Athena Mission Planner's Guide (MPG)

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FOREWORD

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This *Athena Mission Planner's Guide* presents information regarding the Athena Launch Vehicle and related launch services. A range of vehicle configurations and performance capabilities are offered to allow optimum match to customer requirements at low cost. Information is presented in sufficient detail for preliminary assessment of the Athena family for your missions.

This guide includes essential technical and programmatic information for preliminary mission planning and preliminary spacecraft design. Athena performance capability, environments and interfaces are described in sufficient detail to assess a first-order compatibility. A description of the spacecraft processing and launch facilities at our launch sites is also included. This guide also describes the operations and hardware flow for the spacecraft and launch vehicle leading to encapsulation, spacecraft mating and launch.

This guide is subject to change and will be revised periodically.

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1.0 INTRODUCTION

1.1 SUMMARY

The Athena Mission Planner's Guide presents current and potential Athena launch services customers with information about the operational Athena family and related spacecraft services. The Athena family's flight history is shown in Figure 1.1-1. This guide includes a full range of technical planning data to allow the user to assess the compatibility of the user's payload with the various interfaces of the Athena system.

Demonstration Launch Vehicle	Aug 1995
Athena I / Lewis	Aug 1997
Athena II / Lunar Prospector	Jan 1998
Athena I / ROCSAT-1	Jan 1999
Athena II / IKONOS-1	Apr 1999
Athena II / IKONOS-2	Sep 1999
Athena I / Kodiak Star	Sep 2001

Figure 1.1-1. Athena Ic and Athena IIc

1.2 LAUNCH SERVICES

The Lockheed Martin (LM) Athena Launch Vehicle (LV) organization offers commercial and government entities a full launch service, from spacecraft integration, processing, and encapsulation, through launch operations and verification of orbit. The launch services customer has access to a dedicated team of technical and management specialists to readily define the complete and most cost-effective Athena launch services solution.

The typical launch service includes:

1. Launch of Athena from Cape Canaveral Air Force Station (CCAFS) in Florida or Kodiak Launch Complex (KLC) on Kodiak Island, Alaska
2. Launch operations services
3. Mission-peculiar hardware and software design, test, and production
4. Technical spacecraft/LV integration and interface design
5. Launch facilities and support provisions
6. Payload processing facilities
7. Spacecraft support at the launch site
8. Range Safety and support interface
9. Mission management
10. Validation of spacecraft separation sequence and orbit.

1.3 ADVANTAGES OF SELECTING ATHENA

Our LVs and services afford the following key advantages:

1. The launch vehicles are backed by LM—the world's largest aerospace company—which has a history of proven designs for long-term capability in space products and services;
2. More than 50 years of LV development and spacecraft integration experience established the right personnel, procedures, test facilities, and analysis tools to provide a successful launch;
3. A dedicated Mission Manager is supported by the resources and capabilities of LM;
4. A conservative vehicle design provides highly reliable, low-cost access to space;
5. Proven non-segmented solid rocket motors demonstrate high reliability;
6. A large Payload Fairing (PLF) accommodates significant spacecraft volume and volume growth;
7. Moderate payload launch environments (e.g. loads, shock, vibration, acoustic, thermal, and electromagnetic) for Athena are generally lower than those of other LVs in this class;
8. LM's unique Simulation Laboratory (SimLab) configuration "flies" the integrated Athena mission-specific software and avionics hardware in-the-loop before launch;
9. East Coast launch facilities allow the launch of low-inclination spacecraft missions;
10. West Coast launch facilities enable the launch of high-inclination spacecraft missions;
11. LM is an established mission success-focused organization;

1.4 ATHENA LAUNCH SYSTEM

1.4.1 Athena Launch Vehicles

The Athena family consists of two basic configurations, designated Athena Ic and Athena IIc. The family has application for a range of spacecrafts according to mission and program requirements. Also, the Athena family uses components and systems that are common between the Athena Ic and Athena IIc to achieve mission requirements for performance, reliability, and cost; these elements appear in Figure 1.4-1. The modular architecture allows common hardware, build processes, testing, launch site facilities, assembly and checkout, ground support equipment, and launch operations procedures.

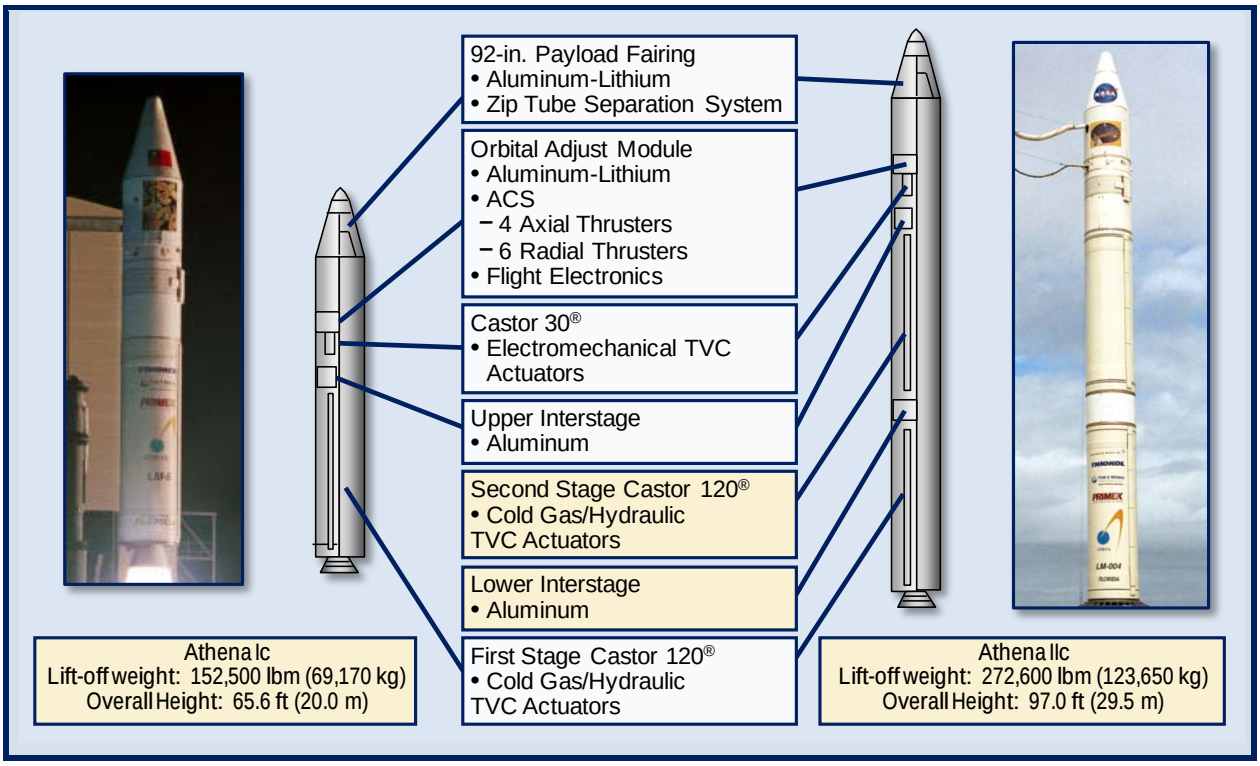


Figure 1.4-1. Athena Launch Vehicle Common Components

1.4.2 Mission Design and Performance

The Athena LV family design provides the small spacecraft community with low-cost, highly reliable access to space. The standard Athena Ic and Athena IIc LVs are capable of accurately delivering up to 700 kg (1,543 lbm) and 1,800 kg (3,968 lbm), respectively, to Low Earth Orbit (LEO). Achievable orbits range from circular to highly elliptical and cover a large variety of inclinations, from low, using our CCAFS facilities, to polar and Sun-Synchronous, using our KLC facilities.

1.4.3 Spacecraft Interfaces

LM has developed simple and reliable mechanical and electrical interfaces that allow efficient spacecraft/LV integration with minimal risk. Our Athena mission standard Model 92 PLF and three standard payload adapters—Models 38, 47, and 66—are addressed in Section 3.0.

1.4.4 Environments

All environments specified for the Athena (e.g., loads, shock, vibration, acoustic, thermal, and electromagnetic) are based on engineering analyses and test. Section 4.0 offers further discussion.

1.4.5 Spacecraft and Launch Facilities

Upon arrival at the launch site, most spacecraft require the use of payload and/or hazardous processing facilities for final checkout and processing of on-board systems before launch. Section 5.0 summarizes the payload processing facilities as well as the operational capabilities and interfaces of the launch facilities the Athena LV uses in operations at CCAFS in Florida and KLC on Kodiak Island, Alaska.

1.4.6 Launch Campaign

The Athena launch campaign processes require the involvement of the launch services customer and the spacecraft contractor. Section 6.0 gives a first-order overview of our operations processes and discusses issues that the potential launch services user may wish to consider early in the mission integration process.

1.4.7 Mission Integration and Management

The mission integration and management process effectively employs the engineering and production talents of LM Space Systems Company, as well as those of the spacecraft contractor organizations, to integrate the spacecraft with the Athena vehicle. In Section 7.0, we discuss our 24-month integration schedule—typical for most spacecraft missions—detail our management approach, and summarize the integration analysis tasks that promote the customer's full confidence in the mission integration process.

1.4.8 System Enhancements

Section 8.0 provides insight into LM's plans for enhancing the Athena to meet the high-end launch services needs of the small LV community. Some of the enhancements include a 120-in. PLF and alternate launch sites.

1.4.9 Supplemental Information

Appendix A defines the desired exchange of technical data requirements to support the initial mission development process. In addition, we discuss the type and format of technical data needed to foster the exchange of information between the spacecraft contractor, launch services customer, and LV contractor during the typical mission integration process.

1.5 CONCLUSION

The members of the Athena team are eager to assist in the definition and development of future Athena missions. The Foreword of this document contains information to allow the potential launch services customer to contact the appropriate Athena representative.

