicle and payload separation systems. These levels are applicable to a payload using the Antares standard payload separation system or attaching to the non-separating interface.



Natural Frequency (Hz)	Peak Acceleration (g,Q=10)
100	40
500	500
1000	1000
10000	1000

Figure 4.3-1. Antares Payload Maximum Flight Level Shock at the Base of the Payload

4.4. Contamination and Environmental Control

Antares mission team understands the importance of maintaining proper thermal and contamination control and is committed to providing environments that meet customer requirements. Antares mission team partners with each payload customer to ensure the required payload environments are identified and maintained at all times. Antares mission team has developed a general environmental control plan for all Antares missions. This plan is tailored for each mission to capture the unique environmental control requirements of each payload.

Prior to payload enclosure, payload thermal and humidity environments are maintained by the HIF facility ECS. Once enclosed, payload environments are maintained by either the Portable Environmental Control System (PECS) or the Pad ECS. The Pad ECS maintains the payload thermal and humidity environments through launch. Each of these systems controls temperature between 12.8 – 28.9 °C (55 – 84 °F) and humidity between 30 to 60%.

4.4.1. Ground Transportation Environments

Environmental control during Antares payload transport activities is maintained by the PECS. The PECS is a trailered, self-contained environmental control system. The system's two independent refrigeration circuits cool and dehumidify incoming air after which the air is reheated to maintain the desired temperature and Relative Humidity (RH) set points. A humidifier is available to add moisture, if needed. The PECS continuously purges the fairing environment with clean filtered air providing a Class 8 (IAW ISO 14644) or better environment during all post-encapsulation operations. Antares's PECS incorporates both a HEPA filter unit for particulate control and carbon filtration for hydrocarbon control. Conditioned air filtration removes 99.97% of all particles with a size greater than 0.3 microns and 95% of all hydrocarbons of molecular weight greater than 70.

4.4.2. Launch Operations Fairing Environment

Once the TEL with the integrated Antares launch vehicle has been secured to the launch pad mount, the fairing air supply is transitioned from the PECS to the pad ECS. During this transition, a short disruption of airflow to the fairing occurs; however, no perceptible changes in the environment are anticipated. The pad ECS then continues to maintain fairing environment control throughout the remainder of the launch operations. Backup power is implemented at the launch site to ensure payload environment controls are maintained at all times.

4.4.3. Contamination Control

Antares' contamination control program is 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 contamination control program, based on industry standard contamination control specifications, ensures that all personnel and processes strictly adhere to payload cleanliness requirements.

Once the payload is encapsulated, the air entering the fairing is maintained to Class 8 or better cleanliness environment at all times through HEPA and carbon filtered air removing 99.97% off all particles with a size greater than 0.3 microns and 95% of all hydrocarbons of molecular weight greater than 70.

The internal surfaces of the Antares payload fairing and payload adapter are cleaned, certified, and maintained to visibly clean, Level II or better. The Antares avionics section, Stage 2 motor, and separation system, all which are located within the payload fairing compartment downstream of the payload, are cleaned to visibly clean.

4.4.4. Upgraded Thermal and Contamination Services

Antares mission team recognizes that some payloads may have more stringent cleanliness requirements than those provided by the Standard Launch Service. Antares offers a variety of upgrades to address these needs. These options are discussed in more detail in Section 8:

4.5. Pressurization Profile

Typical Antares LEO mission ascents have peak pressure decay rates less than 0.7 psi/sec. The internal pressure at fairing jettison is typically less than 0.2 psia. Typical fairing internal pressure is shown in Figure 4.5-1 for Antares 230. The venting characteristics are sensitive to trajectory shape and payload unvented volume.

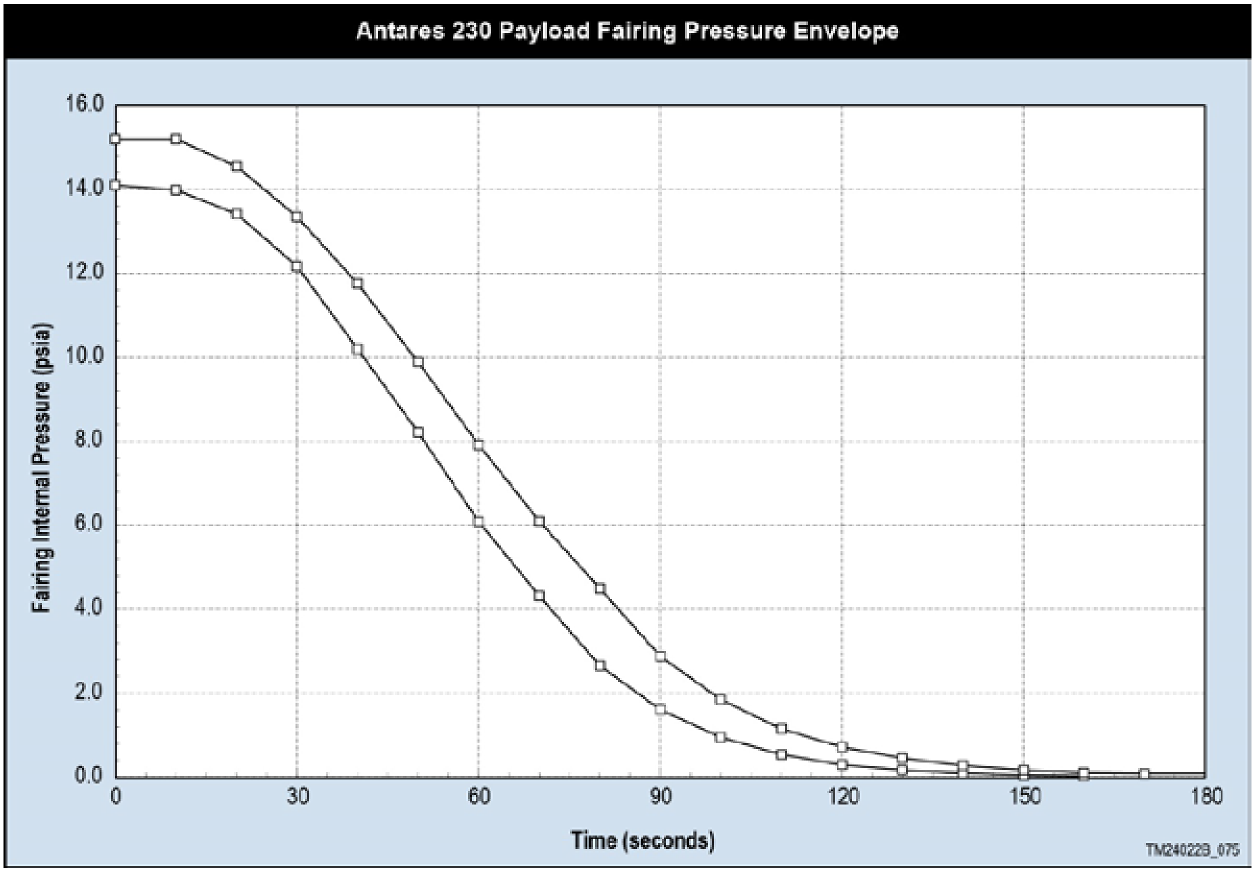


Figure 4.5-1. Typical Antares 230 Fairing Internal Pressure Profile

4.6. Payload RF Environment

As shown in Table 4.6-1, Antares has four RF radiating sources: three S-Band transmitters at 2241.5, 2269.5, and 2287.5 MHz, and a C-Band Transponder that transmits at 5765 MHz. The fairing provides attenuation for the payload RF environment produced by the external aft antennas until the fairing is deployed. Radiation inside the fairing, as a result of vehicle source radiation, is further limited through the use of two sets of antennas. The aft antennas located on the vehicle interstage skin are used until fairing separation. A second set of antennas, located inside the fairing, are used after fairing deployment. The maximum field strength produced by these sources at the payload interface is 5.4 V/m in S-Band and 41.4 V/m in C-Band.

During ground and launch operations, the Range uses multiple radars to track the vehicle and a directional Ultra High Frequency (UHF) transmitter to capture the Flight Termination System (FTS) receivers. Again, the payload fairing provides some measure of attenuation of the RF fields from these sources. The maximum RF levels associated with range sources are actively managed to achieve less than 20 V/m at frequencies from 10 kHz to 1 GHz and 30 V/m from 1 to 40 GHz during launch and ascent. As lower levels are required to protect the payload, Northrop Grumman Innovation Systems will work to coordinate with the range to further limit RF power levels.

Table 4.6-1. Launch Vehicle RF Emitters and Receivers

SOURCE	1	2	3	4	5	6
Function	Command Destruct	Tracking Transponder	Tracking Transponder	Launch Vehicle	Launch Vehicle	Launch Vehicle
Receive/Transmit	Receive	Transmit	Receive	Transmit	Transmit	Transmit
Band	UHF	C-Band	C-Band	S-Band	S-Band	S-Band
Frequency (MHz)	421	5765	5690	2241.5	2287.5	2269.5
Bandwidth (MHz)	0.18	14	14	3.48	3.9	3.9
Power Output	N/A	400 W (peak)	N/A	5 W	5 W	5 W
Sensitivity	-105 dBm	N/A	-70 dBm	N/A	N/A	N/A
Modulation	Tone	ASK	ASK	PCM/FM	SOQPSK	SOQPSK
Maximum Field Strength at Fwd Edge of the Payload Adapter Cone	N/A	41.4 V/m	N/A	5.4 V/m	0.2 V/m	0.9 V/m

5. PAYLOAD INTERFACES

This section describes the available mechanical, electrical and GSE interfaces between the Antares launch vehicle and the payload.

5.1. 3.9 Meter Payload Fairing

The Antares payload fairing encloses the payload and provides protection and contamination control during ground handling, integration and flight. The Antares payload fairing is a 3.9 m (155 in.) diameter structure consisting of two shells constructed of graphite-epoxy facesheets with an aluminum honeycomb core and associated separation systems.

While protecting the payload from environments on the ground and during flight, this composite metal matrix also provides a significant level of RF attenuation for the payload during periods of encapsulated processing.

The two fairing halves are joined with a frangible rail joint along the bi-conic and cylinder sections, and the base of the fairing is attached to Stage 2 using a ring-shaped frangible joint. The frangible rails and rings are clean-separation systems employing sealed stainless steel tubes that fracture notched aluminum extrusions. Severing the rail/ring frangible joints allow each half of the fairing to rotate on hinges mounted on the Stage 2 fairing cylinder. A cold gas generation system is used to drive pistons that force the fairing halves open. All fairing deployment systems are non-contaminating.

5.1.1. Payload Fairing Static Envelope

The Antares payload envelope was developed to ensure that clearances to the payload assembly are maintained during ground operations and ascent. Static envelopes for the 230, 231, 232, and 233 configurations are provided in Figure 5.1.1-1 through 5.1.1-4. These envelopes assume the use of the RUAG 1194VS payload separation system. If a different separation system is used, the static envelopes shown in these figures will be affected.

The static envelope accounts for fairing and payload structural deflections assuming a minimum lateral bending frequency of 8 Hz for the payload. The static envelope accounts for Payload Adapter System (PAS) interface plane deflection and rotation. The static envelope does not account for payload non-rigid body deflections, payload dimensional errors due to manufacturing/design, and tolerance stack-up. Extensions of the static envelope may be accommodated, but must be assessed on a mission-specific basis. No portion of the payload can extend aft of the payload/launch vehicle interface plane, unless otherwise approved in the mission ICD. Payload protrusions beyond the static envelope will be evaluated on a case-by-case basis.

Antares will perform comprehensive dynamic clearance analyses using payload customer-provided models to ensure positive clearance between the payload and the Antares fairing during all phases of ground operations and flight.

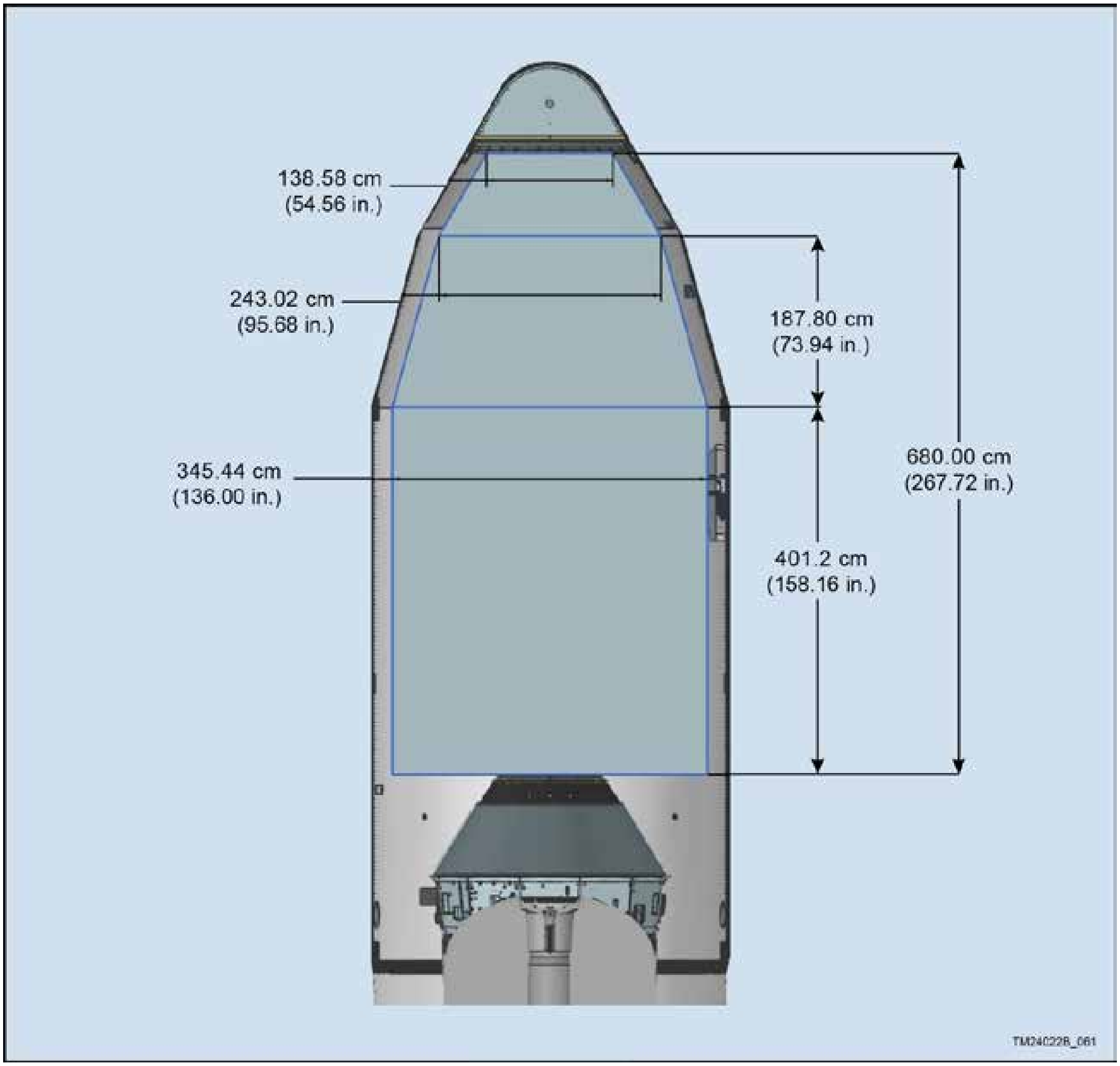


Figure 5.1.1-1. Antares 230 Fairing Static Payload Envelope with RUAG 1194VS PAF Interface

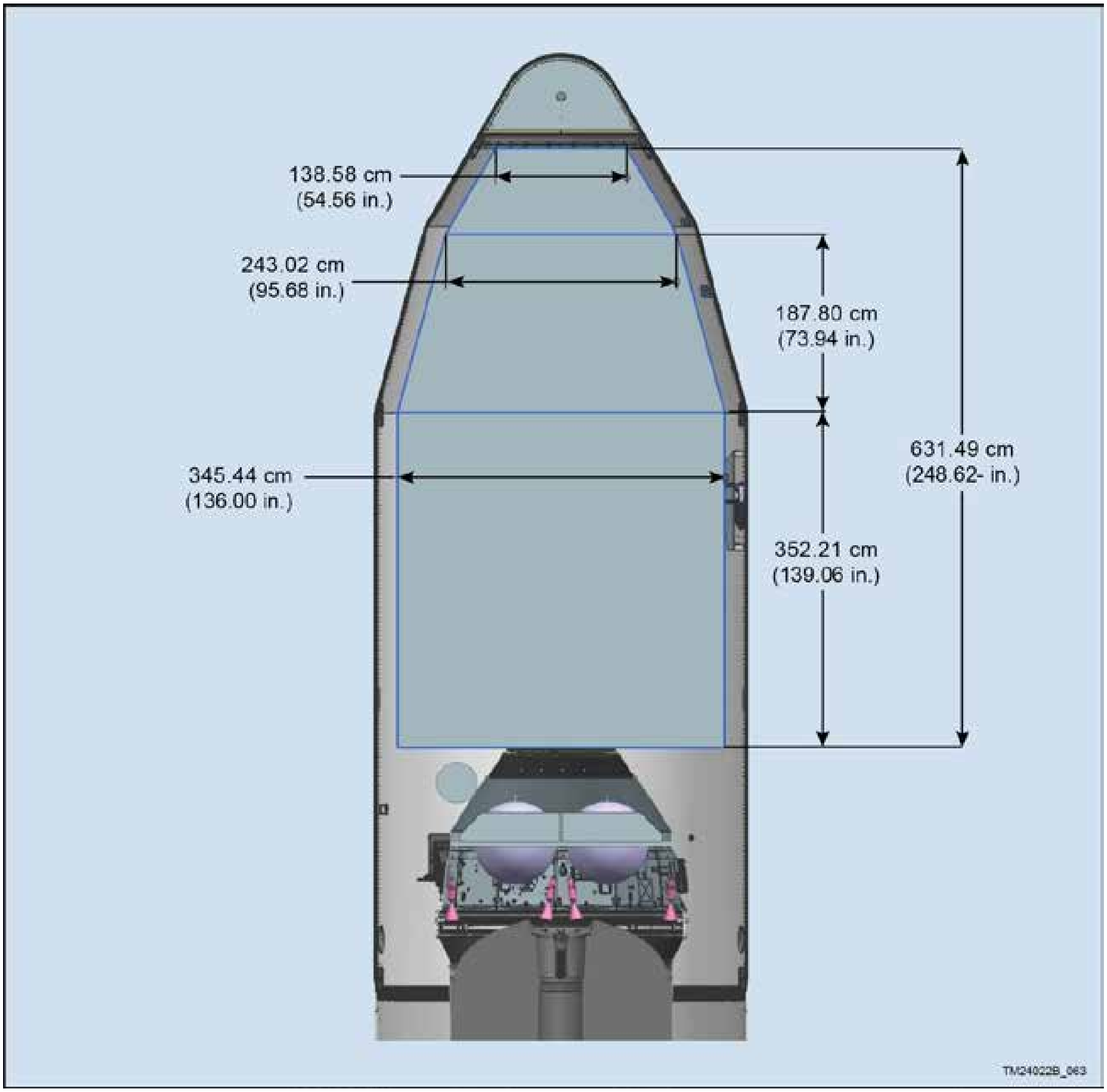


Figure 5.1.1-2. Antares 231 Fairing Static Payload Envelope with RUAG 1194VS PAF Interface

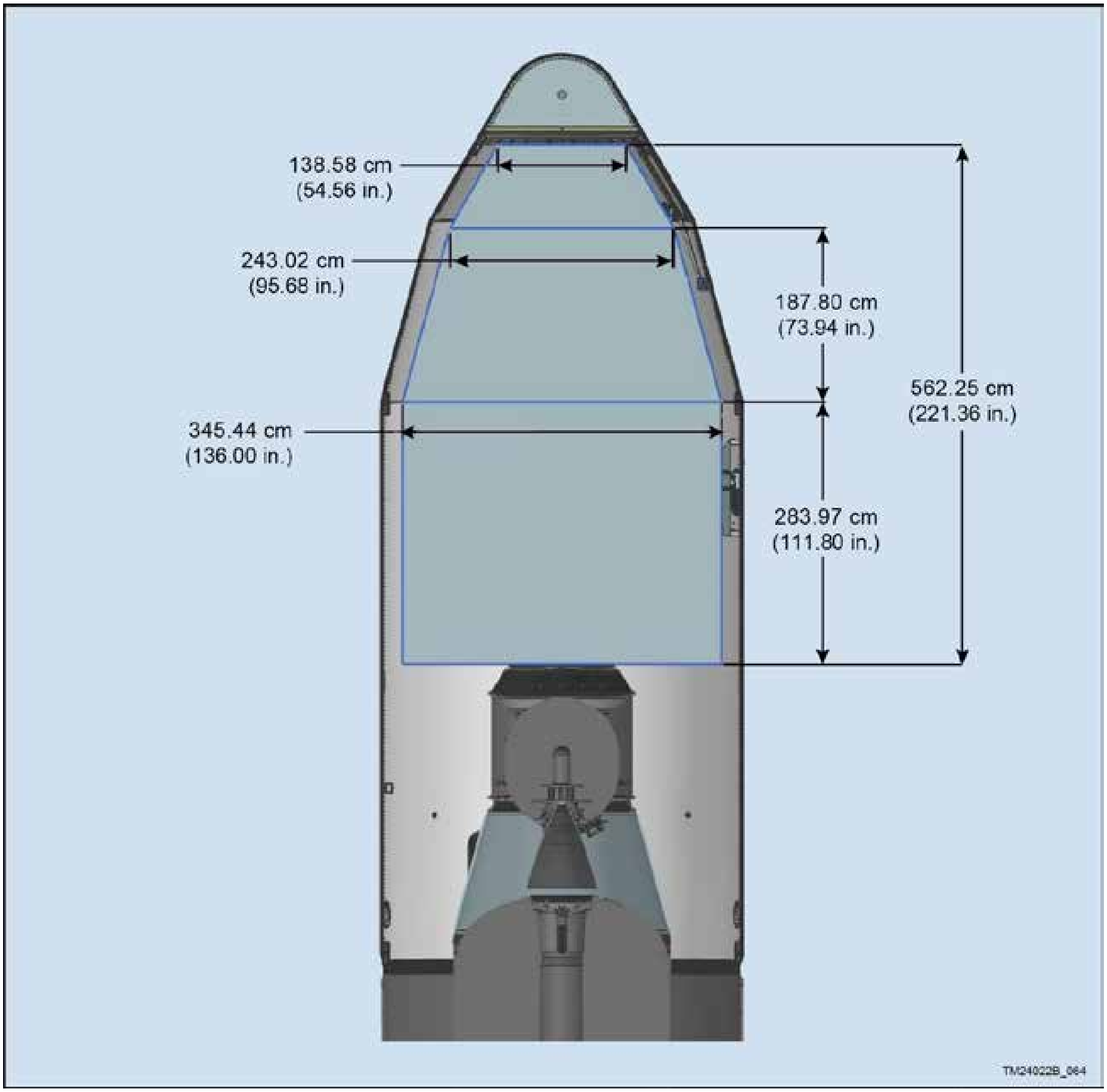


Figure 5.1.1-3. Antares 232 Fairing Static Payload Envelope with RUAG 1194VS PAF Interface

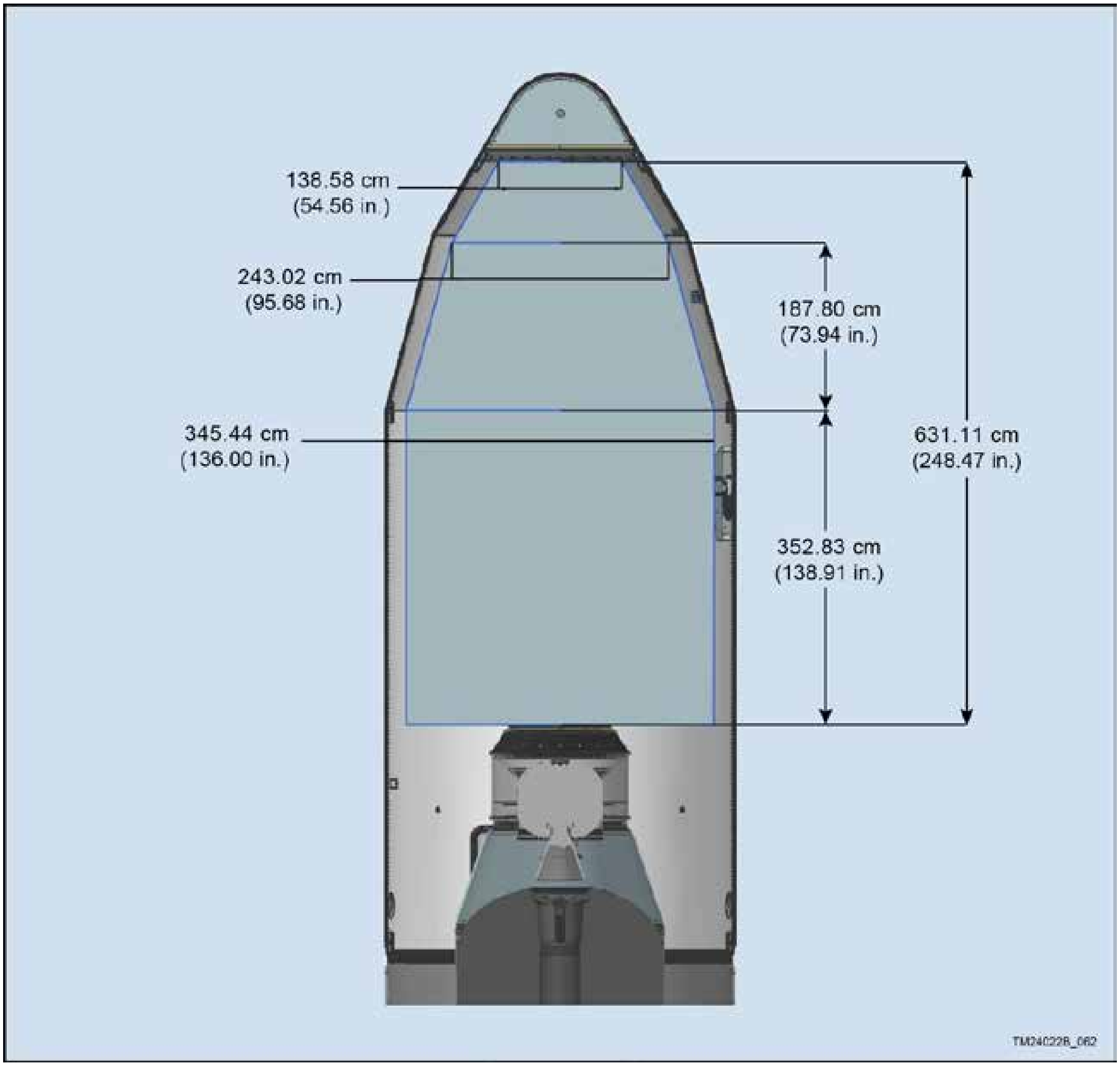
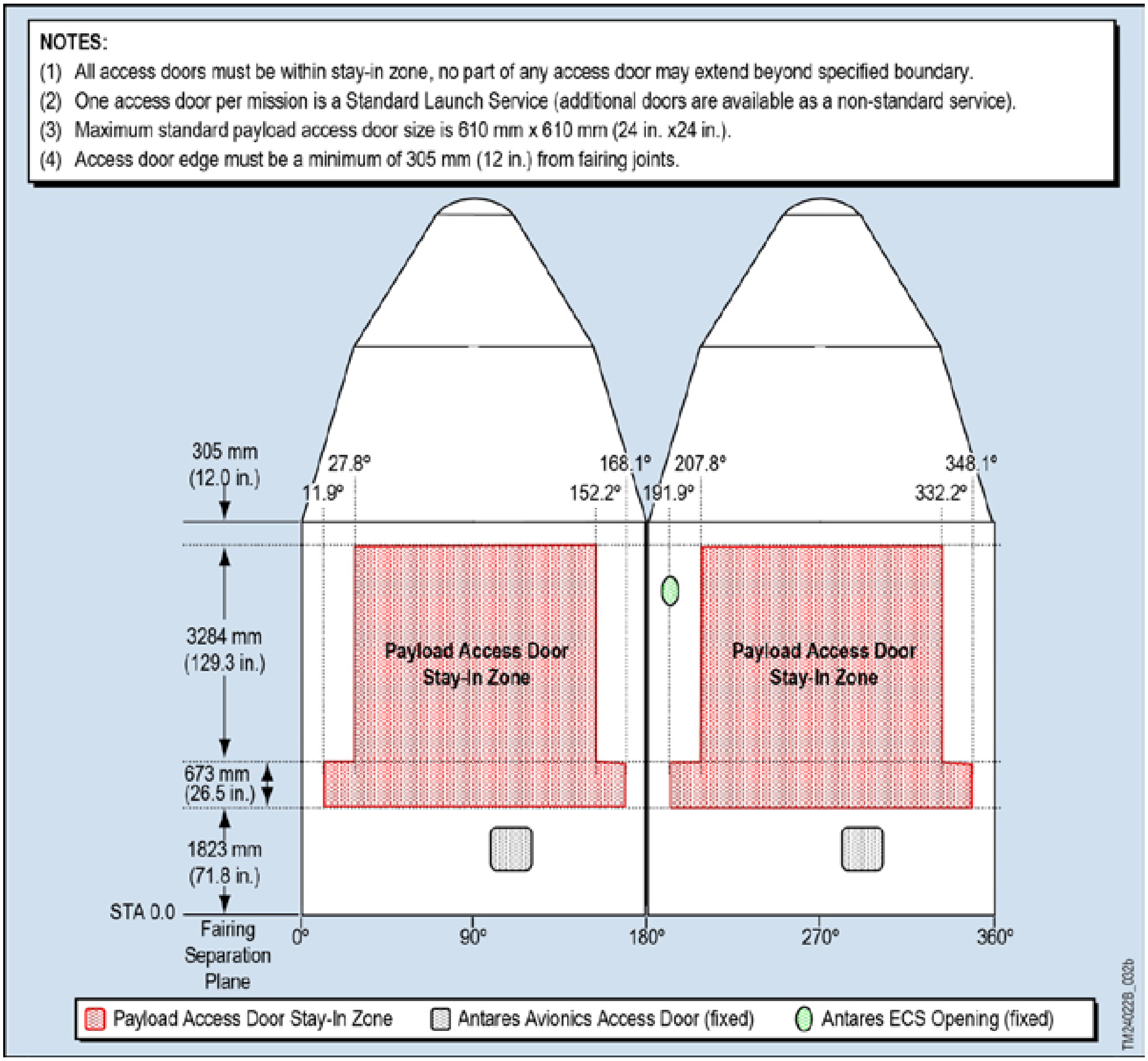


Figure 5.1.1-4. Antares 233 Fairing Static Payload Envelope with RUAG 1194VS PAF Interface

5.1.2. Payload Access Door

Antares provides a 610 mm x 610 mm (24 in. x 24 in.) rectangular RF-opaque graphite-aluminum composite door in the Antares fairing for access to the payload. Antares provides an aluminum non-flight fairing door that the payload customer may modify as required to support EGSE harness or nitrogen purge line routing to the payload during ground operations. This door is removed and the flight door is installed three days prior to launch. The rectangular door is positioned according to payload requirements within the zone defined in Figure 5.1.2-1. If more than one door is desired (reference Section 8), there should be a minimum axial distance between doors of 422 mm (16.6 in.), a minimum of 305 mm (12 in.) between the access door edge and the fairing joint. The payload fairing access door location is documented in the Mission ICD. Additional access doors can also be accommodated, as discussed in Section 8. Operationally, the customer has access through the payload door from the point of fairing enclosure through final vehicle closeout just prior to transport to pad.



NOTES:

(1) All access doors must be within stay-in zone, no part of any access door may extend beyond specified boundary.

(2) One access door per mission is a Standard Launch Service (additional doors are available as a non-standard service).

(3) Maximum standard payload access door size is 610 mm x 610 mm (24 in. x24 in.).

(4) Access door edge must be a minimum of 305 mm (12 in.) from fairing joints.