2.0 ATHENA LAUNCH SYSTEM

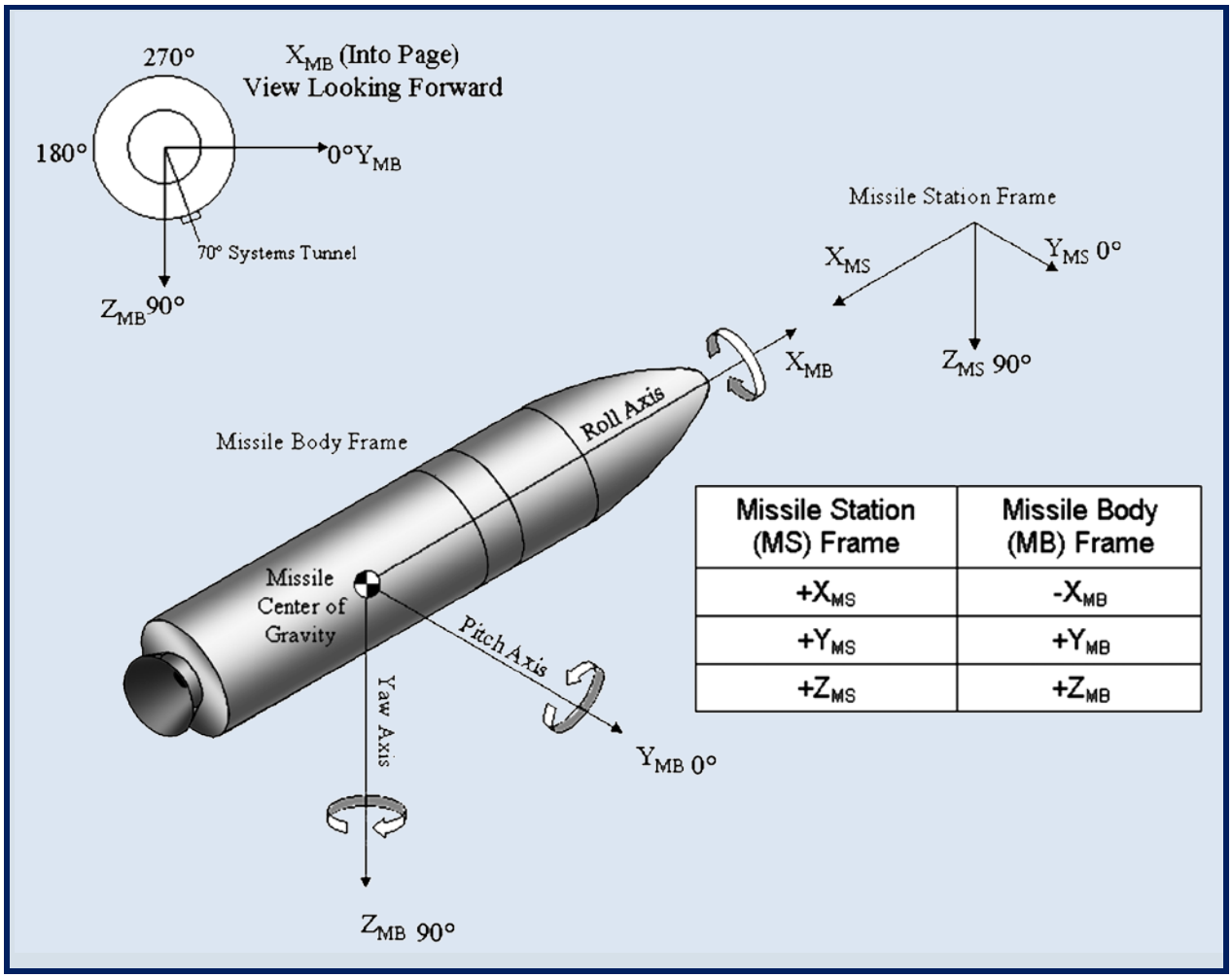
2.1 ATHENA LAUNCH VEHICLE FAMILY

The highly capable Athena Launch Vehicle family can achieve orbits from circular to highly elliptical and a broad range of orbital inclinations, from low—using launch azimuths available from our launch site at Cape Canaveral Air Force Station (CCAFS)—to polar and Sun-Synchronous—using launch azimuths available from our launch site at Kodiak Launch Complex (KLC). The Athena LV can also achieve Geosynchronous Transfer Orbit (GTO) and perform planetary missions. Each past mission boasts a high degree of accuracy for spacecraft position and attitude at spacecraft separation.

Athena Ic—The Athena Ic is a three-stage LV consisting of a Castor 120® first-stage motor; an aluminum upper interstage structure; a Castor 30® second-stage motor; a blow-down monopropellant Orbit Adjust Module (OAM), which includes the equipment section structure, Attitude Control System (ACS), and avionics; the Model 92 Payload Fairing (PLF); and an aluminum-lithium Payload Adapter (PLA).

Athena IIc—The Athena IIc is a four-stage vehicle, consisting of a Castor 120® first stage, an aluminum lower interstage, a Castor 120® second stage (identical to the first stage), an aluminum upper interstage, a Castor 30® third stage, a blow-down monopropellant OAM fourth stage with an aluminum-lithium structure, an aluminum-lithium PLA, and an aluminum-lithium Model 92 PLF.

Athena Coordinate System—The Athena coordinate system, for all Athena configurations, assists the user in the preliminary orientation of the spacecraft. Details of the spacecraft coordinate system and LV coordinate system are required to determine spacecraft accessibility (through the PLF access doors) and to evaluate mission performance as related to spacecraft Center of Gravity offset. The Athena orthogonal coordinate system is shown in Figure 2.1-1. The X axis is longitudinal along the vehicle centerline, with the Y and Z axes oriented as shown in the figure.



Missile Station (MS) Frame	Missile Body (MB) Frame
$+X_{MS}$	$-X_{MB}$
$+Y_{MS}$	$+Y_{MB}$
$+Z_{MS}$	$+Z_{MB}$

Figure 2.1-1. The Athena Coordinate System

2.2 PERFORMANCE CAPABILITY

All data includes performance margins reflecting the maturity of the current vehicle design. In addition to the limited coverage of the special cases of GTO and planetary mission performance, the Athena team can complete and present supplementary analysis. We will incorporate updates into the Athena Mission Planner's Guide as further design and flight performance data becomes available.

2.2.1 Performance Factors and Athena Specifications

The principal factors that affect the performance capability of the Athena include final orbit altitude and inclination, PLA selection, payload mass properties, launch site latitude, Range Safety considerations, and trajectory shaping.

All performance data presented reflects both the Athena Ic and Athena IIc configurations using the standard service Model 92 PLF, Model 66 PLA, and payload separation system. All payload mass performance data shown are assumed to be the separated payload mass. Any additional mission-specific cabling, components, or hardware items that remain with the LV must be accounted for in the separated mass. The separated payload mass data provided assumes a 3-sigma performance reserve based on previous mission designs and dispersion analyses and

accounts for Range Safety considerations including jettisoned-body impact and over-flight restrictions. Performance data using alternate PLA selections is available upon request.

2.2.2 Trajectory Design Optimization

After defining the spacecraft weight and orbit parameters, the Athena team performs mission-unique trajectory analysis. This analysis validates that the orbit parameters are achievable from the site selected, within the performance envelope of the specified Athena configuration. Section 7.0 details this analysis. All data incorporates conservative performance margins, reflecting the current vehicle design maturity. As design and flight performance data becomes available, we update prediction tools and margins.

2.2.3 Low Earth Orbits

Standard Athena Ic and Athena IIc performance capabilities for various inclinations and circular orbit altitudes from 200 to 2,000 km (108 to 1,080 nmi) at each launch site location are shown in Figure 2.2-1, Figure 2.2-2, Figure 2.2-3, and Figure 2.2-4. Payload mass capabilities for low-altitude, low-inclination missions from CCAFS—the typical launch site for inclinations of 28.5°, 38°, and 51.6°—are discontinuous because of stage impact restrictions. Flight from CCAFS to inclinations between 51.6° and 57° are available upon request. Performance data for Athena configurations from KLC includes inclinations of 70° and 90° and Sun-Synchronous orbits. Missions with inclination requirements between 65° and 70° are feasible from the existing KLC launch site and are available upon request.

Launching spacecraft from other sites is possible, and we supply site-specific data and performance upon request. Section 8.2 discusses the use of alternate launch sites.