Figure 5.1.2-1. Antares Fairing Standard Access Door Location

5.2. Payload Mechanical Interface and Separation System

Antares provides for a standard RUAG 1194VS separating payload interface. Antares provides all flight hardware and integration services necessary to attach separating payloads to the Antares launch vehicle. Payload ground handling equipment is typically the responsibility of the payload customer. All attachment hardware, whether Antares or customer provided, must contain locking features consisting of locking nuts, inserts or fasteners. Additional mechanical interface diameters and configurations are readily provided as an upgraded option.

5.2.1. Separating Payload Interface

Antares Launch Service offers the commercially available and flight proven RUAG 1194VS 1194 mm (47 in.) diameter Payload Adapter System (PAS) (Figures 5.2.1-1 and 5.2.1-2). Antares provides all hardware and integration services necessary to attach the payload to and separate the payload from the Antares launch vehicle. As a Non-Standard Service Antares can provide either the RUAG 937S, the RUAG 1666VS, the RUAG 2624VS PAS or support a 1575 mm non-separating interface. Details on these alternate payload interfaces are discussed in Section 8. Payloads employing customer-furnished separation systems and payload adapters can also be accommodated through coordination of the interfaces with the Antares launch vehicle program office.

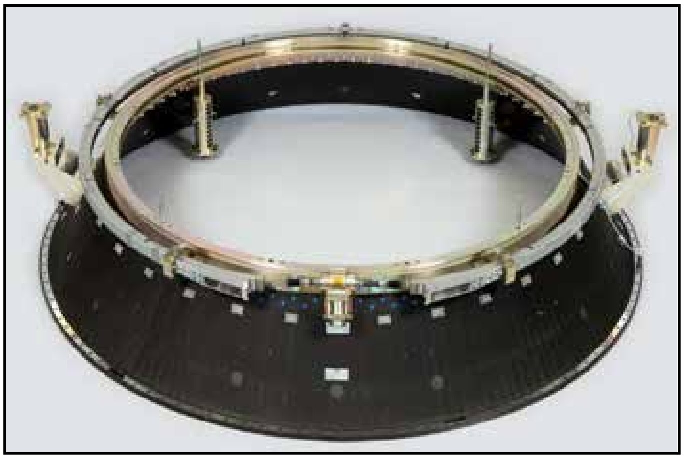


Figure 5.2.1-1. RUAG 1194 VS Payload Adapter

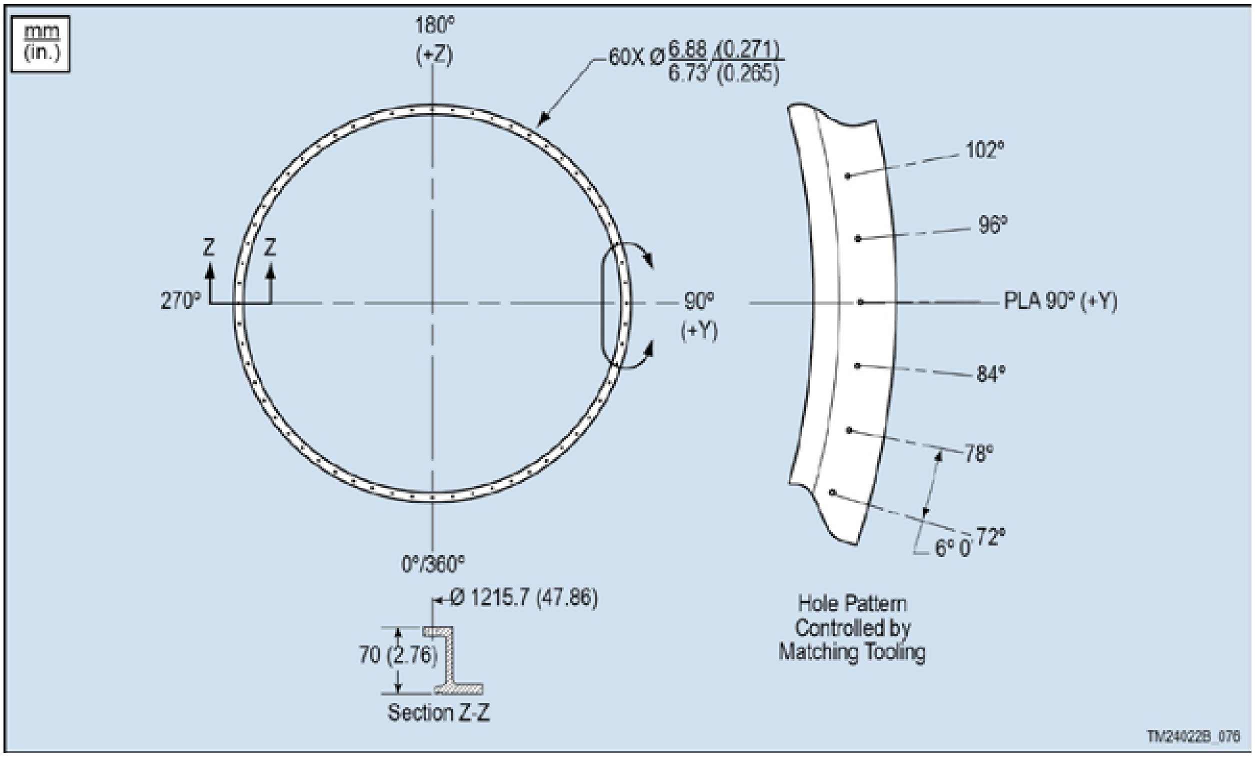


Figure 5.2.1-2. Antares 1194 mm (47 in.) Separating Payload Mechanical Interface

5.2.2. Optional Mechanical Interfaces

Antares offers three separation systems and one non-separating interface as non-standard services instead of the 1194 mm interface. These are based on the RUAG 937S, 2624VS, 1666VS separation systems and a 1575 mm non-separating bolted interface. Additional details on these separating interfaces are found in Section 8.

5.2.3. Mechanical Interface Control Drawing (MICD)

All mechanical interfaces between the payload and Antares are defined in the mission ICD and a mission-specific MICD. The MICD is a dimensional drawing that captures the payload interface details, separation system, payload static volume within the fairing, and locations of the access doors. Antares provides a tolerance MICD to the customer to allow accurate machining of the spacecraft fastener holes to the payload interface.

5.3. Payload Electrical Accommodation Requirements

The Antares payload electrical interface, shown in Figure 5.3-1, supports battery charging, external power, discrete commands, discrete telemetry, analog telemetry, serial communication, and payload separation indications using configurable flight qualified avionics components. Two 61-pin electrical connectors located at the launch vehicle interface plane at clocking angles 45° and 225° provide the standard electrical interface. Antares offers a number of non-standard telemetry services to the customer. These options are detailed in Section 8.

Payload Separation Sensing: Antares provides two breakwire circuits for the payload to sense separation from the LV and two independent breakwire circuits for the Antares vehicle to sense separation of the payload. If an Antares-provided payload separation system is used, the Antares system issues redundant electrical signals to activate the redundant NASA standard initiators on the RUAG separation system.

Payload Pass-Through: Antares provides pass-through wires between the payload interface plane and EGSE in-stalled in the LEV at the launch pad. Antares provides three standard sized 19 in. racks within the LEV for payload EGSE. Prior to liftoff, the payload is electrically connected to the payload EGSE in the LEV via two umbilical harnesses. These two payload umbilical harnesses connect to the Antares vehicle via two separating umbilical connectors (each with 61 pins). Payload electrical connections travel through #20AWG twisted shielded copper wire from the vehicle, through the two umbilical harnesses, to the TEL junction box and the payload junction box. To reduce round trip resistance, heavier gauge wiring connects the TEL junction box to the payload junction box in the LEV. Two 61-pin connectors are provided at the payload junction box to support connection to the payload EGSE. These interfaces can be configured to support different combinations of conductors defined in the LV/SV ICD. The power conductors provide minimal power loss to support battery charging, external power, and other current needs of less than 4 amps. The data conductors are typically used for discrete and analog signals and to support RS-422 communication with the payload.

Payload Electrical Harnesses: Antares fabricates the harnesses on the launch vehicle side of the interface. The payload is responsible for the harnesses forward of the interface plane. The payload side of the Antares electrical interface may be two individual harnesses or a single Y harness that connects to both the LV 45° the LV 225° connectors. Payload flight or flight spare harnesses shall meet the requirements specified in the Electrical Interface Control Drawing (EICD). The length and routing of the payload flight harnesses are specified in the mission-specific MICD.

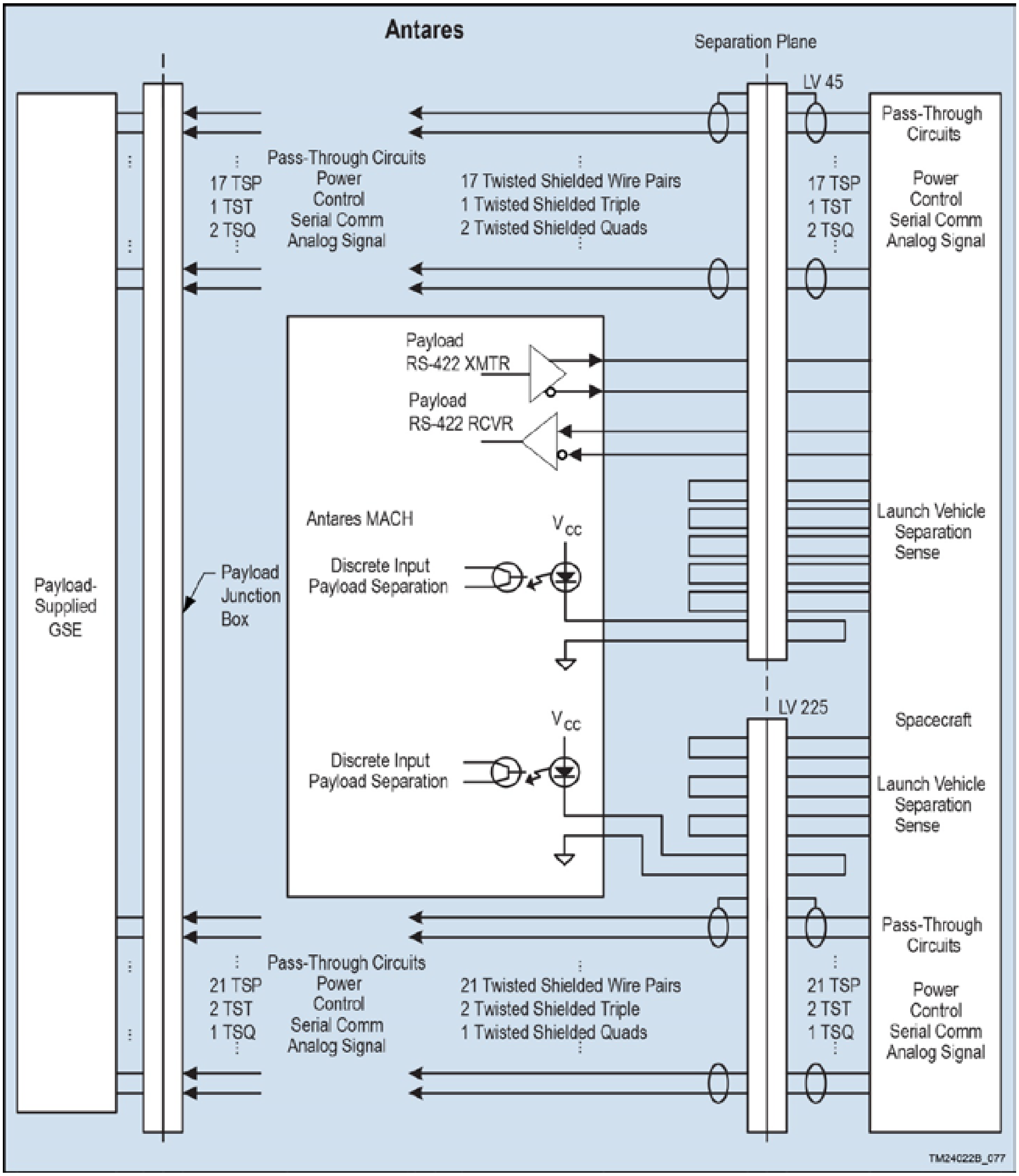


Figure 5.3-1. Antares Electrical Interface Block Diagram

5.4. Payload Design Constraints

The following sub-sections provide design constraints to ensure payload compatibility with the Antares system.

5.4.1. Payload Center of Mass Constraints

The axial location of the payload center of mass is typically constrained by the structural capability of the payload separation system. The 1194 mm separating interface capability is defined as a function of payload mass and center of gravity and is defined in Figure 5.4.1-1. Capabilities for the various separation systems upgrades are defined within Section 8.

The lateral offset of the payload center of mass is constrained by the payload separation tip-off requirements and the structural capability of the particular separation system. If preliminary design assessments indicate that the lateral center of gravity offset of the payload may exceed 2.5 cm (one inch), the customer is encouraged to contact the Antares Program Office to verify the feasibility of achieving the specific payload tip-off requirements.

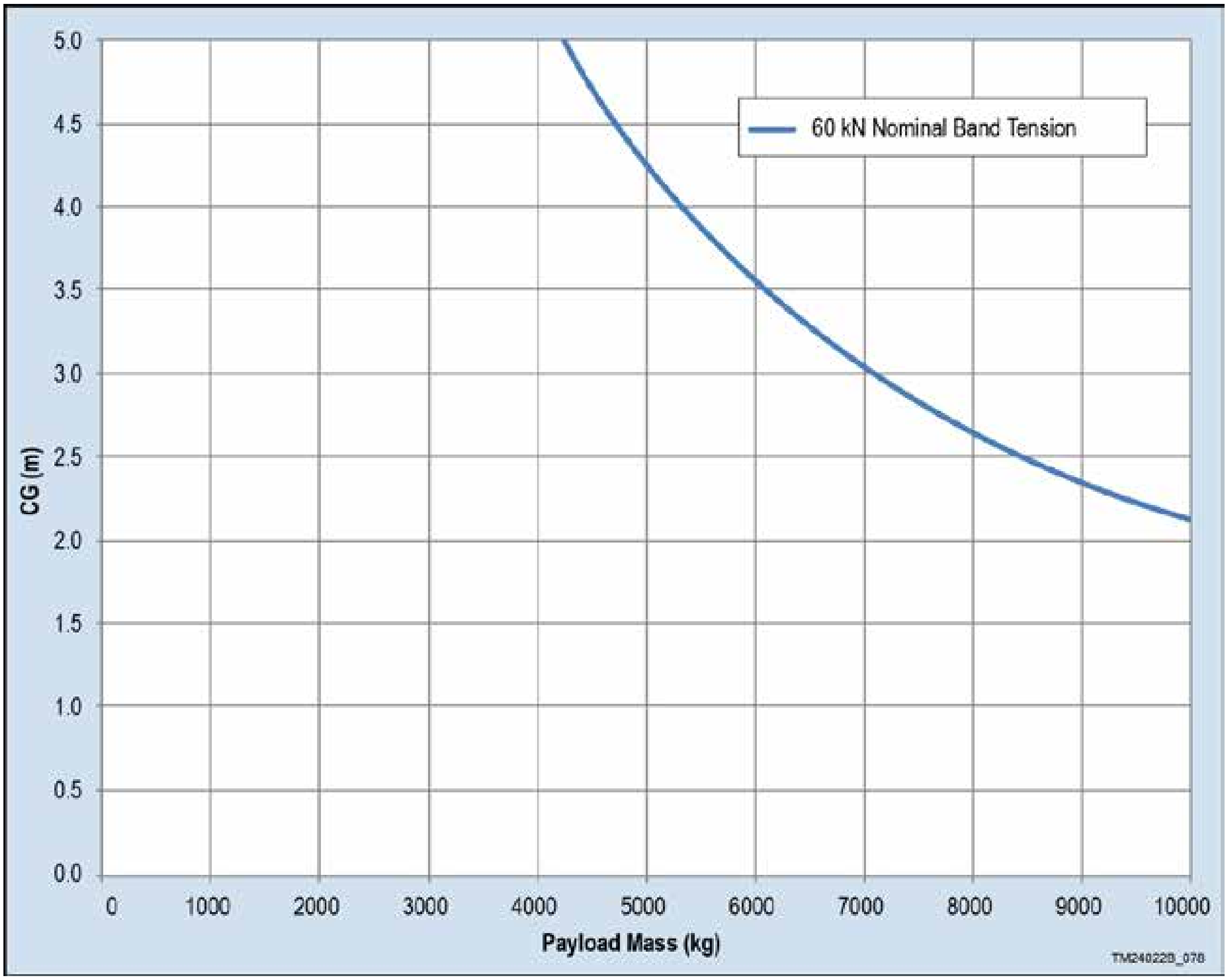


Figure 5.4.1-1. RUAG 1194VS Separation System Mass and CoG

5.4.2. Final Mass Properties Accuracy

As shown in Table 5.4.2-1, the final mass properties statement must specify payload weight to an accuracy of better than 15 kg, the payload center of mass to an accuracy of at least 5 cm in the Y and Z axes and +10/-20 cm in the X axis, and the products of inertia to an accuracy of at least ±500 kg-m^2. 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	±15 kg (±33 lb.)
Center of Mass	Y and Z Axes: ±5 cm (±1.97 in) X Axis: +10/-20 cm (+3.94/-7.78 in)
Moments of Inertia	±15%
Products of Inertia	±500 kg-m^2 (±11,865.2 lb-ft^2)

5.4.3. Grounding and Isolation

The Antares vehicle provides an earth ground reference for the payload via the bonded interface and attachment provisions to the launch facility grounding grid. Antares is mechanically mated to the payload at the payload interface plane to achieve a resistance of less than 500 milliohm between the structures.

5.4.4. Payload Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) Constraints

Antares avionics share the volume inside the fairing with the payload such that radiated emissions compatibility is paramount. The Antares vehicle RF susceptibility levels have been verified by test. The payload design must incorporate inhibits that are at least single-fault tolerant to inadvertent RF radiation. While encapsulated within the fairing, payload RF transmissions are not permitted. During flight, payload RF transmissions are permitted following fairing separation. The exact time after fairing separation when the payload may transmit is defined during the Mission Integration Working Group (MIWG) process and is documented in the mission ICD. Prior to launch, Northrop Grumman Innovation Systems requires review of the payload radiated emission levels to verify overall launch vehicle EMI safety margins.

While at the launch site, all payload RF transmission frequencies must be coordinated with Antares mission team and Range officials to ensure non-interference with Antares and other Range transmissions. Additionally, payload RF tests at the launch site are scheduled through Antares mission team to obtain proper Range clearances and frequency protection.

5.4.5. Payload Dynamic Frequencies

To avoid unfavorable dynamic coupling of the payload with the launch vehicle dynamic forcing functions, the payload should be designed with a structural stiffness to ensure that the payload structure first mode fundamental frequency is greater than 20 Hz axially (thrust axis) and above 8 Hz in the lateral axes. As dynamic load response is largely governed by payload characteristics, mission-specific coupled loads analyses will be performed in order to provide more precise load predictions. The results of this analysis will be documented in the mission ICD.

5.4.6. Payload Propellant Slosh

The customer should provide slosh models at 1, 3, and 6G for payloads with liquid propellant. The first sloshing mode data is required, and data on higher order modes is desired. The model, in either a NASTRAN or a Craig/Bampton format, should be submitted in conjunction with the payload finite element model submittals.

5.4.7. System Safety Constraints

Antares mission team considers the safety of personnel and equipment to be of paramount importance. The Range Safety User Requirements Manual, RSM 2002, and Federal Aviation Administration (FAA) Safety Requirements outline the safety design criteria for Antares payloads. These compliance documents must be strictly followed as tailored for Antares. It is the responsibility of the customer to ensure that the payload meets all Antares mission team and Range imposed safety standards.

Customers designing payloads that employ hazardous subsystems, processes, or hardware are advised to contact Antares mission team early in the design process to verify compliance with system and Range Safety standards.

The customer is required to conduct at least one dedicated payload safety review prior to arrival of any payload hardware at the integration facility and/or launch site. The customer is also required to submit all required safety documentation to Antares mission team as detailed in Section 6.

The customer must perform payload testing and/or analysis to ensure the safety of ground crews. To verify that the payload can meet safety criteria, the customer must provide Antares mission team with the applicable safety-related test results and/or analyses prior to payload arrival at the integration facility.

6. MISSION INTEGRATION

Northrop Grumman Innovation Systems first and foremost consideration is to provide a successful mission with an absolutely safe and reliable launch service for our customers. Antares's established engineering, production, testing, and quality assurance approaches are designed to ensure these considerations. Another top priority is to ensure timely launch services, with emphasis on maintaining high schedule confidence and flexibility. The active production lines and proven launch vehicle operations capability, coupled with management attention to potential risk areas, minimizes the risk of launch delays. Furthermore, Northrop Grumman Innovation Systems provides launch services that meet or exceed customer's mission requirements.

Antares executes missions on schedule and with strict adherence to all technical requirements. Using an established management system, the Antares Program Director monitors resource utilization, schedule and technical progress, and contract compliance.

6.1. Mission Management Approach

Antares establishes a mission-unique organizational structure on each launch service to manage and execute key mission roles and responsibilities. Open communication between Antares mission team and the payload customer, with an emphasis on timely data transfer and prudent decision-making, ensures efficient launch vehicle/payload integration operations. The Mission Management Office provides the direct interface to our customers and ensures the requirements of each mission are satisfied. The integrated Antares organizational structure, as shown in Figure 6.1-1, provides open communication between the Antares Mission Manager and the customer, emphasizing timely transfer of data and prudent decision-making, ensuring efficient launch vehicle-to-payload integration operations.

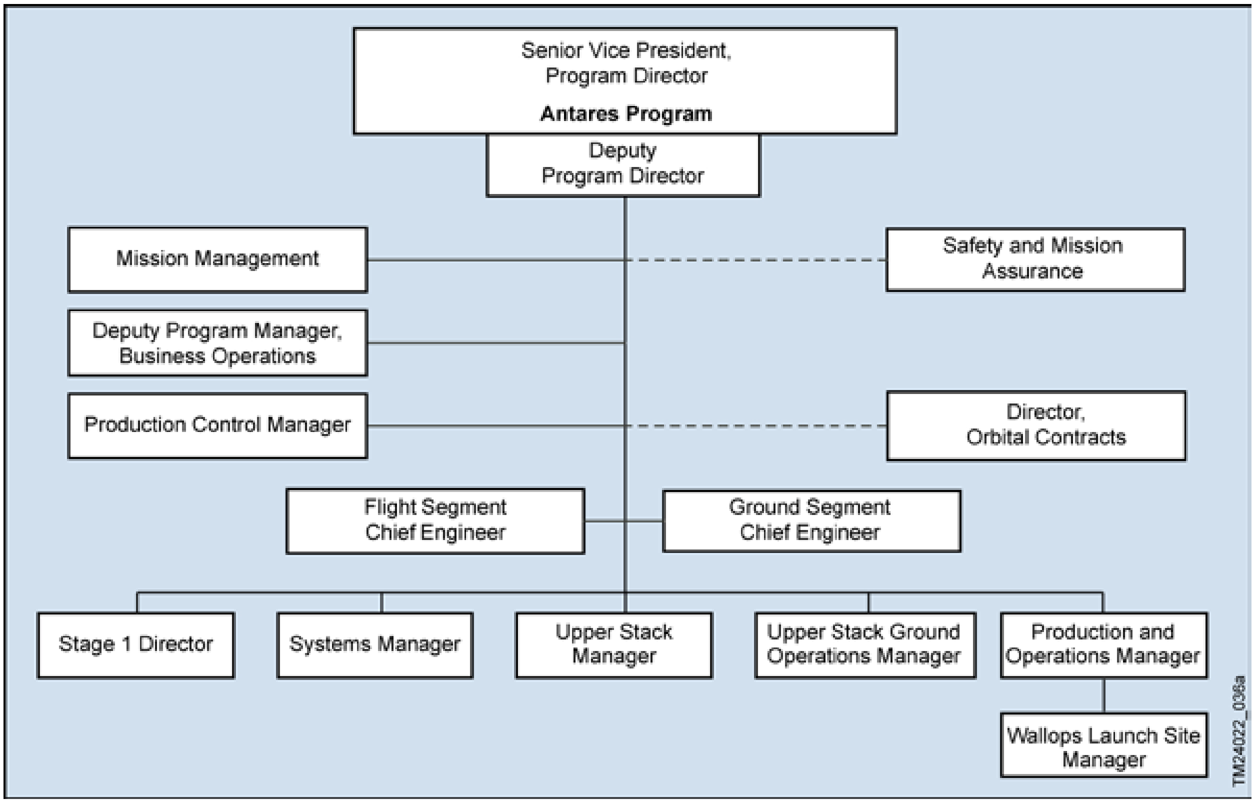


Figure 6.1-1. Antares Program Structure

6.1.1. Mission Responsibilities

Mission responsibilities fall into four primary areas: Program Management, Mission Management, Mission Engineering, and Launch Site Operations. Key positions and responsibilities of the Launch Service Team are provided in Figure 6.1.1-1 and detailed below.

6.1.1.1. Antares Mission Management

A Mission Manager is assigned for each mission to provide the management focus to ensure all mission requirements are satisfied. The Antares Mission Manager is the single Point of Contact (POC) for all aspects of a specific mission, and has overall program authority to ensure that payload requirements are met and the appropriate launch services are provided. Mission Managers lead Antares' mission integration teams. Antares' mission integration teams work directly with their mission counterparts to form a highly integrated organization.

The Antares Mission Manager chairs the MIWG, which is the primary forum for customer and launch vehicle technical interchanges. The Mission Manager's responsibilities include oversight of detailed mission planning, payload interface definition, payload requirements definition, mission-peculiar systems engineering, design and analyses coordination, launch site and Range coordination, integrated scheduling, launch vehicle production coordination, payload launch site processing, and payload-unique flight operations.

6.1.1.2. Antares Chief Engineers/ Engineering Leads

The Antares Chief Engineers direct the engineering activities within the Antares Program. The Chief Engineers are supported by an engineering staff representing all of the required engineering disciplines including mechanical, electrical, systems, environmental, Guidance, Navigation, and Control (GNC), software, mission/trajectory analysis, and integration and test.

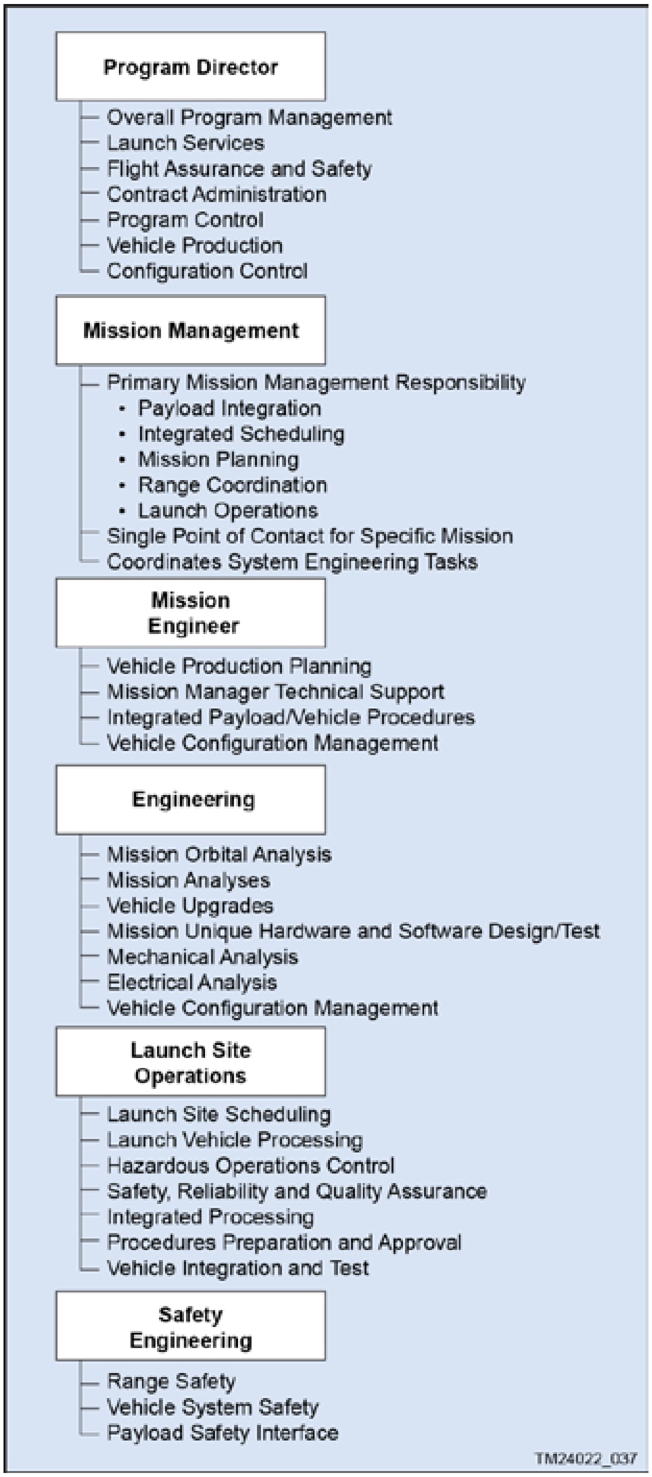


Figure 6.1.1-1. Mission Responsibilities

6.1.1.3. Antares Mission Engineering

The Mission Engineer provides technical support to the Mission Manager and is the technical focal point to the customer and payload teams to ensure that the Antares vehicle satisfies all payload requirements. Reporting to the Antares Systems Engineering Manager, the Mission Engineer is responsible for the development of the mission interface requirements and related documentation and for the verification of these requirements. The Mission Engineer is also responsible for any launch vehicle/payload integrated procedures used during assembly, integration, or launch operations.

The Antares engineering support organization provides engineering and integration activities for all Antares missions. Primary support tasks include mission analyses; software development; mission-unique hardware design and testing; vehicle integration, procedure development and implementation; and flight operations support.

6.1.1.4. Antares Launch Site Manager

Antares vehicle processing and integration operations occur at WFF. Antares Launch Site Manager provides day-to-day scheduling and direction for integration efforts at WFF. The Launch Site Manager provides consistency of integration standards and overall onsite management authority. Scheduling of payload integration with the launch vehicle and all related activities are coordinated with the Launch Site Manager and the Mission Manager.

The Antares Launch Site Manager directs and approves all work that is scheduled to be performed at the launch site. This includes preparation and execution of work procedures, launch vehicle processing, and control of hazardous operations. Range Safety, the Launch Site Safety Manager, and the Antares Safety Manager also approve all hazardous procedures prior to execution. In addition, Antares Safety and Quality Assurance engineers are always present to monitor critical and hazardous operations.

6.2. Mission Planning and Development

Antares mission team will assist the customer with mission planning and development associated with Antares launch vehicle systems. These services encompass all aspects of the mission including interface design, launch vehicle analyses, facilities planning, range services, and integrated schedules and special operations.

The procurement, analysis, integration and test activities required to place a payload into orbit are conducted over a standard sequence of events called the Mission Cycle. This cycle normally begins 24 months before launch, and extends to eight weeks after launch. Antares has the flexibility to negotiate either accelerated cycles, which may take advantage of the Antares multi-customer production sets, or extended cycles required by payload requirements, such as extensive analysis, complex payload-launch vehicle integrated designs, tests or funding limitations.

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 Antares vehicle production schedule with typical payload activities and milestones. A typical Mission Cycle is based on a minimum 24-month interval between mission authorization and launch. This interval has been shown to be an efficient schedule based on Antares' past program execution experience. Antares does allow flexibility to negotiate either accelerated or extended mission cycles to accommodate 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.