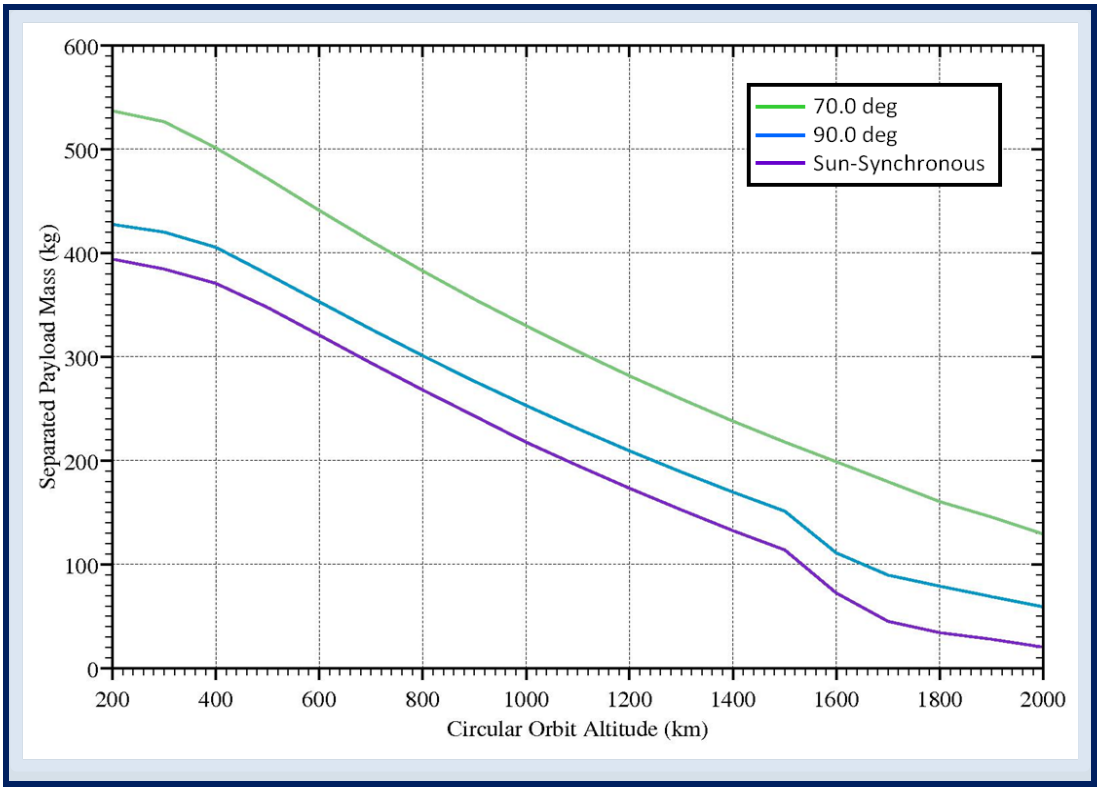


Figure 2.2-1. Maximum LEO Capability for Athena Ic LV-KLC

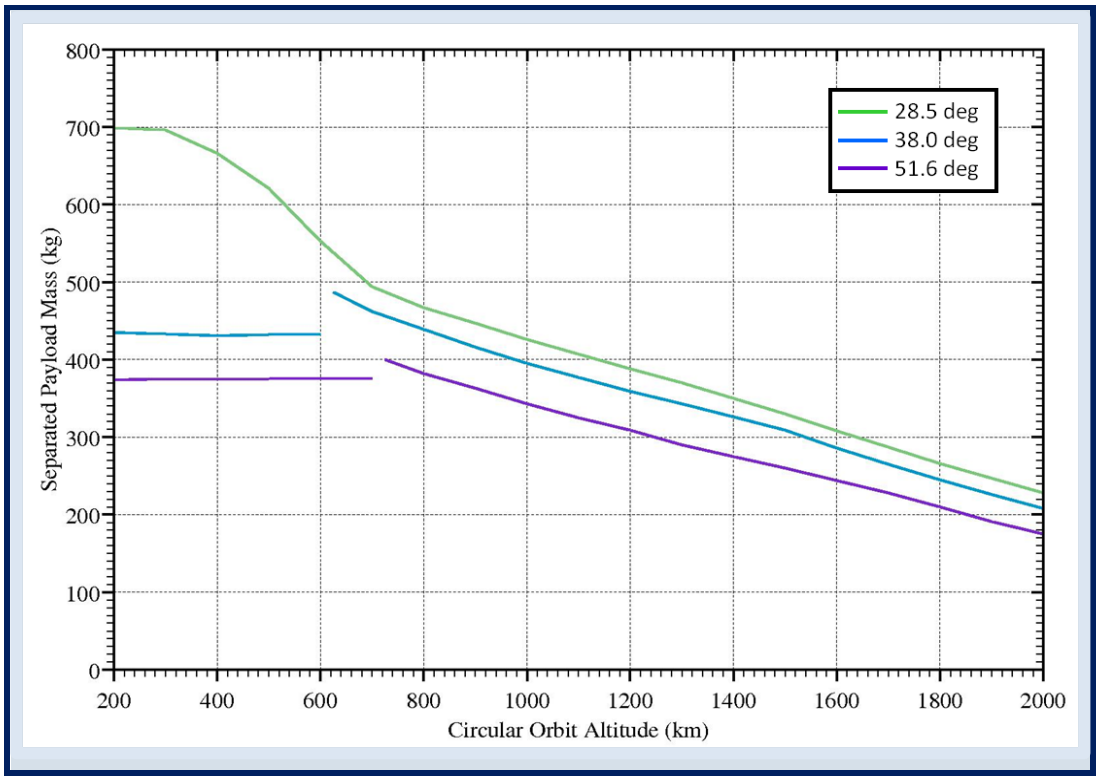


Figure 2.2-2. Maximum LEO Payload Capability for Athena Ic LV-CCAFS

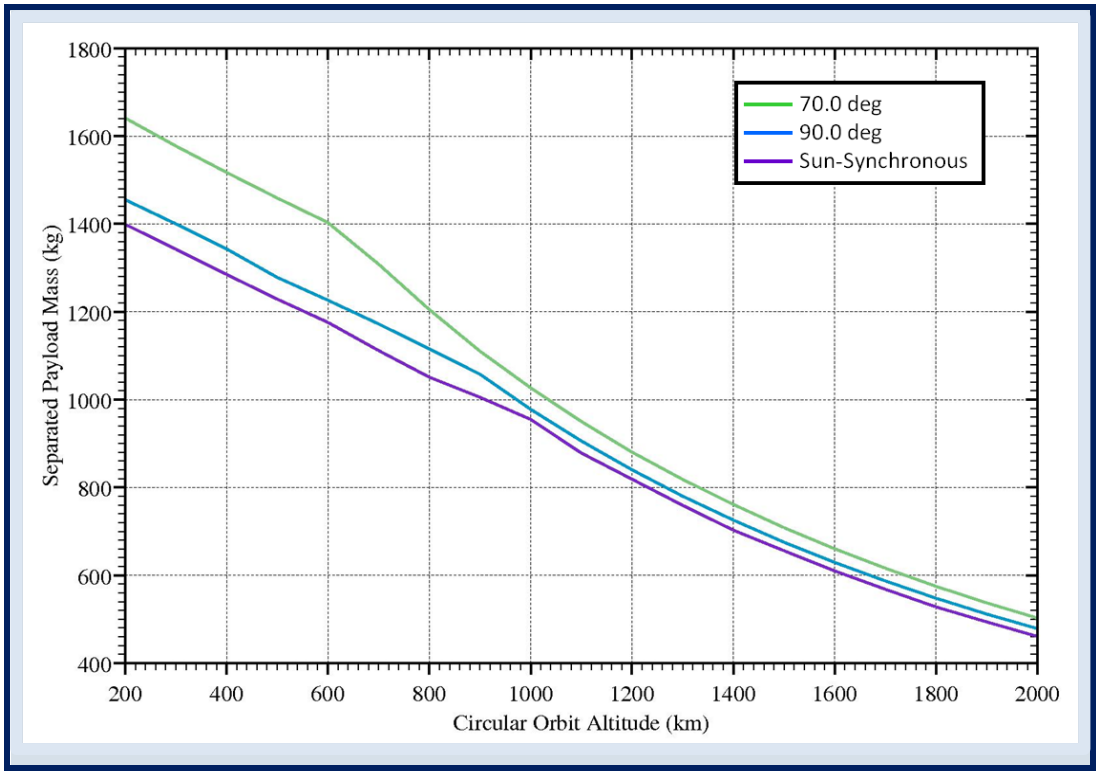


Figure 2.2-3. Maximum LEO Payload Capability for Athena IIc LV-KLC

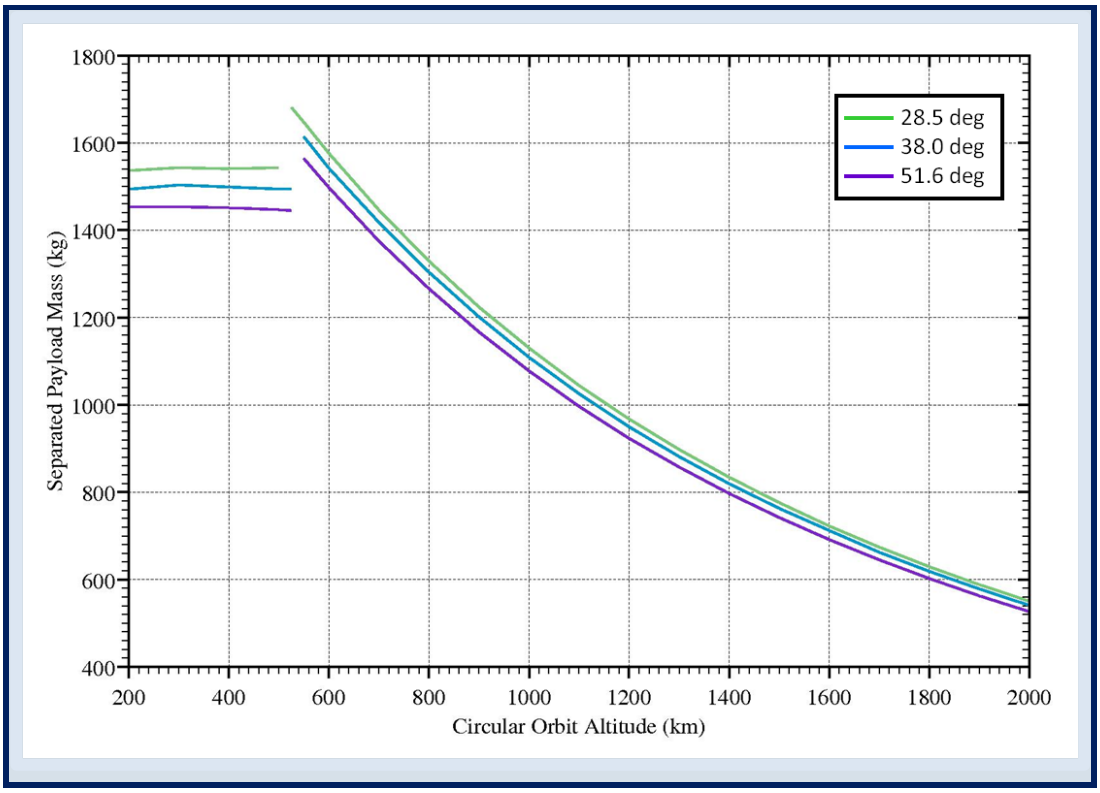


Figure 2.2-4. Maximum LEO Payload Capability for Athena IIc LV-CCAFS

2.2.4 High Energy Mission Performance

The Athena IIc LV has the capability to perform high elliptical, high-energy missions, including GTO. These missions involve the Athena IIc LV with the addition of a Star 37FM kick stage. The kick stage includes the solid rocket motor and stage components including structure, adapters, cables/avionics, destruct system, and collision avoidance system based on the Lunar Prospector (LP) Mission trans-lunar injection stage. High-energy missions are conducted from LC-46 at CCAFS. For elliptical missions, including GTO, the minimum perigee altitude is assumed to be 185 km (100 nmi). Lower-inclination elliptical orbits typically require an initial 185 km (100 nmi) circular parking orbit, inclined at 28.5°. The kick stage is used to place the spacecraft into the final orbit at the desired lower inclination. Missions to lower inclinations are spacecraft- and upper stage-dependant. Please contact the LM Athena team to assist in the development of an optimum orbit injection solution. Table 2.2-1 summarizes the performance capability for elliptical orbits, including GTO, for the Athena IIc LV at various inclinations. Table 2.2-2 and Figure 2.2-5 provide the payload mass capability for C_3 values from -10 to 50 km^2/s^2 (-3.86 to 19.31 mi^2/s^2) for an Athena IIc LV with the Star 37FM kick stage. Please contact the Athena team for specific planetary mission performance capability.

Table 2.2-1. Athena High Energy Performance

Apogee Altitude (km)	Separated Payload Mass (kg)					
	Inclination (deg)					
	28.5°	27.0°	24.0°	20.0°	15.0°	10.0°
10,000	450	435	401	340	242	143
80,000	469	451	416	359	252	148
50,000	534	514	474	408	288	173
35,788	605	591	538	463	315	191

Notes:
- Athena IIc LV with Star37FM kick stage is mission-unique service
- Kick stage includes Star37FM solid rocket and stage components based on LP mission
- Includes 3s performance reserve of 183 m/s (600 ft/s) for park orbit
- Assumes CCAFS LC-46 launch site
- Includes Range Safety restrictions for over-flight and jettisoned-body impacts

Table 2.2-2. High Energy Mission Payload Capability for Athena IIc

C_3 Value (km^2/s^2)	Launch Vehicle Configuration Athena IIc LV with Star 37FM Kick Stage
	Separated Payload Mass (kg)
-10	488
-5	429
0	374
5	317
10	269
15	226
20	188
25	154
30	124
35	97
40	73
45	51
50	31

Notes:
Athena IIc LV with Star 37FM kick stage is a mission-unique service
Separated payload mass capability:
1. Includes 3-sigma performance reserve of 183 m/s (600 ft/s) for Park Orbit
2. Assumes CCAFS LC-46 launch site
3. Includes Range Safety restrictions for over-flight, jettisoned-body impacts
4. Assumes maximum payload radial CG offset of 76 mm (3 in.) for OAM duty cycle

Kick stage includes Star 37FM SRM and stage components based on LP mission

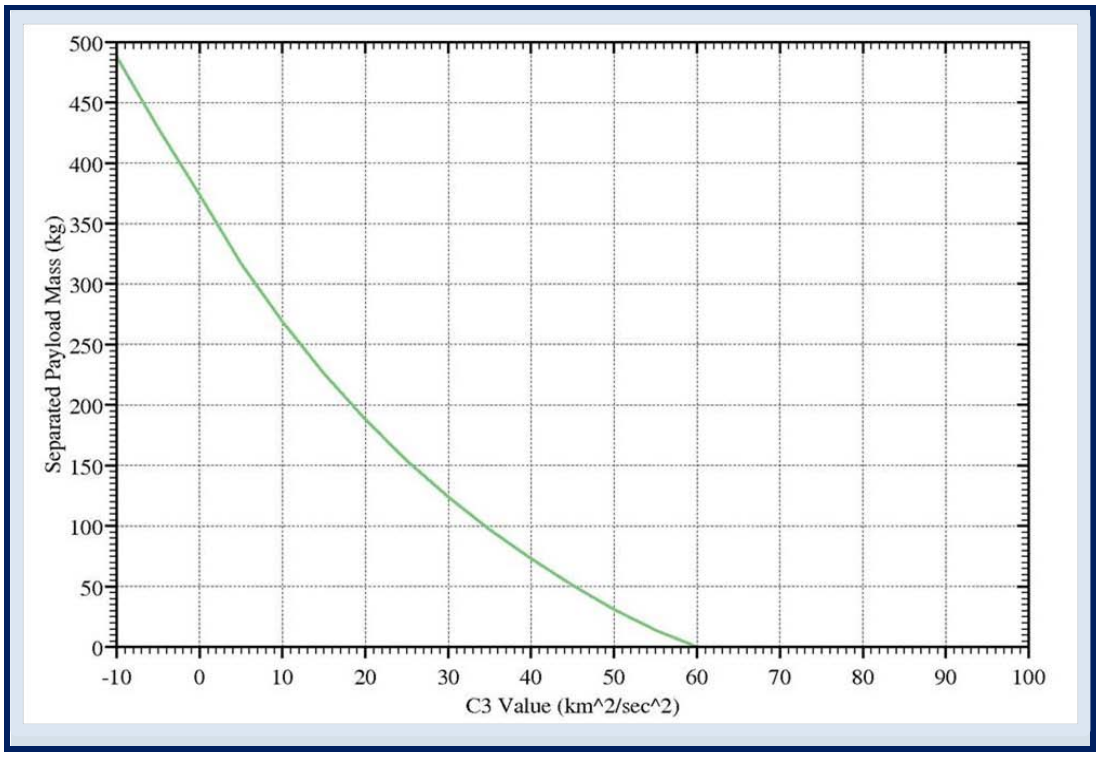


Figure 2.2-5. The Athena IIc High-Energy Mission Capability

2.3 ORBIT INJECTION ACCURACY

To ensure proper error tracking during flight, the avionics processor package continually updates the trajectory based on data from the Inertial Measurement Unit (IMU). Motor vectoring commands and coast periods adjustments drive the measured deviation from the updated trajectory to zero. During the burn of each motor, commands to the Thrust Vector Control System correct pitch, roll, and azimuth errors. The ACS enables a finer correction capability. The IMU accuracy and gyro drift rates limit the accuracy of the calculated orbit injection throughout the time of flight; determining the error for a specific orbit requires a calculation within the IMU of the cumulative effect of the various error sources. We can supply the errors applicable to a specific orbit upon request.

2.4 SEPARATION CONTROL

The separation approaches used on Athena are based on more than 35 years of spacecraft and payload separation system design implementation experience. Personnel have developed data to control separation sequences for single- and multiple-spacecraft injections. Section 7.0 describes the available services for conducting these analyses.