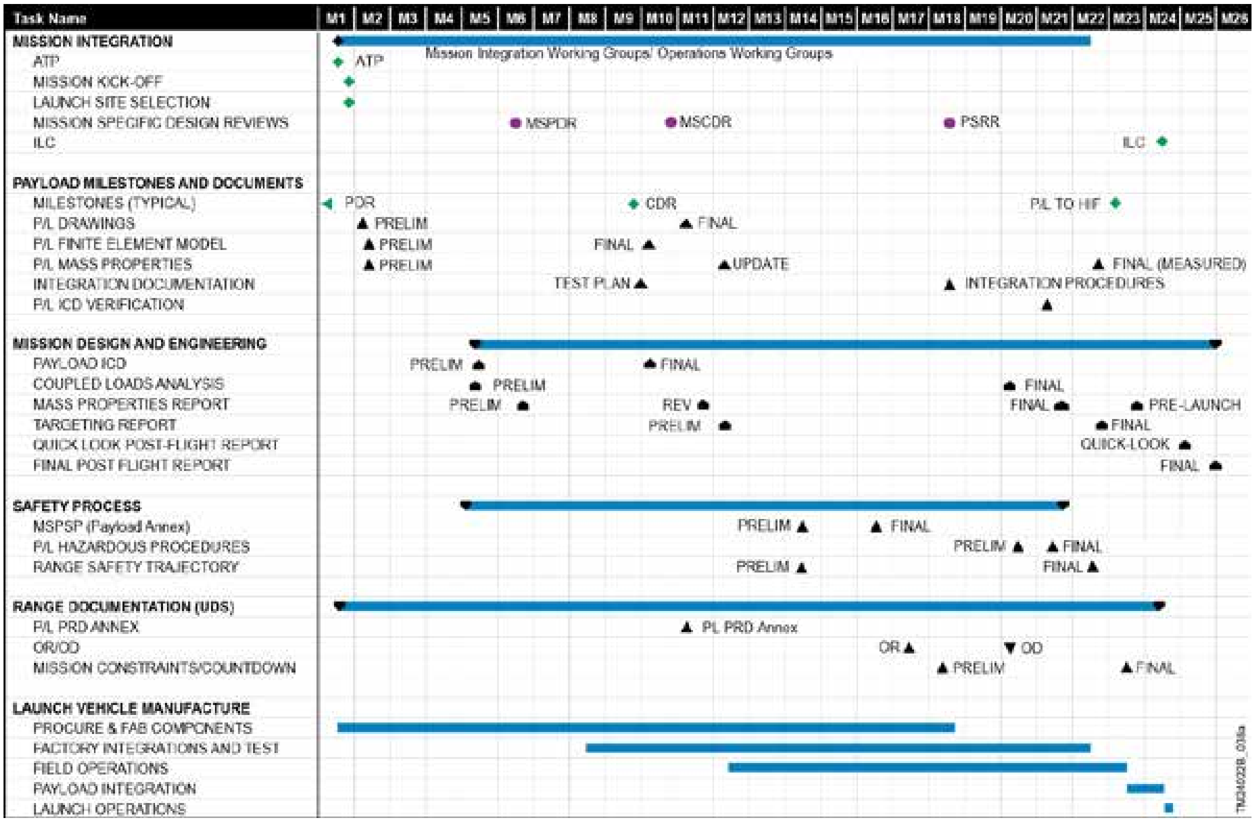


Figure 6.2-1. Antares Mission Cycle

6.3. Mission Integration Process

Antares uses a successfully proven approach to mission integration management. The core of the mission integration process consists of a series of Mission Integration Working Groups and Range Working Groups.

6.3.1. Mission Integration Working Group (MIWG)

Antares conducts quarterly MIWGs from the onset of the mission through launch (Table 6.3.1-1). Each MIWG, chaired by the specific Antares Mission Manager, includes representatives from Antares engineering and operations organizations as well as their counterparts from the various mission organizations. The MIWG is the forum for defining all launch services provided to the customer and physical interfaces between the payload and the Antares launch vehicle. Throughout the mission, each MIWG meeting will change focus as the integration process matures and eventually transitions from integration to launch site preparation and, ultimately, to the launch operation itself. The main focus of the initial working group meetings includes introduction of the team members from the launch vehicle, customer, and the payload and identification of all mission requirements. As the integration process develops, documentation in the form of the ICD, MICD, and EICD are generated to formally document mission requirements. The MIWG also is the forum to plan and discuss all the mission-specific items such as mission analyses, mission-unique hardware and software, and integrated procedures.

Table 6.3.1-1. Overview of Typical Mission Integration Working Group Flow

L-23	MIWG #1	· Introductions, Roles and Responsibilities · Develop Master Schedule · Review P/L Questionnaire With Preliminary Mass Properties · Assess Draft Safety Assessment · Identify Mission Specific and Mission Unique Requirements
L-20	MIWG #2	· Review Preliminary ICD · Review Results: Clearance, CLA · Review Production Schedules · Review Test Environments · Preliminary Safety Review
L-17	MIWG #3	· LV/Payload Status · Review MDR-1 Results · Review Preliminary Verification Status · Review ICD · Review ICD Verification
L-14	MIWG #4	· LV/Payload Status · Sign Baseline ICD
L-11	MIWG #5	· LV/Payload Status · Review Results: CLA · Review Verification Status · Review PRD Inputs · Review Results: Payload Separation, Venting, Clearance, EMC
L-7	MIWG #6	· LV/Payload Status · Review Results: Thermal · Review Payload Integration Support · Requirements · Ground Operations Overview · Close Verification Items, As Applicable · Review Results: MDR-2, CLA (Final)
L-4	MIWG #7	· LV/Payload Status · Review OR Inputs, Launch Operations Payload · Processing Schedule · Close Verification Items, As Applicable
L-2	MIWG #8	· LV/Payload Status · Close Verification Items · Review Results: Clearance, EMC · Review Operations Flow, Procedure Input · Launch Operations Overview and Checklist/ Mission Constraints Document (MCD) Review

In addition to the MIWG process, Antares provides a mechanism to focus smaller technical groups on specific issues that either does not require coordination of the entire mission team, or requires quick turnaround in resolving technical issues. This mechanism is referred to as a Technical Interchange Meeting (TIM) and has proven to be an effective means to resolve technical issues quickly throughout the contract.

6.3.2. Range Working Group (RWG)

The RWG is chaired by the Antares Mission Manager and includes representatives from both the Antares Launch Vehicle and customer organizations as well as Range personnel. The RWG focuses on planning for and executing the activities that will occur at the launch site. As such, 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.

6.3.3. Mission Reviews

In addition to the MIWG and RWG, a number of mission reviews are conducted as required to ensure the launch service and payload integration activities are progressing according to schedule. During the integration process, mission reviews are held to provide coordination with a broader audience of mission and management participants who do not participate in either of the Working Groups. Due to the variability in complexity of different payloads and missions, the content and number of these reviews are tailored to customer requirements.

6.3.3.1. Mission Specific Design Reviews

Typically, two mission specific design reviews are held to determine the status and adequacy of the launch vehicle preparations. Designated Mission Specific Preliminary Design Review (MSPDR) and Mission Specific Critical Design Review (MSCDR), these design reviews are held at 6 months and 10 months, respectively, after Authority to Proceed (ATP). They are each analogous to a development program's Preliminary Design Review (PDR) and Critical Design Review (CDR), but focus on mission-specific and mission-unique elements of the integrated launch vehicle effort.

6.3.3.2. 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 and established as part of the mission integration process.

6.3.4. Customer-Provided Documentation

Integration of the payload requires detailed, complete, and timely preparation and submittal of interface documentation, data, models, and drawings. The major products associated with these documents are divided into two areas: those products that are provided by the customer, and those produced by Antares mission team. Customer-provided documents represent the formal communication of requirements, safety data, system descriptions, and mission operations planning. Documentation produced by the customer, as detailed in the following paragraphs, is critical for enabling the Antares mission team to perform their responsibilities and prepare for and manage the Antares launch of the payload. The documentation delivery requirements are included in the Mission Planning Schedule.

6.3.4.1. Payload Questionnaire

The payload questionnaire is designed to provide the Antares Program with the initial definition of payload requirements, interface details, launch site facilities requirements, and preliminary safety data. When appropriate, the customer provides a completed payload questionnaire form (Appendix A) as soon as the spacecraft definitions are reasonably firm but preferably not later than one week after authority to proceed. The customer's responses to the payload questionnaire define the most current payload requirements and interfaces and are instrumental for the Antares mission team for preparation of numerous documents including a draft of the mission ICD, preliminary mission analyses, and drafts of the launch range documentation. Additional pertinent information, as well as preliminary payload drawings, should also be included with the response. Northrop Grumman Innovation Systems understands that a definitive response to some questions may not be feasible, and that many of these items will be defined during the normal mission integration process.

6.3.4.2. Mission ICD Inputs

The Antares-to-payload ICDs (mission, mechanical, electrical, and commanding/telemetry) detail all the mission specific requirements agreed upon by Antares Launch Team 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 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, payload drawings, and ground support requirements.

6.3.4.3. Payload Finite Element Model

A payload mathematical model is required for use in Antares' 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 required.

6.3.4.4. Payload Thermal Model for Integrated Thermal Analysis

A payload thermal model is required from the customer for use in Antares' integrated thermal analysis. The analysis is conducted for three mission phases:

- Prelaunch ground operations
- Ascent from lift-off until fairing jettison
- Fairing jettison through payload deployment

6.3.4.5. Payload Launch Site Integration Procedures

For each mission, Antares requires detailed spacecraft requirements for integrated launch vehicle and payload integration activities. With these requirements, the Antares mission team 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 for review prior to first use.

6.3.4.6. Mission ICD Verification Documentation

Antares 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, the Antares mission team 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, the customer will be provided with a form to complete for each interface requirement that is the responsibility of the payload to meet. The form clearly identifies the documentation to be provided as proof of verification. Insurance will be given to the customer with similar data for all interfaces that are verified for the launch vehicle.

6.3.4.7. Safety Documentation

The Antares mission manager is the interface with Range Safety. To fulfill this critical role, the Antares mission manager will require payload safety information from the customer. The Flight Facility Range Safety Manual, RSM 2002 provides detailed Range Safety regulations to which the payload must comply. The Antares mission manager will provide the customer with coordination and guidance regarding applicable safety requirements. These applicable safety requirements must be incorporated into the earliest stages of spacecraft design as Range Safety discourage the use of waivers.

To obtain approval to use the launch site facilities, specific payload safety data must be prepared by the customer and submitted to Antares mission manager. This information includes a description of each payload hazardous system and evidence of compliance with safety requirements for each system. Major categories of hazardous systems include ordnance devices, radioactive materials, propellants, pressurized systems, toxic materials, cryogenics, and RF radiation. 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 and procedures should be included. In addition, all payload hazardous procedures, procedures relating to hazardous systems, and any procedures relating to lifting operations or battery operations should be prepared for safety review submittal. The Antares mission manager will provide this information to the appropriate Range Safety office for approval.

6.3.5. Documentation, Data, and Analyses

Mission documentation produced by Antares mission team are detailed in the following paragraphs.

6.3.5.1. Mission ICD

The launch vehicle-to-payload mission ICD details all of the mission-unique requirements agreed upon by Antares mission team and the customer. The mission 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 mission ICD contains the payload description, electrical and mechanical interfaces, environmental requirements, targeting parameters, mission-peculiar vehicle requirement description, and unique GSE and facilities required. Details of the mechanical and electrical requirements are documented in the Mechanical ICD (MICD) and Electrical ICD (EICD), respectively. Additionally, depending on the interface requirements for spacecraft telemetry and commanding, a Serial Telemetry and Commanding ICD (ST&CICD) may also be developed. As a critical part of the mission ICD, Antares mission team will provide a comprehensive matrix that lists all ICD requirements and the method in which these requirements are verified, as well as who is responsible.

The mission ICD, as well as the MICD, EICD and ST&CICD, are configuration-controlled documents that are approved by Antares mission manager 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.

6.3.5.2. Mission ICD Verification Documentation

Antares mission team 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 6.3.4.6, the Antares mission team will provide the customer with data for all interfaces that are the responsibility of the launch vehicle to verify. This documentation will be used as part of the team effort to complete a thorough verification that all ICD requirements have been met.

6.3.5.3. Preliminary Mission Analysis (PMA)

Antares mission team will perform a PMA to determine the compatibility of the payload with the Antares launch vehicle and to support development of the mission requirements such as launch vehicle trajectory analysis, performance capability, accuracy estimates and preliminary mission sequencing.

6.3.5.4. Coupled Loads Analyses (CLA)

Antares has developed and validated finite element structural models of the Antares vehicle for use in CLAs with Antares payloads. The Antares mission team will incorporate the customer-provided payload model into the Antares 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 Antares mission manager, a final CLA load cycle is completed. Through close coordination between the customer and the Antares Program, interim results can be made available to support the customer's schedule critical needs.

6.3.5.5. Radio Frequency (RF) Link Analysis

Antares mission team will perform an RF link analysis for each mission to ensure that a sufficient RF link margin exists for the telemetry system and for the flight termination system.

6.3.5.6. Final Mission Analysis (FMA)

The FMA presents a detailed trajectory analysis for the payload using final payload mass property inputs. The FMA includes results from a Six Degrees of Freedom (6DOF) simulation; a separation analysis for the stage and payload separation events; and results of a Monte-Carlo analysis defining dispersions for the orbit insertion parameters.

6.3.5.7. Integrated Launch Site Procedures

For each mission, Antares mission team will prepare 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 Antares launch vehicle; fairing encapsulation; flight simulations; final vehicle closeouts, and transport of the integrated launch vehicle/payload to the launch pad. Once customer inputs are received, Antares mission manager 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.

6.3.5.8. 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 Antares MSPSP.

The customer must provide all safety information pertaining to the payload. The Antares Team assesses the combined vehicle and payload for hazards and prepare a findings report. The report will be forwarded as part of the integrated assessment to the appropriate launch Range for review and approval.

6.3.5.9. Mission Constraints Document (MCD)

This Antares-produced document summarizes launch day operations for the Antares launch vehicle as well as for the payload. Included in this document is a comprehensive definition of the Antares 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.

6.3.5.10. Final Countdown Procedure

The Antares mission manager produces the launch countdown procedure that readies the Antares launch vehicle and payload for launch. All Antares and payload final countdown activities are included in the procedure.

6.3.5.11. Post-Launch Analyses

Antares provides post-launch analyses to the customer in two forms. The first is a quick-look assessment provided within five 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.

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

6.3.6. Range Documentation

For each mission, Antares mission manager is responsible for the Range interface and provides all required Universal Documentation System (UDS) submittals to the Range to document mission requirements (to include payload requirements). All U.S. Launch Sites utilize the UDS to provide a common language and format for stating mission requirements and preparing support responses. Required Range UDS documentation is tailored for each mission and launch site.

7. GROUND AND LAUNCH OPERATIONS

Antares ground and launch operations are conducted in three major phases:

- **Launch Vehicle Processing/Integration:** Includes receipt and checkout of the launch vehicle components, followed by assembly and test of the Antares vehicle.
- **Payload Processing/Integration:** Includes receipt and checkout of the payload, payload interface verification, mate to the payload adapter followed by integration with Antares launch vehicle, and encapsulation within the Antares fairing.
- **Launch Operations:** Includes completion of readiness reviews and rehearsals, transport of the integrated launch vehicle to the launch pad, arming, erection, checkout, fueling, countdown activities, and launch.

7.1. Antares Launch Processing and Integration Overview

The Antares launch system is designed to minimize vehicle and payload handling complexity and launch site integration effort. The Antares program utilizes horizontal integration to simplify integration procedures, increase safety, and provide improved access for the integration team. The Antares vehicle processing methodology is also designed to reduce the time between spacecraft integration and launch operations. The concept of operations for the launch vehicle maximizes processing and testing done in parallel to payload operations, reducing the duration and complexity of joint operational requirements. In addition, Antares has established mechanical and electrical interfaces and checkout procedures reduce vehicle and payload integration times, increase system reliability and minimize vehicle demands on payload availability.

The Antares launch vehicle horizontal integration process also eliminates the need for a mobile service tower or large cranes at the launch pad. Vehicle components including motor stages, engines, fairing, avionics, payload adapter, separation system and all structures are received and integrated at the Horizontal Integration Facility (HIF). At approximately L-15 days, the payload arrives at the HIF for integration to the payload adapter, interface verification testing, mission simulation testing, and encapsulation within the fairing. At approximately L-3 days, the integrated vehicle is transported to the launch pad on the TEL, rotated to vertical, and installed on the launch mount. After umbilical connections are completed and vehicle checks are performed, the first stage is fueled starting approximately 90 minutes before launch.