2.4.1 Attitude Rates and Stabilization

Bending modes, products of inertia, center of gravity offset, ACS thruster behavior, and separation force asymmetry affect spacecraft rates of rotation (tip-off rates) at separation. Because these factors are unique for most missions, we perform an analysis and simulation on a mission-specific basis. Taking these factors into account, spacecraft stabilization may require as much as 90 seconds for three-axis stabilized payloads to allow for correction, compensation, and oscillation damping. Spin-stabilized payloads may need more time, depending on their spin-up

rates. The OAM can rotate at a rate of approximately 3 rpm to assist in thermal control (barbecue mode) and pre-separation stabilization.

2.4.2 Attitude Orientation and Pointing Accuracy

Orientation and pointing accuracy before spacecraft separation is a function of the capabilities of the avionics and ACS. For three-axis stabilized payloads, assuming spacecraft mass property misalignments are negligible, the pointing accuracy that can be maintained is 1° or less. For spin-stabilized payloads, pointing errors can combine with tip-off effects, as well as spacecraft-to-OAM axis misalignment, to produce post-separation pointing and nutation errors. While spacecraft mass properties ultimately determine specific errors, the OAM can maintain separation conditions such that the spacecraft maximum pointing errors are typically less than 3° and maximum attitude rates are less than 1.05° per second.

2.4.3 Separation Velocity

Separation acceleration and velocity must consider any impulse sensitivity and extremity re-contact potential of the spacecraft. The mission-unique spring design and the minimum relative velocity between the spacecraft and the OAM determine separation acceleration. The ACS can accommodate vector considerations.

2.5 COLLISION AND CONTAMINATION AVOIDANCE MANEUVER (CCAM)

The obvious needs of avoiding re-contact between the separated bodies and avoiding exposure of sensitive spacecraft components to potential contaminants establish the CCAM requirement. Analysis of the mechanics of each separation event, as well as an assessment of any post-separation maneuvering of the separated bodies, determines re-contact potential. Designing the spacecraft to be resistant to the local environment's unavoidable contamination and determining the maneuvers that best avoid contamination minimize the detrimental effects on the spacecraft. Section 7.0 describes analytical services available to identify the CCAM requirements.

The ACS propellant load is sized for 3-sigma worst-case conditions so sufficient propellant remains, following the injection sequence, to allow for a simulation-validated CCAM. In most cases, following spacecraft deployment, the avionics system commands the ACS to carefully maneuver the OAM out of the spacecraft orbit. When the required clearance is achieved, the vehicle orients for a de-orbit assist maneuver and the thrusters fire until a very short life perigee is established. At that time, opposing thrusters are fired until the remaining propellant is depleted. This maneuver relieves residual pressure in the ACS tanks and assures de-orbit of the spent OAM.

3.0 SPACECRAFT INTERFACES

3.1 SPACECRAFT-TO-LAUNCH-VEHICLE INTERFACES

3.1.1 Mechanical Interfaces—Payload Fairing

The Payload Fairing (PLF) is a thermal and acoustic enclosure that protects the payload during prelaunch operations through atmospheric ascent and PLF jettison. Cork insulates portions of the external surfaces of the PLF, limiting temperatures to acceptable values. Non-contaminating thermal-control coatings on internal surfaces reduce incident heat fluxes to the spacecraft. Low out-gassing parts and materials inside the PLF reduce spacecraft contamination.

The Model 92 PLF is a 92-in. diameter, contoured shell that attaches to the Payload Adapter (PLA) and to the 233.7-cm (92-in.) Orbit Adjust Module (OAM) at a common field joint. Lift points on the PLF allow the encapsulated assembly, which includes the PLF, the PLA, and the payload, to be mated to the OAM. The Model 92 PLF provides the Athena LV with a substantial payload volume for this class of vehicle—easing packaging restrictions on the spacecraft designer—which reduces cost and risk. Figure 3.1-1 shows the large Model 92 PLF during the encapsulation process.

Figure 3.1-1. The Model 92 PLF

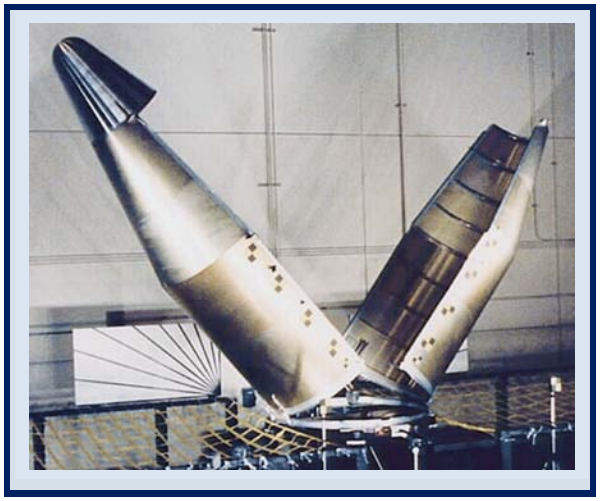


Figure 3.1-2. Model 92 PLF Separation Test

The Model 92 PLF consists of an aluminum-lithium, ring-stiffened, monocoque structure and ordnance components. The conical section tapers at 15° to reduce aerodynamic drag, and an external cork lining thermal protection maintains payload temperature within specified limits. The PLF separates into two halves when jettisoned. Figure 3.1-2 shows the Model 92 PLF successfully completing a separation test.

Zip Tube®, an LM-patented clean pyrotechnic separation system, severs the PLF along a circumferential joint at the base and along two longitudinal joints. Thruster springs, located along the base joint, and helper springs, located along the upper half of the longitudinal joint,

supply the energy required to separate the PLF from the LV. Each PLF half rotates on two hinges located at its base; the hinges release the PLF halves when they have rotated past 45°. This design reduces PLF radial deflection and increases the dynamic envelope.

Payload Fairing Usable Volume—The PLF's dynamic envelope accounts for structural tolerances as well as static and dynamic deflections. The aft portion of the envelope around the PLA varies for each user, depending on which PLA they select. Figure 3.1-3 shows the PLF's dynamic envelope with each of the three standard PLAs: Models 38, 47, and 66, respectively. A conditioned-air coupling, located on the PLF barrel section, serves as the inlet for prelaunch encapsulated assembly climate-controlled air (temperature, humidity, and cleanliness). Air exits the PLF envelope through one-way air valve assemblies, located on the PLA, and enters the OAM during prelaunch operations. During ascent through PLF jettison, the conditioned air inlet is sealed and air in the PLF envelope vents into the OAM through the one-way air valve assemblies.

Coupled loads and clearance analyses for all flight events verify the PLF dynamic envelope for each mission. Slight protrusions into the standard envelope may be accommodated on a case-by-case basis; such requests must be accompanied by documentation that meets stringent drawing and specification standards. The Athena team subjects all requests to analyses that may include worst-case payload attachment tolerances, spring and retractor tolerances, wind gusts, bending, and asymmetrical loads effects, effects of flexing of the separating bodies, and thermal distortion assessments.

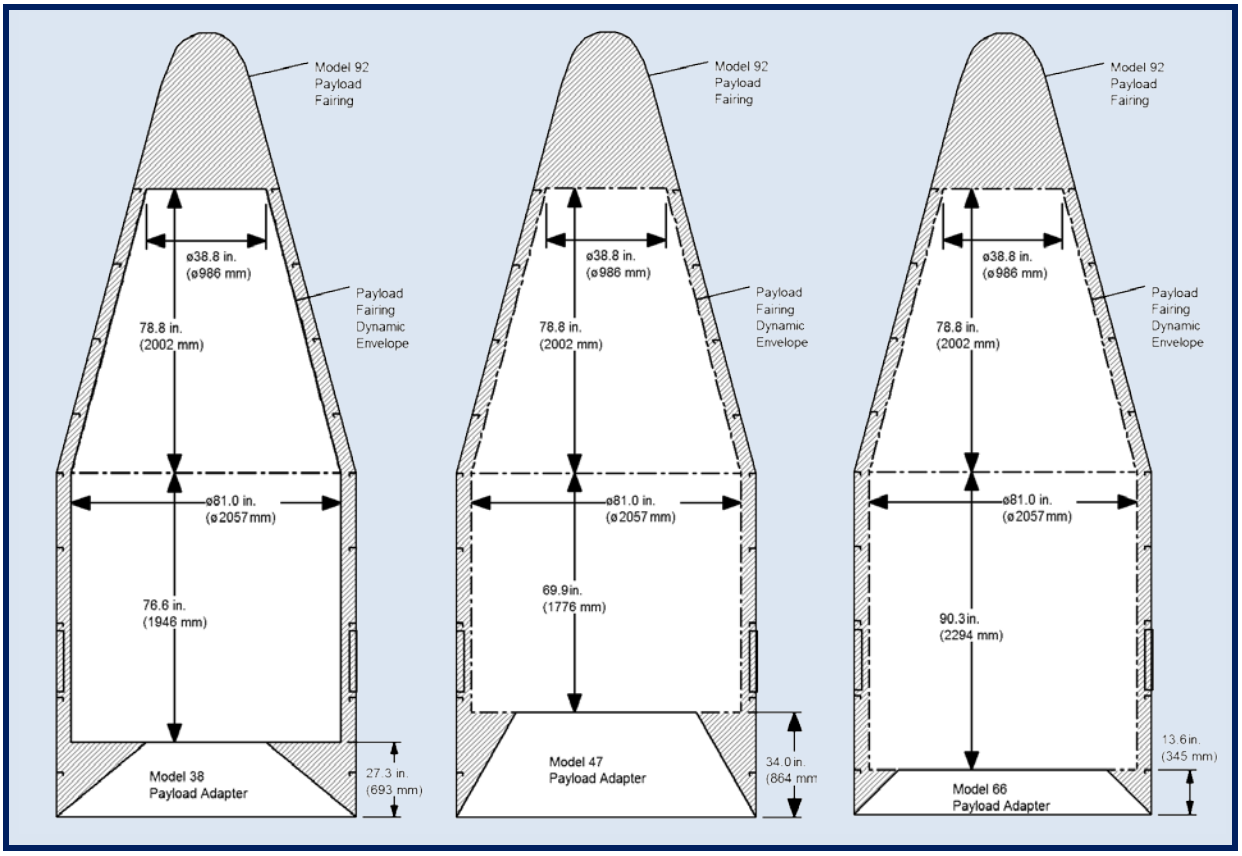


Figure 3.1-3. The PLF Dynamic Envelope with Models 38, 47, and 66 PLAs

Payload Accessibility—The Model 92 PLF design has two payload access doors, and our standard launch service includes locating the 45.7-cm (18-in.) high by 61.0-cm (24-in.) wide doors to ease the customer access to the spacecraft during prelaunch operations. These doors can be located axially between ring stiffeners and radially between the longitudinal separation joints, excluding the conditioned air coupling, as shown in Figure 3.1-4.

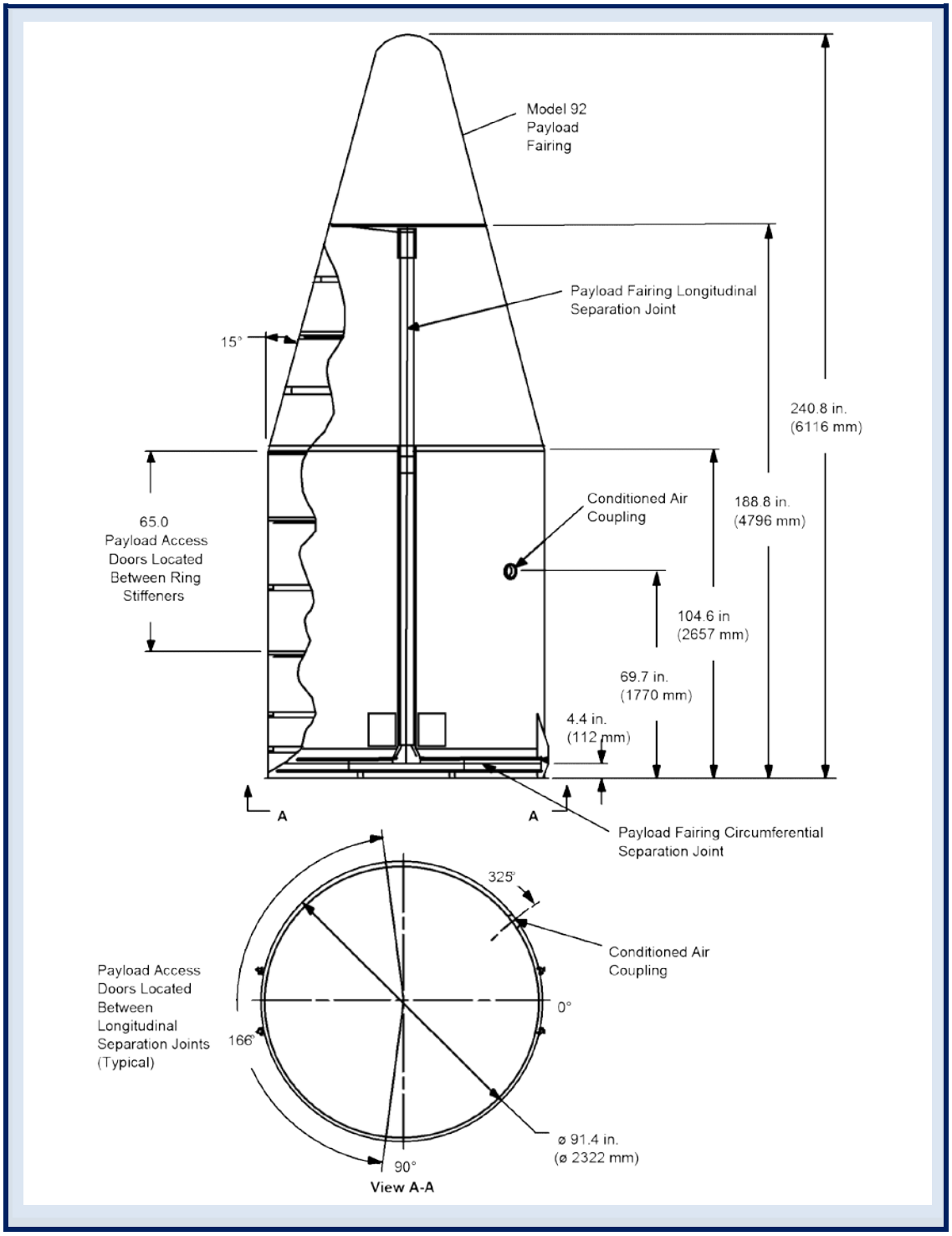


Figure 3.1-4. Model 92 PLF Access Door Placements

Payload Fairing Enhancements—Enhancements to the Model 92 PLF include additional nonstandard payload access doors and acoustic blankets. The location and size of additional access doors must be coordinated with LM. The Athena vehicle offers the transmission of payload telemetry data through the LV telemetry system. LM also has the capability to supply a larger PLF. Section 8.1 details our Model 120 PLF.

3.1.2 Mechanical Interfaces—Payload Adapters and Separation Systems

The PLA is the mechanical interface between the payload, separation system, and the LV. LM offers three standard PLAs, each design maintaining the proper clearances and unobstructed separation.

Payload Adapters—The three standard PLAs offered for the Athena family are listed in Table 3.1-1 and shown in Figure 3.1-5, Figure 3.1-6, and Figure 3.1-7. Models 38 and 66 are constructed from high-strength, low-weight aluminum-lithium, while the Model 47 PLA is composed of aluminum. Each PLA attaches to the aft end of the PLF and reduces the 233.7-cm (92-in.) diameter of the OAM to a smaller diameter bolt circle. A contamination shield seals the encapsulated assembly and minimizes contamination of the controlled environment within the PLF after leaving the clean room. One door in the contamination shield allows access to service areas inside the PLA forward of the contamination shield. The additional height of the Model 47 PLA can accommodate a typical kick motor nozzle assembly.

Table 3.1-1. Standard PLAs for Athena Missions

Payload Adapters		
Model 38		
	Diameter (bolt circle, interface)	38.81 in. (986 mm)
	# Bolt Circle Holes	60
	Bolts	0.203 in. (5.16 mm)
	Height above OAM	27.33 in (694 mm)
	Contamination Shield Door	19 in. (483 mm)
	Maximum Radial CG Offset	2 in. (51 mm)
	Maximum Axial CG Offset	44 in. (1,118 mm)
Model 47		
	Diameter (bolt circle, interface)	47.835 in. (1,215 mm)
	# Bolt Circle Holes	
	Bolts	
	Height above OAM	34.00 in. (864 mm)
	Contamination Shield Door	19 in. (483 mm)
	Maximum Radial CG Offset	
	Maximum Axial CG Offset	
Model 66		
	Diameter (bolt circle, interface)	66.00 in. (1,676 mm)
	# Bolt Circle Holes	120
	Bolts	0.266 in. (6.76 mm)
	Height above OAM	13.63 in. (346 mm)
	Contamination Shield Door	19 in. (483 mm)
	Maximum Radial CG Offset	3 in. (76.2 mm)
	Maximum Axial CG Offset	