The Antares integration and test process ensures that all vehicle components and subsystems are thoroughly tested at successive levels of integration to reduce risk in the schedule closer to launch. Antares maintains launch site management and test scheduling responsibilities throughout the entire launch operations cycle. Antares integration activities are controlled by a comprehensive set of Antares Work Packages (WPs) that thoroughly describe and document every aspect of integrating the Antares launch vehicle and the payload. Mission-specific work packages are created, as required, to handle mission-unique, payload-specific, or one-time vehicle configuration procedures. Payload and launch vehicle integrated procedures are formally reviewed with the customer during the MIWGs.

7.2. Antares Processing and Launch Facilities at WFF

Antares is launched from the NASA WFF in Virginia. At WFF, the vehicle is assembled and processed in the HIF, Building X-79. The HIF is shown in Figure 7.2-1.

Figure 7.2-1. Antares HIF at WFF

The HIF includes an extensive vehicle integration and test area with two bridge cranes. The HIF also has two laboratory areas, one configured for battery processing and the other configured to support small component testing.

The HIF provides compressed gasses, security, power, water, phone, data, and fiber-optic networks. In addition, the HIF's heating, ventilation and air conditioning system maintains temperature between 15.5°C to 25.5 °C (60 °F to 80 °F). The facility also incorporates fiber optic lines for data communications between the HIF, the LCC and the launch pad.

7.2.1. Ground Support Equipment (GSE)

Northrop Grumman Innovations Systems has developed and tested a wide variety of Mechanical Ground Support Equipment (MGSE) for the transport, integration and lifting operations associated with processing Antares components at WFF. This MGSE includes transportation trailers, dollies, handling and mate fixtures, adapters, handling rings, breakover assemblies, lifting adapters and beams, integration stands, and maintenance platforms. All Antares MGSE are designed to meet the factors of safety and are periodically proof tested to Range Safety requirements.

Antares supplies the Electrical Ground Support Equipment (EGSE) required to perform field-testing, verification, and launch of the Antares vehicle. The Antares EGSE has been fully verified to support the requirements of the Antares processing and launch. The GSE that is particularly noteworthy to an Antares payload integration are discussed in the following paragraphs.

7.2.1.1. Transporter-Erector-Launcher (TEL)

The TEL, shown in Figure 7.2.1.1-1, is a multi-use device that provides structural support to the LV during integration and transport and the capability to rotate the integrated LV from the horizontal to vertical position at the launch site. The TEL includes a support structure for the integrated launch vehicle and routing support for umbilicals. The TEL system includes two remotely guided transporters and a hydraulic erector system, which is integral to the launch pad.

Once the Antares is in its fully integrated configuration, the LV is transported from the HIF to Pad 0A on the TEL and its associated transporters. At the launch pad, the hydraulic erector system interfaces with the TEL strongback, rotates the LV to vertical, and positions it for mate to the launch mount. Vehicle electrical, mechanical, and hydraulic connections are mated and checked, including payload pass through connections to payload GSE. The TEL also serves as the launch tower, retracting just prior to liftoff.

Figure 7.2.1.1-1. Transporter-Erector-Launcher (TEL)

7.2.1.2. Portable Environmental Control System (PECS)

The required payload environments are maintained during transport activities by the PECS, shown in Figure 7.2.1.2-1. The PECS is a trailered, self-contained environmental control system. The system's two independent refrigeration circuits cool and dehumidify incoming air after which the air is reheated to maintain the desired temperature and RH setpoints. A humidifier is available to add moisture, if needed. The PECS continuously purges the fairing environment with clean filtered air providing an ISO 14644 Class 8 or better environment during all post-encapsulation operations. PECS incorporates both a HEPA filter unit for particulate control and carbon filtration for hydrocarbon control. The HEPA filter removes 99.97% of all particles with a size of 0.3 microns and greater and the carbon filtration is sized to remove hydrocarbons of molecular weight 70 or greater with 95% efficiency.

Figure 7.2.1.2-1. Portable Environmental Control System (PECS)

7.2.1.3. Payload EGSE Accommodations

Antares provides accommodations for payload EGSE within the Launch Equipment Vault (LEV) located at the launch site. The LEV serves as the vehicle copper-to-fiber interface and contains the vehicle external power supplies and battery chargers as well as a number of other vehicle interface control racks. Space is provided in the LEV for up to three full sized payload racks. The LEV provides the following power sources: 120V single phase, 60 Hz, 208V single phase, 60 Hz; 208V 3 phase, 60 Hz. Connectors can be modified to meet payload requirements.

Communication between the LEV and other WFF facilities is via the NASA WFF fiber optic network infrastructure. These fibers carry all launch vehicle and payload communication and data signals out from the pad and distribute as required. As part of the end-to-end continuity check, Antares assists in the installation of payload GSE in the LEV. Antares mission team will support the checkout of this equipment and provides payload communication accommodations from the pad to the MCC or elsewhere on WFF. Connectivity to the PPF, if required, is provided via the Wallops fiber optic network.

7.2.2. Launch Facilities at WFF

Launch day activities conduct from three major facilities at WFF: the Launch Pad 0A, the Launch Control Center (LCC), and the Mission Control Center/Range Control Center (MCC/RCC). The LCC houses the launch vehicle and launch pad operators and controllers, and the MCC/RCC houses the engineering and management staff for the payload, launch vehicle and Range.

7.2.2.1. Antares Launch Pad at WFF

Figure 7.2.2.1-1. WFF Launch Pad 0A

Antares missions from WFF are launched from MARS' Spaceport Pad 0A, shown in Figure 7.2.2.1-1. The launch pad and launch site are owned and operated by MARS and provide the facilities and infrastructure required to support the erection, fueling, final checkout, and launch of the Antares integrated launch vehicle. The Pad 0A facility:

- Supports the horizontal transportation of the LV to the launch pad deck, erection and hold down of the integrated launch vehicle, and performance of Wet Dress Rehearsals (WDRs) and launch operations
- Houses the EGSE in an environmentally controlled area, protecting the EGSE from the launch environment, and provides communication and data connectivity
- Provides environmental control to the integrated launch vehicle, including payload
- Supports the storage and conditioning of fluids and propellants and the loading and unloading of propellants to and from the launch vehicle
- Protects the launch vehicle and pad structure from acoustic and thermal environments induced by the engine plume during launches and stage testing

The WFF Launch Pad 0A complex provides the following support elements:

- Raised pad consisting of launch mount, flame duct, and lightning towers
- Launch vehicle erection mechanism accommodations
- Water deluge system
- LEVs for protection of EGSE
- Fueling systems and tanks and compressed gas storage tank skid
- Cable and fueling trenches
- ECS accommodations
- Facility infrastructure, including road access, power, and communications
- Safety provisions, including hazardous operation indications, emergency situation warning systems, and lightning protection
- Security provisions, including launch complex access and enclosure of the launch complex by a perimeter fence.

7.2.2.2. Mission Operations Control Center (MOCC)

The NASA WFF MOCC, shown in Figure 7.2.2.2-1, provides launch control for Antares launches from WFF. The MOCC houses the control and telemetry consoles for the Antares launch vehicle and pad personnel supporting launch control operations. The MOCC provides launch command and control primary and backup positions for the Antares launch vehicle control, Antares fueling control, Antares engineering, and WFF site control (i.e., propellant farm, ECS, and telemetry, power, and network support equipment).

Figure 7.2.2.2-1. NASA MOCC

7.2.2.3. Range Control Center (RCC)

The RCC, shown in Figure 7.2.2.3-1, serves as the launch authority center for Antares launches. The RCC is on the main base at WFF that will be utilized for mission control of Antares launches.

The WFF RCC houses the Antares and customer launch management teams. The RCC provides hardline and RF telemetry consoles, voice net communications, and launch Pad 0A live video. Observation and VIP guest accommodations are provided at the RCC.

The RCC also serves as the command, control, and launch authority center for the WFF Range Safety personnel. The RCC houses the WFF Range Safety, WFF launch team, FAA, and WFF Launch Authority personnel.

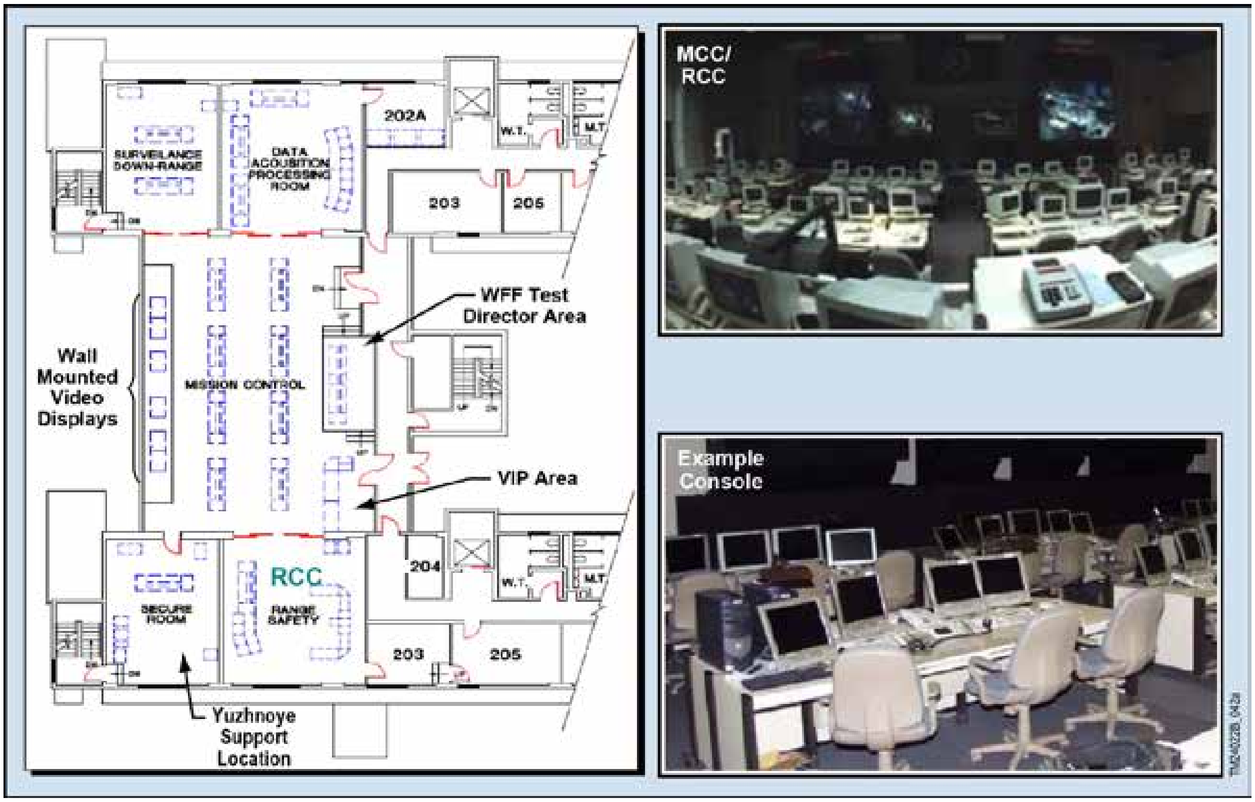


Figure 7.2.2.3-1. NASA RCC

7.3. Launch Vehicle Processing

All major vehicle subassemblies are delivered from either Antares' production facilities or directly from the vendor to the HIF. Figure 7.3-1 depicts the typical flow of hardware from the factory to the launch site. Once the major vehicle components and subassemblies are delivered to the HIF, the vehicle is horizontally integrated and tested prior to the arrival of the payload. Vehicle integration is performed on platforms set at convenient working heights, which allows relatively easy access for component installation, inspection and test.

The transformation of engines, rocket motors, avionics, and sub-assembled structures into an integrated launch vehicle occurs at the HIF. A small group of skilled engineers and technicians perform the following major functions at this facility:

- Receive and inspect all motors, rocket engines, subassemblies, and vehicle components
- Integrate rocket engines and mechanical, electrical, ordnance components, and subassemblies to the individual stages
- Perform electrical testing of the integrated motors, composite subassemblies, and the avionics section
- Receive the payload, test interfaces, integrate the payload to the LV, and encapsulate the payload within the fairing

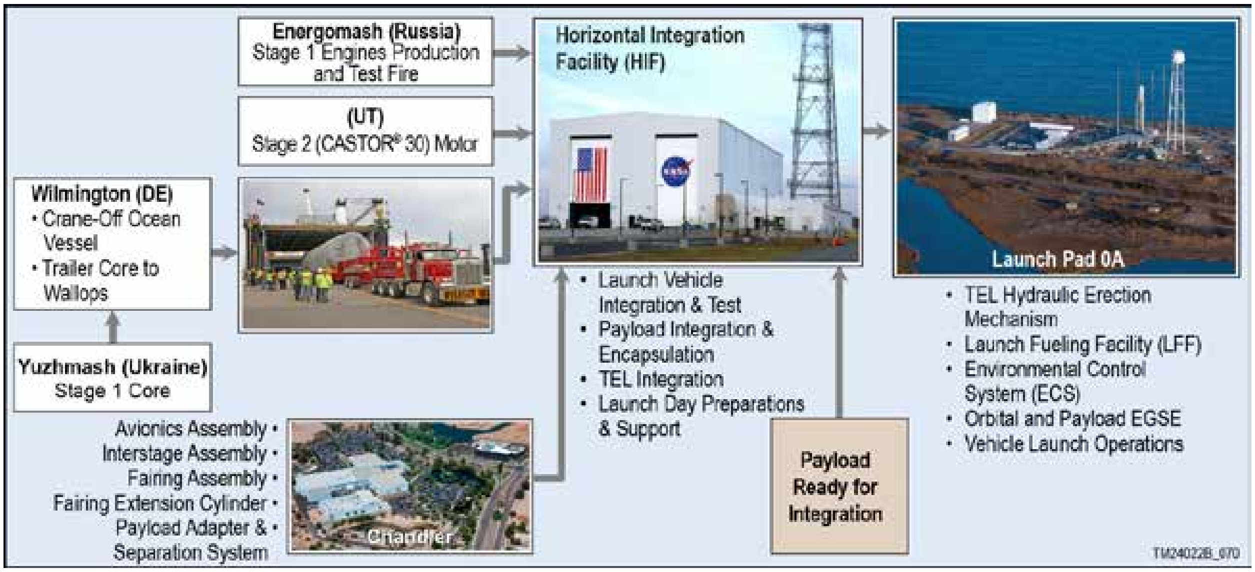


Figure 7.3-1. Flow of Antares Hardware to the Launch Site

7.3.1. Stage 1 Motor

Upon arrival at the HIF, the Stage 1 core is lifted from the overland transporter and placed on GSE using HIF cranes. Functional checks are performed to validate electrical and pneumatic systems are properly performing after the core's transport. The aft bay of the core is removed providing access for avionics, ordnance, and MES installations. Once the MES is mated the Stage 1 core, electrical, functional, and leak checks are performed. Following this validation, the motor aft bay is reinstalled completing the Stage 1 Core subassembly.

7.3.2. Stage 2

The Stage 2 solid rocket motor is received via overland transporter and transferred to its MGSE dolly in the HIF using the HIF cranes. Mechanical, electrical, and ordnance installation is performed followed by Thrust Vector Actuator (TVA) performance testing. The avionics section, which is shipped as an assembly from Northrop Grumman Innovation Systems Chandler facility, is attached to the forward ring of the Stage 2 motor. This assembly, referred to as the "upper stack", completes a series of tests to verify power buses, software, communications, telemetry, RF systems, and ordnance circuits.

7.3.3. Stage Integration

After both stage subassemblies are completed, the Stage 2 is horizontally mated to the Stage 1 core. The first flight simulation test, which is a "fly to orbit" test exercising the avionics and control systems of the vehicle, is then performed.

7.4. Payload Processing/Integration

Antares' approach to payload processing places few requirements on the customer. Once the payload is fully assembled, checked out, and fueled (if required), the payload is transported to the HIF approximately 15 days before launch, and integrated to the launch vehicle.

Payload mate occurs with the Antares launch vehicle in a horizontal position in the HIF with the second stage section cantilevered over the facility floor. The HIF's overhead crane will be used to lift the payload off the transporter using the payload's lifting fixture and place the payload onto the Payload Mate Fixture (PMF). The PMF contains the payload adapter. Next, the electrical connections between the payload and the Antares payload adapter are made and verified. Then the PMF, supporting the integrated payload, is rotated to horizontal and placed on ground dollies. Once horizontal, this payload adapter/payload structure is mated to the forward end of the launch vehicle using these dollies. Following mate, the flight vehicle is ready for the final integrated systems test.