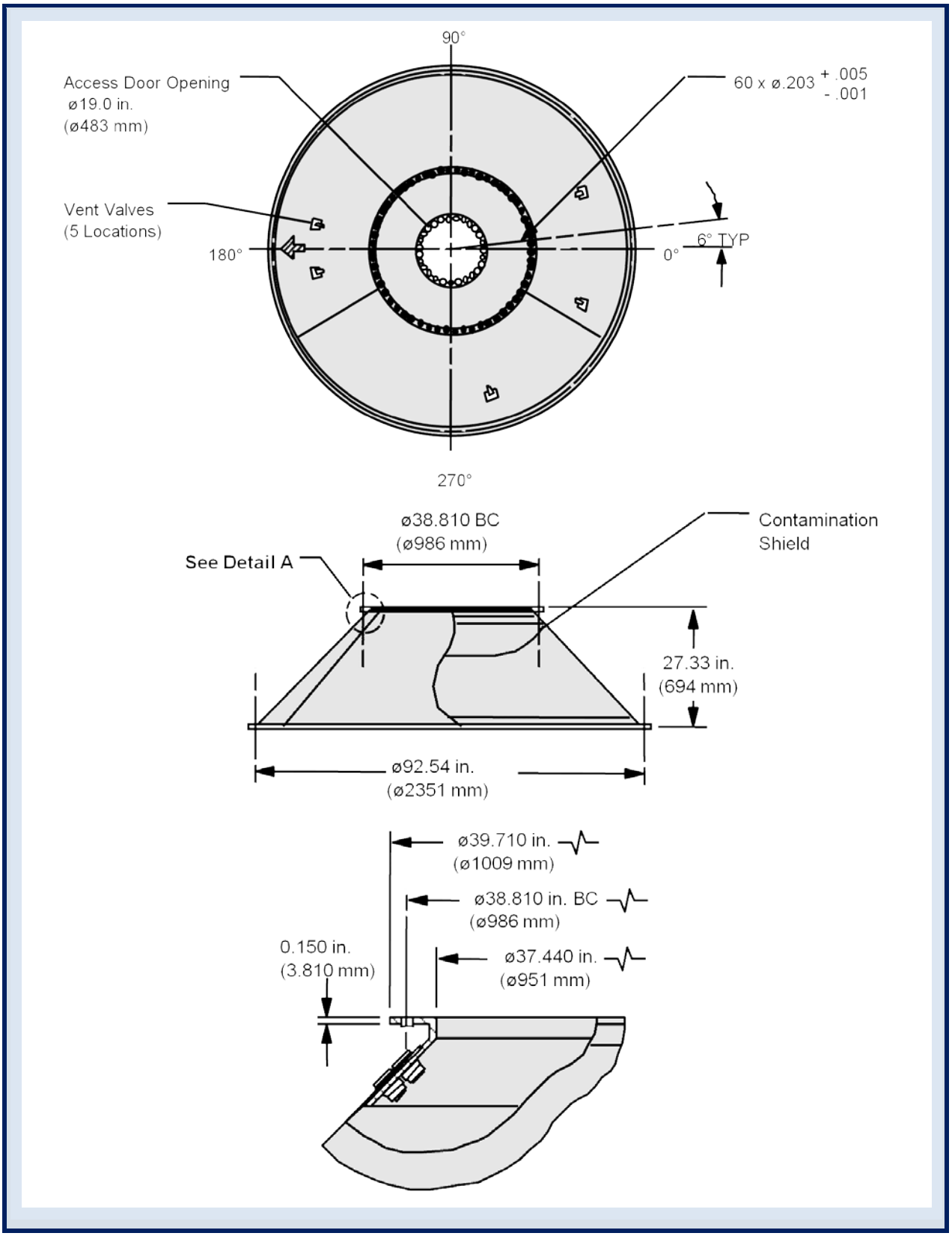


Figure 3.1-5. Model 38 Payload Adapter

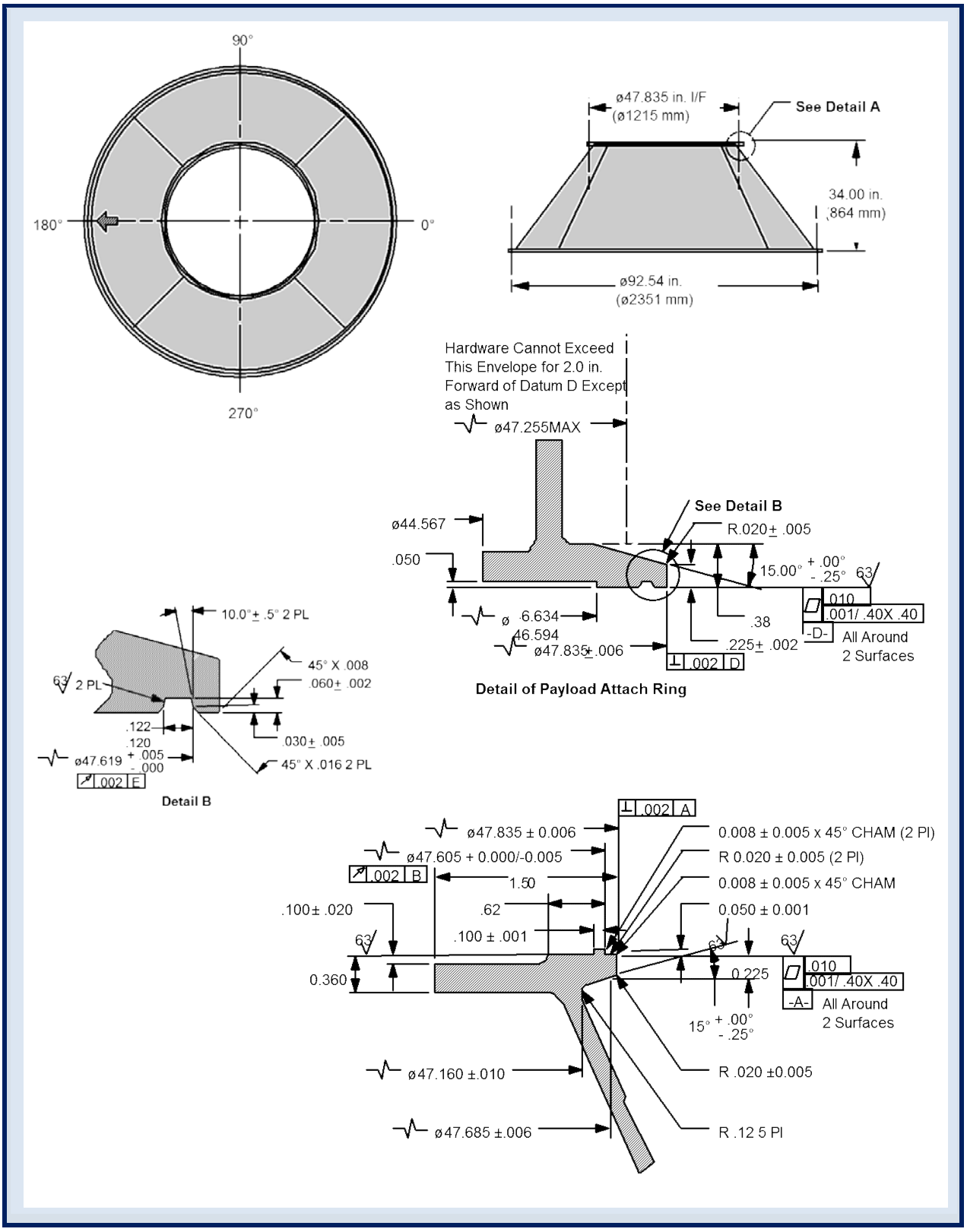


Figure 3.1-6. Model 47 Payload Adapter

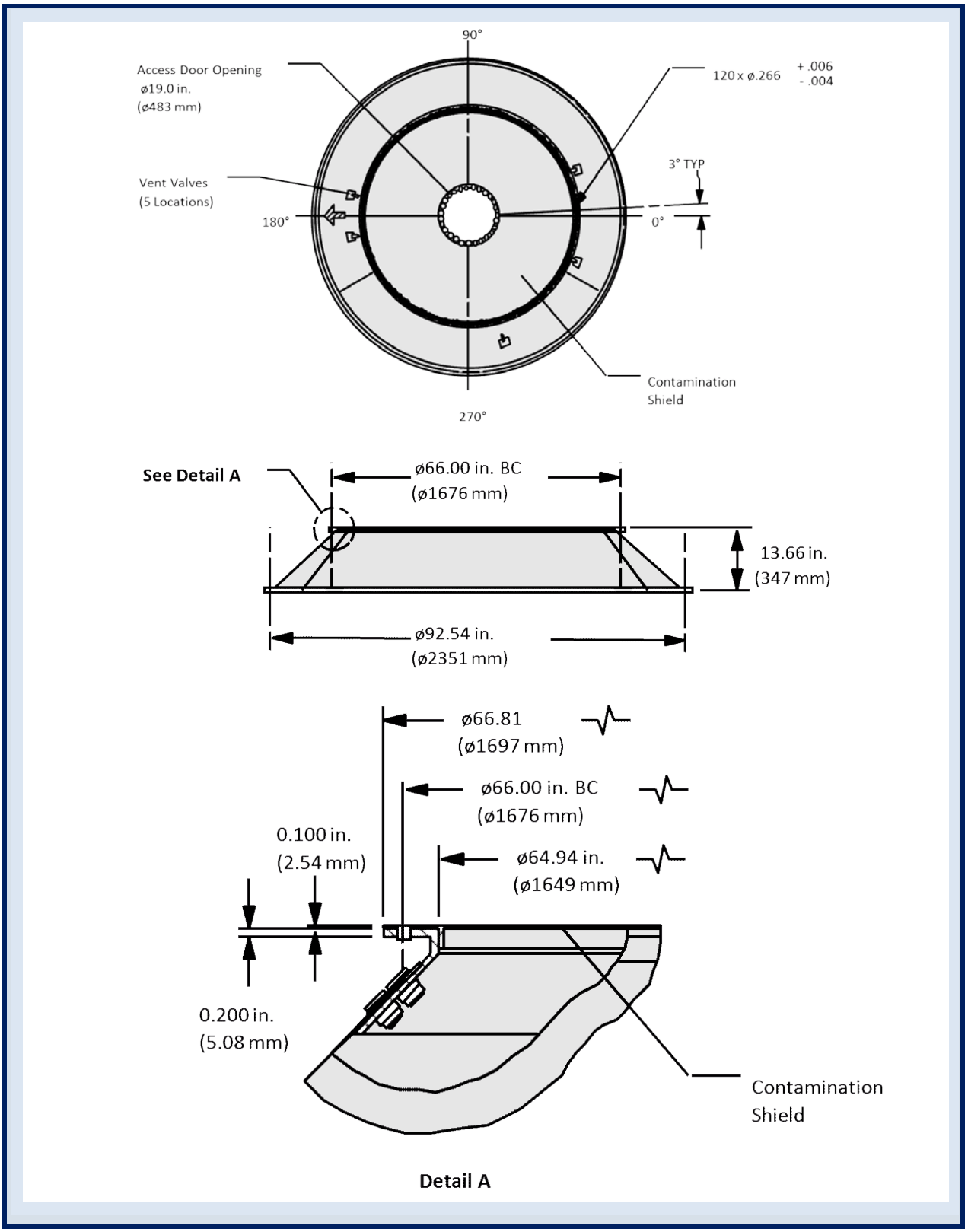


Figure 3.1-7. Model 66 Payload Adapter

Payload-Unique Adapters—
The Athena team can design additional PLAs to provide users with a variety of mounting options, including different diameters and multiple payload configurations to fully exploit the LV's capabilities.

Payload Separation Systems—LM offers a flight-proven, industry-standard clamp band separation system. The RUAG Payload Adapter System (PAS) consists of an adapter assembly, 1194VS clamp band set, separation spring set, and harness. The adapter assembly includes the adapter structure, brackets and supports for umbilical connector installation, various electrical connectors, the umbilical harness, and the pyrotechnical harness. The clamp band structure, clamp band retention hardware, and catcher comprise the clamp band set. The spring set uses four springs to impart the necessary separation energy to the spacecraft. The separation springs impart a relative separation velocity and tip-off rates, and they can be tuned to meet specific spacecraft requirements.

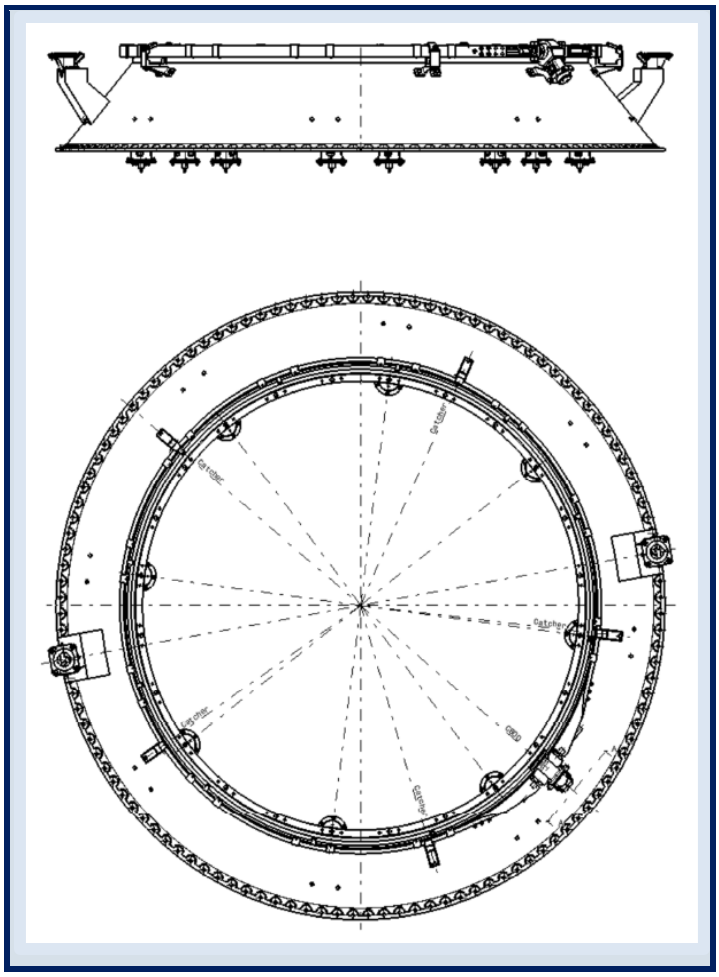


Figure 3.1-8. The RUAG Payload Adapter System (PAS)

Figure 3.1-8 and Figure 3.1-9 show the Athena standard PAS and the clamp band separation interface, respectively. The bolt pattern for the upper interface ring, which attaches to the spacecraft, is identical to the bolt pattern of the corresponding PLA. Continuity loops, installed in the electrical separation connectors, detect positive spacecraft separation, and the ground station receives telemetry of this data. This system provides near real-time, positive confirmation of the spacecraft separation event.

Spacecraft customers can choose to use either an Athena standard separation system or provide their own separation system, pending coordination with LM during the mission integration process.

Payload Adapter and Separation System Structural Capabilities—If the customer requirements exceed the structural capabilities of each Athena standard PLA and separation system, LM can strengthen the PLAs or separation systems to meet mission-specific needs.

Spacecraft mass and Center of Gravity capabilities should be used only as a guideline in preliminary design. They use generic spacecraft interface ring geometry and quasi-static load factors. Actual spacecraft design allowables may vary depending on interface ring stiffness and results of spacecraft mission-peculiar coupled loads analyses. Please contact LM for further discussion regarding spacecraft designs that exceed these generic allowables.

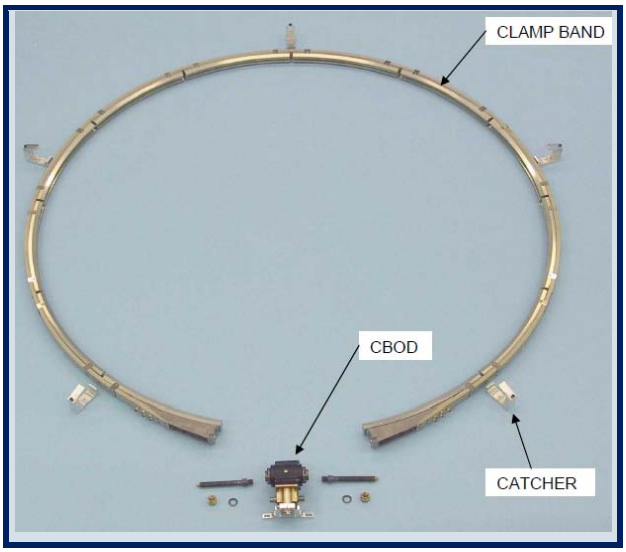


Figure 3.1-9. The RUAG Clamp Band Separation Interface

Electrical Interfaces—LM supplies the Athena customer with a flexible electrical interface structure. Figure 3.1-10 shows the Athena standard electrical interfaces between the spacecraft and the LV. LM also provides mission-unique cables that connect the spacecraft to the LV. The data link between the spacecraft and the LV umbilical facilitates prelaunch spacecraft tests; checkout, command, and monitoring; and spacecraft health and status. The data link between the spacecraft and the interlocks package enables monitoring of prelaunch and in-flight spacecraft discrete commands and monitors, and provides separation indication. The link between the spacecraft and the telemetry system also transfers data for prelaunch and in-flight spacecraft health and status (analog-originated data).

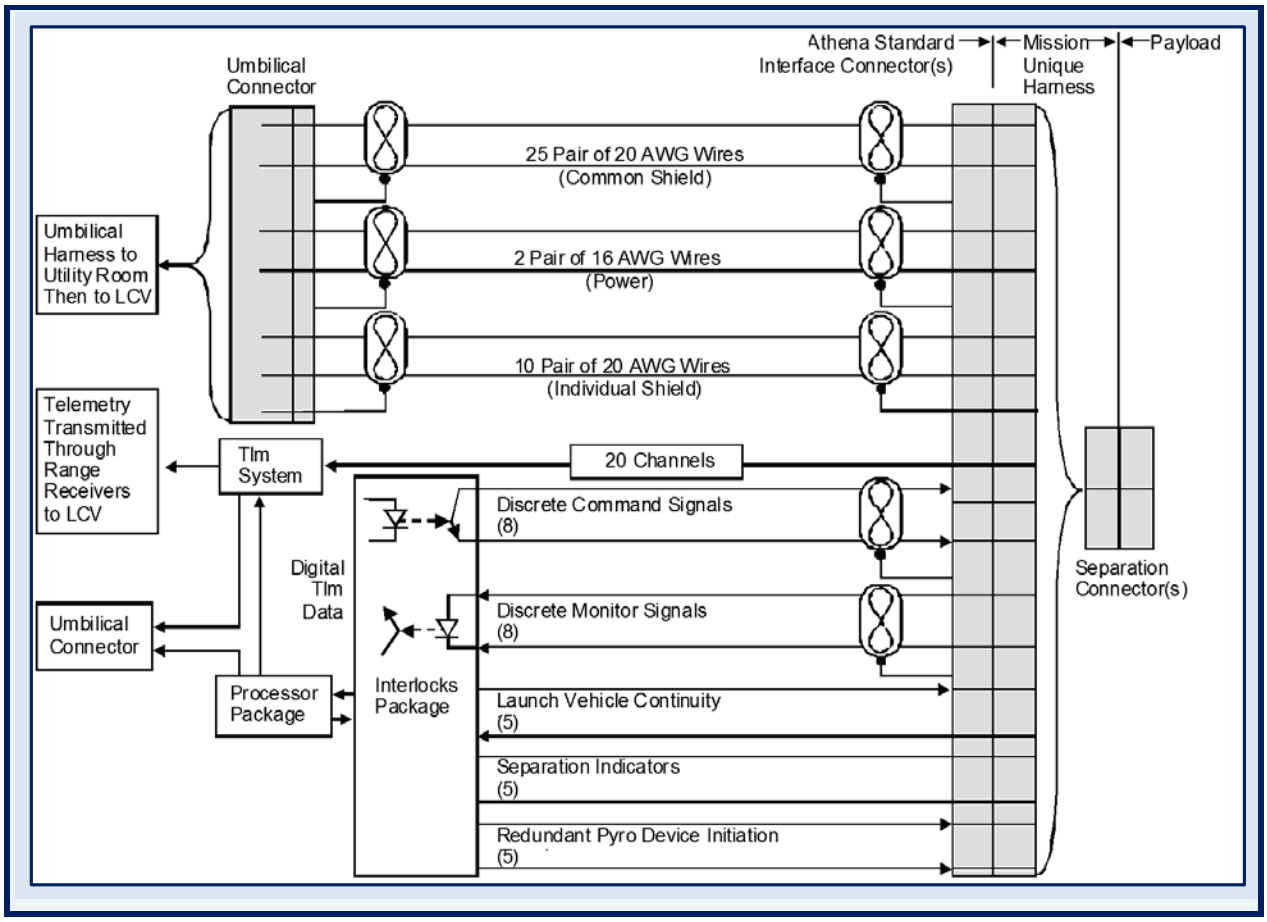


Figure 3.1-10. Athena Standard Electrical Interfaces

Umbilical Interfaces—The LV umbilical connector, a liftoff disconnect, is released from the ground umbilical at ignition by a lanyard pull mechanism during liftoff. Before ignition, the single hardline conduit is the electrical interface between the spacecraft and the Launch Vehicle Control Van (LVCV). Descriptions of the umbilical-to-LVCV landline configurations appear in Section 3.2. Payload-related wiring is routed in three cables on the payload side of the umbilical; one cable carries payload-related wiring to the interlocks package, another to the telemetry unit, and one cable is routed directly to the payload separation connectors.

For prelaunch power and battery charging, there are two pairs of 16-AWG wires that connect the spacecraft to the spacecraft Electrical Ground Support Equipment (EGSE), located in the utility room. Using both pairs of 16-AWG wires enables minimal power loss in supplying external power to support prelaunch checkout, battery maintenance and charging, or other high current load needs. These wires meet a 2-Ω maximum resistance specification.

For prelaunch command and telemetry, 25 twisted pairs of 20-AWG wire and 10 shielded twisted pairs of 20-AWG wire are the data link between the spacecraft and the spacecraft EGSE. These wires meet a 6-Ω maximum resistance specification.

Command and Control Interfaces—The Athena interlocks package affords the capability to issue in-flight commands to the payload and monitor signals generated in the spacecraft. The spacecraft designer can exploit this capability by arranging to program time- or event-related commands for the spacecraft and by conditioning spacecraft signals to feed time- or event-

related information into the interlocks over the span of the spacecraft's flight into orbit, within the limits listed here. All interlocks package interfaces are monitored at 4-ms intervals, and the status is available from the pre- and post-launch vehicle telemetry signals. Interlock package capabilities include:

1. Eight discrete command interfaces with optically-coupled isolators, serially controlled at 12-ms intervals and programmable for a 2- to 510-ms duration, with a maximum current of 10 mA at a voltage of 24 to 34 VDC
2. Eight discrete monitor interfaces with optically isolated circuits polled at 4-ms intervals
3. Five continuity loops to monitor binary events such as on-off switches onboard the spacecraft
4. Breakwire loops to run through up to five separation connectors to give nearly real-time indication of spacecraft separation. Each loop provides a positive and return. The electrical bonding resistance between the spacecraft structure and the Athena equipment section is less than 2.5 mΩ.

Telemetry Interfaces—Twenty telemetry channels are available for spacecraft use through a remote encoder. Sample rates are programmable, with the LV capable of supplying a maximum of 20 channels of spacecraft data, and a maximum 2,048 samples/s data rate for any one channel, up to a total maximum of 3,076 samples/s for the telemetry system. The S-band multiplexed telemetry capability provides both analog and digital spacecraft signal transmission. Telemetry bandwidth allocations are established on a mission-by-mission basis. The spacecraft designer can arrange to use this capability within the sampling and bandwidth constraints specified.

Spacecraft Separation Signals—The Athena LV is capable of providing up to five pairs of Electro-Explosive Device (EED) initiation signals for spacecraft events. Each signal has a duration of 2 to 510 ms and a maximum current of 5 to 10 A, at a voltage of 24 to 34 VDC, for one or a pair of 1-Ω EED bridgewires connected in parallel.

Spacecraft Separation Connectors—Each of the standard separation systems LM contributes contains two separation connectors; the customer can choose from the six standard connectors available, shown in Table 3.1-2. Selected for their high reliability, these connectors separate cleanly at the separation plane. The customer may specify alternative connectors; however, this requires stringent qualification. The spacecraft contractor may elect to supply any such qualified separation connector for incorporation into the LV.

Spacecraft Destruct Option—The Flight Termination System (FTS) can supply a Flight Termination Signal to the spacecraft, if required.

Table 3.1-2. Athena Standard Electrical Connectors

Part Number	Insert Arrangement	Type of Contact
GM 104615-0	25-4, 8 each AWG-16, 48 each AWG-20	Pins
GM 104614-1	25-35, 128 each AWG-22D	Pins
GM 104615-2	25-61, 61 each AWG-20	Pins
GM 104615-5	25-62, 61 each AWG-20	Sockets
GM 105615-6	25-4, 8 each AWG-16, 48 each AWG-20	Sockets
GM 104615-1	25-35, 128 each AWG-22D	Sockets

3.2 SPACECRAFT-TO-GROUND INTERFACES

3.2.1 Ground Support Equipment Interfaces

LM contributes all Mechanical and Electrical Ground Support Equipment (GSE) required to support LV processing and launch. The spacecraft contractor is responsible for providing all GSE needed to support spacecraft processing and integration.

3.2.2 Utility Room Interfaces

The utility room houses the interface between the Athena, the LVCV, and the Launch Operations Control Center (LOCC) at the Kodiak Launch Complex (KLC), or to Hangar AE and the Range Operations Control Center (ROCC) at Cape Canaveral Air Force Station (CCAFS). The utility room is located near the launch mount and houses the Signal Conditioning Set (SCS) and the fiber-optic electronics to interface with the LVCV. The SCS is a two-bay rack containing equipment designed to condition the signals received from the Athena via the umbilical for transmission to the LVCV and display on the consoles. The SCS contains a computer that performs preprogrammed sequences of operations when the van console operator gives the necessary instructions. This implements a "distributed processing" system that allows some autonomous control for emergency shutdown of launch or checkout operations in the event of failure of communications with the LVCV. The SCS also houses the electronics for the payload interfaces to the LVCV.

Space and facility power are provided in the utility room for Customer-Furnished Equipment (CFE), which may interface with the payload using the umbilical hardwire links. The location of the utility room is convenient for other attended activities up to T-4 hours. Spacecraft batteries may be charged remotely via hardwire interfaces from the utility room rather than having to use drag-on cables connected through an access panel. Utility room payload CFE can be locally controlled during nonhazardous prelaunch operations. Remote control from the LVCV payload station is also possible via the SCS using the fiber optic connectivity. The utility room has the following launch site-dependent physical characteristics, as presented in Table 3.2-1.

Table 3.2-1. KLC and CCAFS Launch Site Utility Rooms

Launch Site Utility Rooms	
KLC	
Mechanical	3.3 m^2 (35 ft^2) usable floor space 1.5×2.0 m^2 (5×6.5 ft^2) doors
Electrical	Three 120-V, 20-A, one-phase circuits Two 208-V, 30-A, three-phase circuits (backed by 30-min UPS)
CCAFS	
Mechanical	3.3 m^2 (35 ft^2) usable floor space 0.9×2.1 m^2 (3×7 ft^2) doors
Electrical	TBD

3.2.3 Launch Vehicle Control Van Interfaces

The mobile LVCV is the control center for launch operations, including prelaunch testing and launch countdown. Figure 3.2-1 shows the layout of the LVCV. The LVCV has four operating stations: Payload, Telemetry, Launch Operations, and Range Safety. Each operating station contains an equipment rack, one or more consoles, and monitors. For prelaunch test and

checkout and launch, the LVCV is positioned near Building 596 at KLC and near Hangar K at CCAFS. A fiber optic network links the LVCV to the utility room, and to the LOCC at KLC or to Hangar AE and the ROCC at CCAFS.

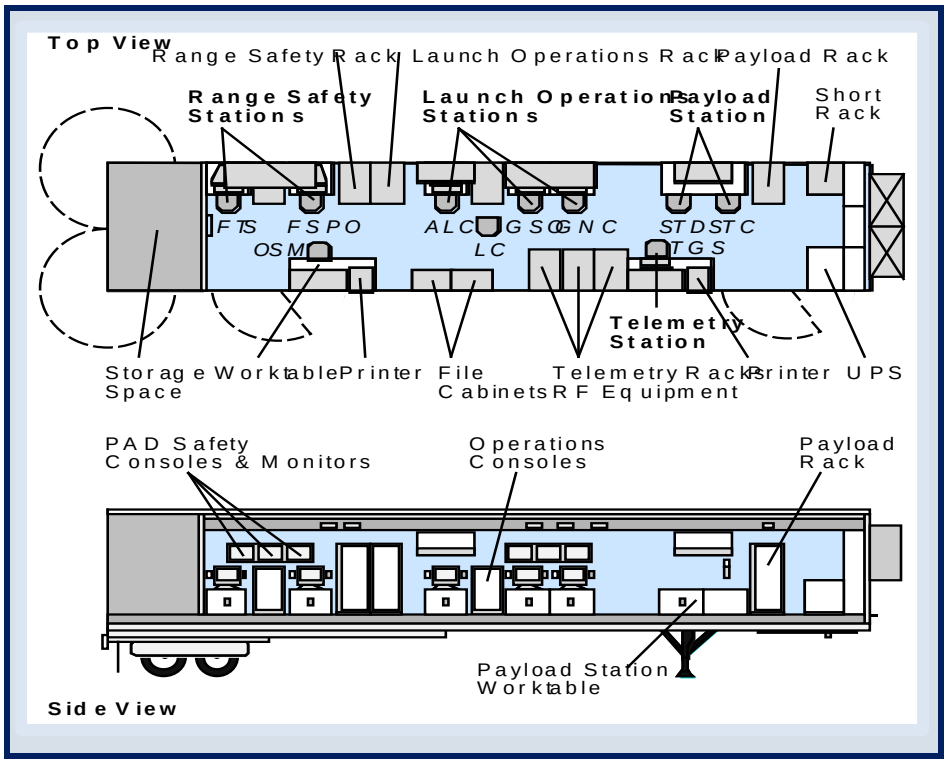


Figure 3.2-1. The Athena LVCV

Payload Station—The Payload Technical Director and the Payload Technical Advisor, who man the Payload Station, monitor and control the spacecraft. The Payload Station has space for one standard-size equipment rack for customer-supplied Electronic GSE.