Once consumables are topped off and the final launch vehicle-to-payload closeout is complete, the payload fairing is installed over the satellite and the second stage assembly with the environmental control system attached to ensure the required payload environments are maintained inside the fairing until launch. Following payload encapsulation in the fairing, the customer will coordinate with the Antares Mission Manager for any further access to the payload.

After integration of the payload to the Antares launch vehicle is complete, final vehicle preparations are accomplished. These include end-to-end FTS testing, ACS and separation systems pressurization to final flight pressure, and final safe and arm verification testing. The vehicle and launch team are then ready for rollout to the pad in preparation for countdown and launch.

7.5. Pre-Launch and Launch Operations

Prelaunch activities begin at approximately L-3 days with transportation of the integrated launch vehicle from the HIF to the launch complex. The exact time of transport from the HIF is flexible and is ultimately based on mission requirements. Integrated procedures control this and all remaining activities through launch, including:

- Payload environmental control switchover from mobile (PECS) to launch pad
- Integration of umbilicals and fueling lines from the pad to the launch vehicle
- Removal of final safing keys for ordnance and FTS

- Vehicle erection and attachment to launch mount
- Combined system testing
- TVA operations
- Stage 1 automated fueling operations
- Launch vehicle and payload countdown operations

7.5.1. Launch Control Management

The launch control organization is comprised of two groups: a management team and a technical team. The management team consists of senior Range, launch vehicle, and payload personnel. At major milestones during the launch count, including the polls to resume the count after a hold and the final poll, the Antares Launch Conductor (LC) will poll the management team members for their respective "GO" status. The management team has overall responsibility for launch operations and success of the launch.

The technical team executes launch-day activities and data review/assessment for the payload, the launch system, the launch site, and the Range. This team consists of the Launch Conductor, vehicle engineers and operators, members of the payload engineering organization, the Range Control Officer, the Spaceport operations personnel, and the supporting engineering and Range personnel. The Launch Conductor is responsible for conducting the countdown procedure and ensuring that all countdown tasks are performed. The Launch Conductor polls the launch team for readiness to support each of the major activities in the sequence. The Antares Chief Engineer has the overall responsibility for the Antares launch vehicle and coordinates the activities of a team of engineers who are reviewing the telemetry to verify that the system is ready for launch. The payload engineering organization is responsible for coordinating the activities of the payload engineering team to verify that the payload is ready for launch. The Spaceport personnel verify that pad systems including the liquid fueling facility are functional and ready to support launch operations. The NASA Program Manager coordinates the range activities.

7.5.2. Launch Rehearsals

Launch rehearsals are conducted prior to each mission to prepare Antares, customer, and Range personnel for a successful launch. Launch vehicle, payload and Range personnel involved with launch day activities are required to participate in launch rehearsals.

A Mission Dress Rehearsal (MDR) is conducted approximately five days prior to launch to train the launch team with control center consoles and communications operations, procedures for reporting issues, problem solving, launch procedures and constraints, and the decision making process. The MDR is typically a full day in duration and consists of a number of countdown simulations performed using abbreviated timelines. All aspects of the team's performance are exercised, as well as simulated holds, scrubs, and recycle procedures.

7.5.3. Launch Countdown

The launch countdown operations are designed to methodically transition the vehicle and launch site from a safe state to that of launch readiness (Figure 7.5.3-1). Payload tasks are integrated into the launch countdown operations, as required, and coordinated by the Antares Launch Conductor. Launch countdown operations begin with the pre-power checkout of ground systems. Once these checkouts are complete, the launch vehicle is powered on and the commodity loading operations begin. During this time, the payload is prepared for launch.

After fueling operations are complete, the vehicle is transitioned from a safed to a launch-ready state (i.e., on internal power, final FTS destruct test, safe and arms rotated to "Armed," open loop telemetry, etc.) through controlled steps. A final launch readiness poll is performed to verify that the team is "Go" for launch. At T-3 minutes, the auto-sequence is started and the sequencing of the vehicle (except for manual abort functions) is controlled by the on-board flight computer. Stage 1 engine ignition is initiated at L-0, after which the flight computer performs an automated health check of each engine's critical operating parameters. Once the engine health is verified, the flight computer commands engine throttle power coincident with vehicle release from the pad.

Figure 7.5.3-1. Antares Launch from WFF

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8. NON-STANDARD SERVICES

The Antares launch service is structured to provide a standard launch service that can then be augmented with optional non-standard services to meet the specific needs of individual customers. These optional capabilities are defined within this section. Should a customer have mission-unique requirements not addressed in this section, please contact the Antares Program Office directly for further assistance.

8.1. Separation Systems

The Antares vehicle features a payload cone with a flight proven 1194VS payload separation system vehicle interface. The customer can also choose to have a standard 1575 mm (62 in.) diameter bolted interface or one of three other separation systems: the 937S, 1666VS, or 2624VS. Each separation system has a conical shaped adapter cone with a lower frame that mates with the Antares standard non-separating interface. RUAG Space, a company with extensive experience supplying separation systems for a wide range of launch vehicles and payloads, manufactures these systems. The Antares separation systems have a flight proven capability to provide clean, highly reliable separation with low tip-off rates, typically less than 1°/sec per axis, imparted to the payload.

All the RUAG-supplied Antares separation systems use a Marmon clamp band design and incorporate low shock Clamp Band Opening Devices (CBODs). Clamp band release is activated by redundant electrical signals into NASA standard initiators. Upon band release, the movement and parking of each band is controlled by a set of eight catcher assemblies. A set of matched springs on the launch vehicle side of the interface impart a separation velocity sufficient to safely separate the payload and to ensure that no recontact occurs.

8.1.1. RUAG 937S Separation System

The Antares launch vehicle standard 1575 mm (62 in.) interface allows use of the standard RUAG PAS937S Payload Adapter System. This 37" Marmon clamp and adapter cone separation system has extensive launch heritage, having flown on Ariane, Atlas, Delta, Proton and other launch vehicles, and has direct heritage to the 37" and 38" systems that has flown on Minotaur launch vehicles. The system (and derivatives) has a 100% record of mission success in over 130 launches since originally developed. The 937S separation system and mass capabilities are illustrated in Figure 8.1.1-1.

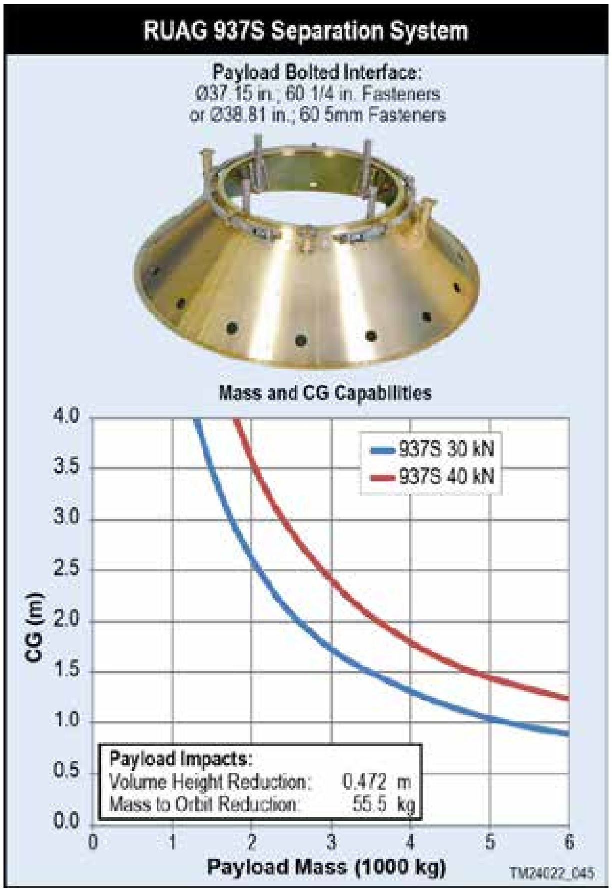

Figure 8.1.1-1. 937S Separation System

8.1.2. RUAG 1666VS Separation System

The Antares launch vehicle standard 1575 mm (62 in.) interface allows use of the standard RUAG PAS1666VS Payload Adapter System. This 66" Marmon clamp and adapter cone separation system has extensive launch heritage on other commercial launch vehicles. The system (and derivatives) have a 100% record of mission success in over 80 launches since originally developed. The 1666VS separation system and mass capabilities are illustrated in Figure 8.1.2-1.

8.1.3. RUAG 2624VS Separation System

Antares offers a commercially available RUAG 2624VS payload separation system. The "S" in the "2624VS" designation indicates that the separation system uses the CBOD low shock design.

The RUAG 2624VS payload adapter structure (Figure 8.1.3-1) has an interface diameter of 2,624 mm (103.31 in.) and a height of 175 mm (6.89 in.). The RUAG 2624VS mechanical interface is designed to handle payloads up to 15,000 kg (33,069 lb.) which have a CoG up to 2.4 m (94.5 in.) above the interface flange, as shown in Figure 8.1.3-1.

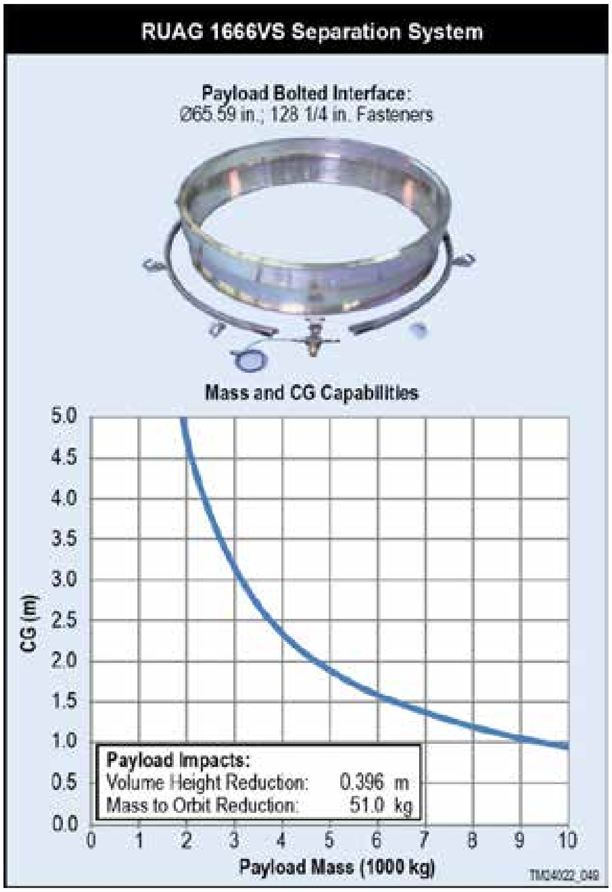

Figure 8.1.2-1. 1666VS Separation System

The RUAG 2624VS Spacecraft Ring structure is manufactured from an aluminum forging similar to the payload adapter. In Figure 8.1.3-2, the bolted interface to the payload has a diameter of 2624 mm (103.31 in.) at a height of 180 mm (7.09 in.) above the PA clamp band interface. The cylindrical ring provides a machined butt joint interface to the payload with 244 holes designed to accommodate SAE 5/16 inch fasteners. Antares team will provide a tolerance MICD to allow accurate machining and drilling of the payload interface to the spacecraft ring fastener holes.

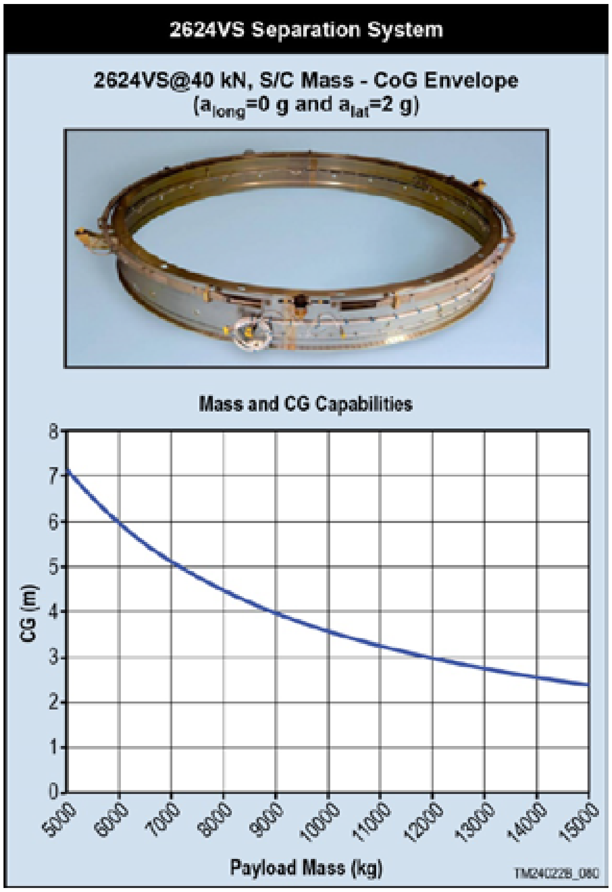

Figure 8.1.3-1. 2624VS Separation System

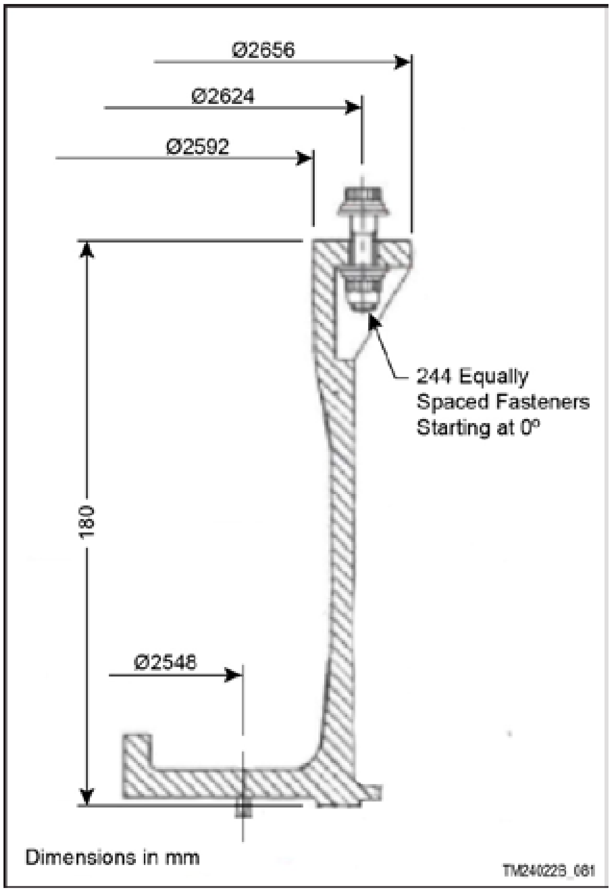

Figure 8.1.3-2. 2624VS Spacecraft Ring

8.2. Additional Access Panel

Antares provides one additional access door of standard size, 610 mm by 610 mm (24 in. x 24 in.), in the fairing within the allowable door envelope defined in Section 5.1.2, as illustrated in Figure 5.1.2-1. The location of the fairing access door is documented within the mission-specific ICD. Note that the additional door location must have a minimum axial distance between doors of 16.6 in. (422 mm), a minimum radial distance between doors of 14.6 degrees, and a minimum of 305 mm (12 in.) between the access door edge and the fairing joint. Antares mission team will perform an analysis to verify the structural integrity of the fairing with the additional door in the desired location. The door location will be further validated in the acceptance test of the flight fairing structure. If more than one additional door is required, this enhancement can be exercised multiple times provided the location restrictions defined above are met. Additionally, Antares can provide one additional access door of standard size, 610 mm by 610 mm (24 in. by 24 in.), located in the bi-conic section of the fairing. Antares mission team will perform the analysis to verify the structural integrity of the fairing with the additional door at the desired location. If this analysis shows the additional door is feasible, Antares production will manufacture the additional door and the modified fairing for the mission. This analysis will then be validated in the acceptance test of the flight fairing structure.

8.3. Nitrogen Purge

Antares provides a gaseous nitrogen purge to the payload after fairing encapsulation through lift-off. The nitrogen purge upgrade delivers gaseous nitrogen to system distribution lines routed along the inner surface of the fairing to meet payload purge requirements. The instrument purge supply system is equipped with flow rate metering that can be configured to meet payload requirements for flow rate and particulate filtering.

The flow rate metering equipment features a replaceable metering orifice to provide a purge system flow rate in the range of 0.01 to 25 Standard Cubic Feet per Minute (SCFM). The system also includes a particulate filter and pressure switches to continuously monitor and control system operation. The entire instrument system is precision cleaned to IEST-STD-CC1246D, Level 100A. The purity of the GN_2 flowing through the system is certified to meet Grade B cleanliness specifications as defined in MIL-P-27401C. The purge system's regulators are set to a desired flow rate during prelaunch processing. The power to the purge system is controllable from the launch equipment vault and the launch control room. The purge rate cannot be adjusted after the launch pad is cleared of personnel.

8.3.1. Payload Spot Cooling up to T-0

Antares can provide spot cooling of payload components from payload encapsulation to liftoff by locating nozzles within the fairing to direct either pure conditioned air or Grade B gaseous nitrogen at the payload, as required. Up to six separate nozzle positions can be specified with a total maximum flow rate of 25 SCFM.

If greater cooling is required than possible with directed nitrogen, Antares can supply spot payload cooling via directed filtered air. The purge air duct inside the fairing will be modified to direct a portion of the incoming purge air at a single payload component or area. The flow rate may be up to 25% of the total flow rate provided to the fairing by the ECS. The cleanliness of the spot cooling air will match that provided to the fairing.

If the customer desires purge capability of specific payload instrumentation, Antares can provide GN2 flow to a pre-defined purge quick disconnect fitting on the payload, which is pulled from this fitting during fairing jettison. The spot cooling quick-disconnect system exerts less than 22.68 kgf (50 lbf) on the payload fitting.

Prior to use, the spot cooling system is precision cleaned to IEST-STD-CC1246D, Level 100A. The purity of the pure conditioned air and/or nitrogen flowing through the system is certified prior to use, and GN2 is certified to meet Grade B cleanliness specifications as defined in MIL-P-27401C.

8.4. Upgraded Contamination Control

To meet the requirement for a low contamination environment, Antares uses existing processes developed and demonstrated on the Minotaur and Pegasus launch vehicle programs. These processes are designed to minimize outgassing, supply a Class 10,000 (ISO 7) clean room environment, assure a high cleanliness payload envelope, and provide a HEPA-filtered, controlled humidity environment after fairing encapsulation. Antares leverages extensive payload processing experience to provide flexible, responsive solutions to mission-specific payload requirements (Figure 8.4-1).

Figure 8.4-1. The Antares Team Has Extensive Experience in a Payload Processing Clean Room Environment

Antares provides an upgraded contamination control service, employing additional measures to increase fairing volume cleanliness and further protect the payload from potential contaminants. Antares design selected materials used within the fairing volume based largely on their designation as non-outgassing. Specifically, to the maximum extent possible, Antares design selected materials having a Total Mass Loss (TML) of less than 1.0 % and a Collected Volatile Condensable Materials (CVCM) of less than 0.1 % when tested in accordance with ASTM E595. Antares production tracks all materials used within the fairing volume in a formal Material Outgassing Data Report, which identifies the TML and CVCM parameters of each material used within the fairing. For any materials that exceed the TML and CVCM requirements, Antares production identifies their specific mass and usage location. Passive and active measures are implemented to eliminate or mitigate the potential for outgassing. For example, encapsulation of a material within a non-outgassing material was shown to be an effective method of outgassing mitigation for some materials.

With this upgraded contamination service, the integration of the payload takes place in a Class 10,000 (ISO 7) environment or better as defined by ISO Standard 14644-1. Antares implements charcoal filtration in the ECS and other active integration measures to minimize the presence of hydrocarbons in the integration area. Hydrocarbon content is monitored to ensure that hydrocarbon concentrations remain less than 15 ppm. Relative Humidity is also actively controlled in the integration space to ensure that it remains within a range of 30 to 60%. These same conditions are maintained whether the payload is in the integration area or encapsulated within the payload fairing. The facility ECS, the mobile ECS used during transportation, and the pad ECS all employ temperature control, relative humidity control, HEPA filtration, and charcoal filtration to maintain the payload in the required environment.

Launch vehicle surfaces within the fairing volume with a view angle to the payload are cleaned to a Visibly Clean Plus Ultraviolet (UV) light cleanliness criteria. Antares production technicians removes particles on these surfaces visible under normal vision from a distance of 6 to 18 inches (15.25 to 45.72 cm) with a lighting environment of 100-foot candles (1076.4 lm/m^2). Additionally, particles that are visible under UV light (3200 – 3800 angstroms (320-380 nanometers)) are removed. Antares production technicians wear clean garments and use various methods (e.g., lint free wipes with appropriate grade Iso-Propyl Alcohol (IPA), HEPA filtered vacuums, etc.) to clean the fairing surfaces to meet the requirements. When the fairing is covered with an appropriate cleanroom compatible material to maintain cleanliness.

8.4.1. Facility Contamination Control

Antares can provide additional contamination control to payloads requiring levels of control beyond the processing facility capability. The Antares mission team can establish a "clean tent" to provide constant Class 10,000 (ISO 7) to the payload while processing at WFF. Once the clean tent is certified to the appropriate level, the contaminant levels are constantly monitored and any violation is reported to the customer. Personnel clean tent attire can also be provided as part of this non-standard service.

8.5. Electrical Interface Options

Antares offers a variety of options to offer the flexibility to meet unique payload electrical interface requirements.

8.5.1. LV Command and Control of the Payload

As a Non-Standard Service, the Antares launch vehicle can provide commands to the payload. Two methods are available:

8.5.1.1. Discrete Sequencing Command and Control (C&C)

The Antares electrical interface can provide discrete sequencing commands to the payload. These will be available to the payload as closed circuit opto-isolator command pulses of 5 A in lengths of 40 ms minimum. Discrete sequencing commands generated by the Antares Ordnance Driver Module (ODM) can be used for any combination of (redundant) ordnance events and/or discrete commands depending on the payload requirements.

8.5.1.2. Full Duplex Ethernet Point-to-Point C&C

The Antares electrical interface can provide Ethernet interfaces configured to support full duplex point-to-point command and control using a 100BASE-TX configuration. These interfaces are implemented using impedance matched cable and connectors and are verified to comply with IEEE-802.3 standards through testing.

8.5.2. Launch Vehicle (LV) Supplied Payload Power Capability

The Antares electrical interface can be equipped with two Power Transfer Switches (PTS) capable of switching up to 4.5 amps each. The PTS is constantly engaged, even if the power source that issues control signals is removed, therefore failure modes are benign.

8.6. Upgraded Telemetry Capabilities - Payload Data

Upgraded telemetry can be provided for mission specific instrumentation and telemetry components to support additional payload, LV, or experimental data acquisition requirements. Antares offers a payload serial telemetry interface that can be used to interleave payload telemetry and state of health data into the launch vehicle telemetry stream. This interface is implemented with a 4-wire RS-422 serial communication link between the Antares flight computer and the payload. Another alternative is 100BASE-TX Ethernet, which can be supported as a Non-Standard upgraded telemetry service.

Both the RS-422 serial communication link and 100BASE-TX Ethernet options use a poll/response protocol. The Antares flight computer polls the payload at a 1 Hz rate and receives a pre-determined block of payload data (the payload telemetry data volume cannot exceed 250 bytes/sec) that is incorporated into the launch vehicle telemetry stream. The serial telemetry interface utilizes unused pins in the LV connector at the separation interface and, therefore, does not affect the standard electrical interface.

As part of this Non-Standard Service, Antares incorporates two text-based and one graphical-based data display pages into the telemetry software to display this payload data in the launch control facility during ground operations for both launch and ascent. Antares mission team will support up to two stand-alone tests with the payload prior to integrated operations to verify the interface protocol and payload data format. These tests will be performed with an Engineering Development Unit (EDU) flight computer.

Additional instrumentation such as strain gauges, temperature sensors, accelerometers, analog data, and digital data can be configured to meet mission specific requirements.

The first flight of the Antares vehicle included extensive instrumentation on a dedicated payload simulator telemetry package. While this first-flight instrumentation is not included for operational missions, an upgraded telemetry package may be derived from the first-flight telemetry system design. Depending on a specific mission's desired measurements, development is necessary to design the encoder, cabling, and software. Updates to the integration and test procedures are also necessary. Typical upgraded telemetry instrumentation includes accelerometers to capture high frequency transients such as shock and random vibration, microphones to measure lift-off acoustics, and strain gages to determine flight loads.

8.7. Launch Vehicle Mounted Cameras

Antares can support launch vehicle mounted cameras. Antares team will work with customers to review mission specific requirements of video services.

8.8. CubeSat Deployer

A CubeSat deployment canister can be mounted on Stage 2 and/or Stage 3 (if applicable) as a non-standard upgraded Antares service. For this service, Antares provides all required hardware to mount the canister to Stage 2 and/or Stage 3 (if applicable), monitor the CubeSat Deployer door status throughout the mission, and provide two (redundant) electrical pulses to initiate the door actuator, enabling the CubeSats to be ejected after the primary payload is deployed. This non-standard service also includes the necessary mission integration support as well as required documentation and verification of the interface as part of the vehicle processing.

This non-standard service can be exercised multiple times to support multiple CubeSat deployment canisters. The maximum number of canisters is determined on a mission-specific basis.

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APPENDIX A

PAYLOAD QUESTIONNAIRE

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SPACECRAFT IDENTIFICATION

FULL NAME:	
ACRONYM:	
OWNER/OPERATOR:	
INTEGRATOR(s):	

ORBIT INSERTION REQUIREMENTS*

SPHEROID	q Standard q Other:	
ALTITUDE	Insertion Apse: ____________ ± _____ q km ____________ ± _____ q nmi	Opposite Apse: ____________ ± _____ q km _____________ ± ___________ q nmi
or...	Semi-Major Axis: ____________ ± _____ q km ____________ ± ____________ q nmi	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:

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

<table>
<tr><th colspan="4">GROUND SUPPORT EQUIPMENT</th></tr>
<tr><td colspan="4">Describe any ground support equipment, mission control facilities (e.g.; LCC, MCC) and Range facilities (e.g., Launch Equipment Vault (LEV) which the Spacecraft intends to use:</td></tr>
<tr><td rowspan="7">LEV</td><td colspan="3">Describe (in the table below) Spacecraft EGSE to be located in the LEV.</td></tr>
<tr><th>Equipment Name / Type</th><th>Approximate Size (LxWxH)</th><th>Power Requirements</th></tr>
<tr><td></td><td></td><td></td></tr>
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</table>

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

SPACECRAFT SEPARATION REQUIREMENTS	
ACCELERATION	Longitudinal: = _________ g's Lateral: = _________ g's
VELOCITY	Relative Separation Velocity Constraints:
ANGULAR RATES (pre-separation)	Longitudinal: __________________ ± ________________ deg/sec Pitch: ________________________ ± _______ deg/sec Yaw: _________________________ ± _______ deg/sec
ANGULAR RATES (post-separation)	Longitudinal: ________________ ± ________________ deg/sec Pitch: __________ ± _________ deg/sec Yaw: ___________ ± _________ deg/sec
ATTITUDE (at deployment)	Describe Pointing Requirements Including Tolerances:
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:________ ☐ in ☐ cm Diameter: ___________ ☐ in ☐ 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 electronic files of dimensioned drawings for both stowed and on-orbit configurations.

SPACECRAFT MASS PROPERTIES*		
PRE-SEPARATION	Inertia units: ☐ lbm XCG:______________ ☐ in YCG:______________ ☐ in ZCG:______________ ☐ in	☐ lbm-in^2 ☐ kg-m^2 Mass: ☐ kg Ixx:__________ Ixy:__________ ☐ cm Iyy:__________ Iyy:__________ ☐ cm Izz:__________ Ixz:__________ ☐ cm
POST-SEPARATION (non-separating adapter remaining with launch vehicle)	Inertia units: ☐ lbm XCG:______________ ☐ in YCG:______________ ☐ in ZCG:______________ ☐ in	☐ lbm-in^2 ☐ kg-m^2 Mass: ☐ kg Ixx:__________ Ixy:__________ ☐ cm Iyy:__________ Iyy:__________ ☐ cm Izz:__________ Ixz:__________ ☐ cm

** Stowed configuration, spacecraft coordinate frame*

ASCENT TRAJECTORY REQUIREMENTS	
Free Molecular Heating at Fairing Separation:	FMH = ________________ q W/m^2 q Btu/ft^2/hr
Fairing Internal Wall Temperature	T = ________________ q deg C q deg F
Dynamic Pressure at Fairing Separation:	q = ________ q N/m^2 q lb$_f$/ft^2
Ambient Pressure at Fairing Separation:	P = ________ q N/m^2 q lb$_f$/in^2
Maximum Pressure Decay During Ascent:	Δ P = ________ q N/m^2/sec q lb$_f$/in^2/sec
Thermal Maneuvers During Coast Periods:	

SPACECRAFT ENVIRONMENTS	
THERMAL DISSIPATION	Spacecraft Thermal Dissipation, Pre-Launch Encapsulated: ________ Watts Approximate Location of Heat Source:
TEMPERATURE	Temperature Limits During Ground/Launch Operations: Max ________ q deg F q deg C Min ________ q deg F q deg C
	Component(s) Driving Temperature Constraint: Approximate Location(s):
HUMIDITY	Relative Humidity: Max ________ % Min ________ % ***or***, Dew Point: Max ________ q deg F q deg C Min ________ q deg F q deg C
GAS PURGE	Specify Any Gas Purge Requirements (e.g.; Nitrogen), 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's Lateral = _______ g's

MECHANICAL INTERFACE	
DIAMETER	Describe Diameter of Interface (e.g. Bolt Circle, Separation System, etc.) and provide illustration if available:
SURFACE FLATNESS	Flatness Requirements for Sep System or Mating Surface of Launch Vehicle:
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:
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: Longitudinal __________ q in q cm Clocking (deg), Describe:
DYNAMICS	Spacecraft Natural Frequency: Axial ____________ Hz Lateral ____________ Hz Recommended: > TBD Hz > TBD Hz
OTHER	Other Mechanical Interface Requirements:

ELECTRICAL INTERFACE
Bonding Requirements:
Are Launch Vehicle Supplied Pyro Commands Required? Yes / No If Yes, magnitude: __________ amps for _________ msec When _________ seconds before separation
Are Launch Vehicle Supplied Discrete Commands Required? Yes / No If Yes, describe:
Is Electrical Access to the Satellite Required? After Encapsulation? Yes / No At Launch Site?Yes / No
Is Spacecraft 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 (e.g.; coax, fiber, etc.):

Please complete attached sheet of required pass-through signals.

RF RADIATION
Time After Separation Until RF Devices Are Activated: (Note: Typically, spacecraft radiation is not allowed from encapsulation until after fairing separation.)
Frequency: _________________ MHz Power: _______________ Watts
Location(s) on Spacecraft (spacecraft coordinate frame): Longitudinal __________ q in q cm Clocking (deg), Describe: Longitudinal __________ q in q cm Clocking (deg), Describe:

REQUIRED PASS-THROUGH SIGNALS

Item No.	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							
13							
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23							
24							
25							
26							
27							
28							
29							
30							

REQUIRED PASS-THROUGH SIGNALS

Item No.	Pin	Signal Name	From LEV	To Satellite	Shielding	Max Current (amps)	Total Line Resistance (ohms)
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
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50							
51							
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53							
54							
55							
56							
57							
58							
59							
60	---	Reserved for separation loop	---	---	---	---	---

REQUIRED PASS-THROUGH SIGNALS

Item No.	Pin	Signal Name	From LEV	To Satellite	Shielding	Max Current (amps)	Total Line Resistance (ohms)
61	---	Reserved for separation loop	---	---	---	---	---
62							
63							
64							
65							
66							
67							
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91							

REQUIRED PASS-THROUGH SIGNALS

Item No.	Pin	Signal Name	From LEV	To Satellite	Shielding	Max Current (amps)	Total Line Resistance (ohms)
92							
93							
94							
95							
96							
97							
98							
99							
100							
101							
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115							
116							
117							
118							
119							
120							
121	---	Reserved for separation loop	---	---	---	---	---
122	---	Reserved for separation loop	---	---	---	---	---

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