The Payload Station work area is equipped with power, shelving, and a desktop area for customer use. It is located next to the signal entry panel and is close to one of the two equipment-loading doors. The payload customer brings in rack-mounted hardware that can be loaded into a 1,550-mm (61-in.) high by 480-mm (19-in.) wide industry-standard Electrical Industry Association rack equipped with its own uninterruptible 120-VAC, 60-Hz, 15-A power source. This rack is removable if the customer prefers to put other equipment in this space, in which case the customer can mount equipment to the payload rack slide mounting plate. The LVCV also contains a 760-mm (30-in.) deep by 2,030-mm (80-in.) long worktable that accommodates two seated payload operators.

All landline links to the pad use the fiber optic link between the CFE in the utility room and that in the LVCV operations station. The CFE interfaces in the LVCV are accessible through the fiber optics equipment and Ethernet bridge, located in the operations station console. CFE and discrete payload fiber optic channels out of these fiber optics modules are available at BNC-type connectors, to be linked using BNC-type coaxial cables. Payload-related links are then cabled to the Payload Station, as appropriate.

Telemetry Station—The Telemetry System Observer (TSO) and Guidance System Observer man the Telemetry Stations, receiving and archiving both digital and analog raw telemetry Pulse Code-Modulated data from the LV and spacecraft. This system monitors prelaunch data to determine a go/no-go status and reports that status to the launch operations stations for display and recording. The TSO can play back the archived data and distribute the data to other consoles for analysis or simulation. The architecture of the Telemetry Station controller allows access to telemetry data not routinely displayed on the van consoles. This decommunication system can be used to monitor the data, determine the go/no-go status, and report the status to the operations console for display and recording.

Launch Operations Station—The Athena launch conductor controls the testing and launching of the Athena vehicle from the Operations Station two-person console. The computer at this console controls the sequencing of the vehicle and verifies proper vehicle response to commands. The launch conductor is the single point command authority for all issues regarding the launch vehicle and supporting equipment.

Range Safety Station—The Flight Safety Officer (FSO), the FTS Observer, and the Complex Safety Officer (CSO), who man the pad safety station, provide vehicle and launch equipment status during checkout and launch operations. The FSO has the means to manually inhibit a launch. During flight, the status of the FTS is continuously displayed; before flight, the console can also display any safety-critical information that the checkout equipment processes

Pad safety personnel use area surveillance monitors in the LVCV to observe the pad area during hazardous operations and launch. Several remote-controlled color video cameras are strategically located at the pad to provide a view of the launch area. Each camera can be independently controlled from the pad safety console for pan, tilt, and zoom.

LVCV Equipment—Other LVCV-supplied equipment of potential use and interest to payload station personnel is listed in Table 3.2-2.

Table 3.2-2. Launch Vehicle Control Van Equipment

Storage Areas	Electrical Equipment	Additional Amenities
Hardware cabinets	Two 4-Ton Air Conditioning Units	Public address system
File cabinets	Two 15-kW Heating Units/Humidity Control	Area warning system
Drawers	Electrical System UPS – 120/208 VAC, 60 Hz, 100A	Two smoke alarms
Bookcase	Antenna – 76.2 cm (3 in.) diameter, 6.4 m (21 ft) long	Two side access doors
Two under-van compartments	Range-synchronized IRIG-B time base generator	Status and alert panels
	Range interface to LVCV countdown clock	Air terminal
	Surge protectors for hardwire signals	Standard semitrailer spring and shock absorber suspension at rear axle with solid-post jacks supporting trailer tractor end (under Payload Station)

3.3 RANGE AND SYSTEM SAFETY INTERFACES

3.3.1 Requirements

To launch from either CCAFS or KLC, LV design, spacecraft design, and ground operations must be executed in accordance with applicable launch site Range Safety requirements and United States Air Force (USAF) regulations concerning explosives safety and occupational safety and health. In addition, when using spacecraft processing facilities operated by Astrotech International Corporation, NASA, or USAF, compliance with their respective facility safety policies is also required. The Range, LM, and the spacecraft contractor agree upon other compliance documents at the outset of the mission integration process.

3.3.2 Applicability

At the start of mission integration (or soon after), the relevant Range Safety documents are tailored to the particular spacecraft. Tailoring defines the safety criteria specifically interpreted for application to the spacecraft. A major component of the launch site Range Safety regulations concerns spacecraft design and operational requirements that must be met to obtain Range Safety approval. For all spacecraft and missions, safety submittals specifically review compliance with the applicable range safety regulations.

LM System Safety engineers evaluate, analyze, and provide guidance for spacecraft design to support Range Safety approval. LM develops a specific set of design and operational requirements that define spacecraft-peculiar Range Safety and processing requirements. LM acts as the spacecraft agent for all interface activities with the launch site Range Safety office as part of our standard launch service.

3.3.3 Safety

The typical process the Athena program uses to safety-certify spacecraft at the Range is illustrated in Figure 3.3-1. The figure lists the documents or tasks required of the spacecraft contractor. For all mission integration efforts, LM provides a qualified System Safety engineer to help the spacecraft contractor through the Range approval process. The Athena program submits all requests for Range approval, regardless of whether they apply to spacecraft or LV data. Approval to fly on the Range is based on documentation of the spacecraft design that proves the design meets the intent of the applied Range Safety requirements document.

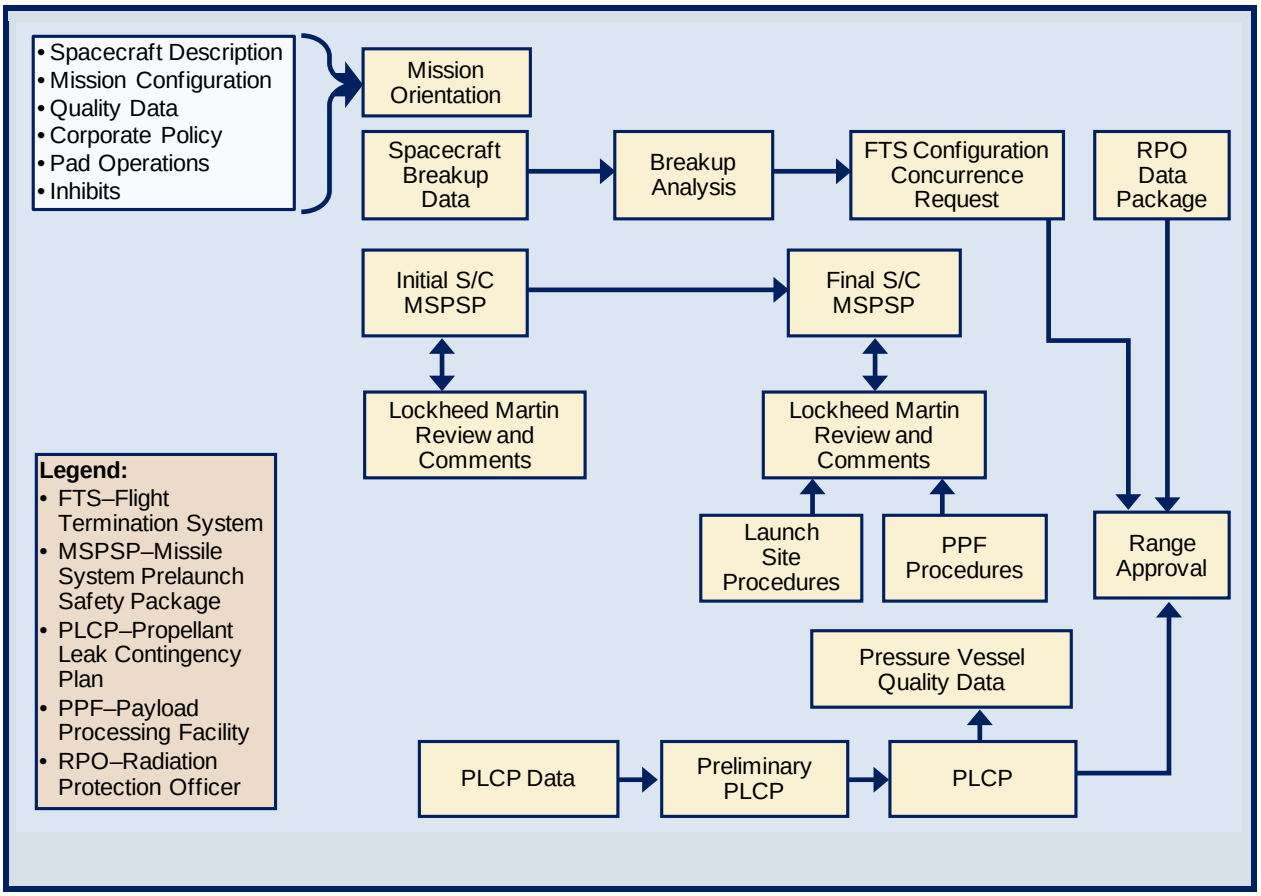


Figure 3.3-1. System Range Safety Interface Process

Mission Orientation—LM and the spacecraft contractor introduce a new system or mission to the Range in a mission orientation meeting, sometimes also known as a Program Introduction, at the Range soon after contract award. The mission orientation meeting identifies any peculiar design or operational issues so they can be resolved early in the integration phase of the mission. The mission orientation also provides the opportunity to determine which Range Safety requirements will be imposed on spacecraft design and operations. Athena and spacecraft personnel jointly develop a contingency fuel offload procedure for Range Safety approval. If the spacecraft carries fuel, Athena technicians perform the offload if it becomes necessary.

System Safety Approaches and Requirements—LM leverages previously established relationships and contracts with the Kodiak Test Range, a recognized Federal Launch Range, to satisfy the provisions of the FAA ground safety process. The Athena IIc LV received FAA Licensing in 2001. This licensing agreement was based, in part, on the implementation of the EWR 127-1, *Eastern and Western Range 127-1 Range Safety Requirements*.

The Athena IIc Missile System Prelaunch Safety Package (MSPSP), which received approval prior to the last launch in September 2001, provides a solid foundation from which updates can be made for particular missions. Design upgrades made to the Athena family of LVs, the PLA interface, and the specific payload will comply with the safety requirements found in AFSPCMAN 91-710, as tailored for the mission.

The spacecraft contractor-developed MSPSP describes the spacecraft, its associated hazards (e.g. pressure systems, ordnance control systems, toxic hazards, access requirements, processing

issues, etc.), and the means by which the spacecraft contractors plan to eliminate or control each to an acceptable degree. The payload MSPSPs, the hazard analysis they contain, and other technical data provided with the end items supports an integrated safety compliance assessment, Range approval, and the FAA Licensing Process. The spacecraft contractor typically submits the initial MSPSP to LM about 14 months before Initial Launch Capability (ILC). The Athena team reviews the document and forwards it, with comments, to the Range for further review and comment. The Athena program relays comments to the spacecraft contractor for incorporation into the final spacecraft MSPSP, which they will submit to the Athena program approximately five months before ILC.

Mission-Unique MSPSP—LM combines the data in the spacecraft MSPSP with data from the Athena booster MSPSP and the ICD to perform and document a safety analysis and assessment across the booster-spacecraft interface. We deliver the results to the Range as the formal mission-specific MSPSP, both in preliminary and final documents.

Range Safety Data Package—LM develops a preliminary Range Safety data package that provides the basic spacecraft configuration, the preliminary flight profile, and the time of launch. LM forwards this package to the Range for comment, together with a preliminary Flight Plan Approval (FPA) request, about 12 months before launch. Approximately 60 days before ILC, the Athena program submits the final Range Safety data package to the Range with a request for a final FPA. The Range usually delivers the final FPA about 30 days before ILC.

Spacecraft Breakup Data—The spacecraft contractor supplies LM with spacecraft breakup data for the Range Safety data package. LM uses this breakup data to perform a breakup analysis of the spacecraft in expected mission conditions.

Flight Termination System Configuration Concurrence—Based on the breakup analysis, the Athena program submits an FTS configuration concurrence request to the Range. The purpose of this concurrence request is to obtain an agreement with the Range as to the requirement for a spacecraft destruct capability. With most spacecraft, LM usually pursues FTS concurrence without a spacecraft FTS destruct system, as there is no appreciable additional public safety hazard.

Pressure Vessel Qualification Data—The spacecraft contractor provides pressure vessel qualification data, through the Athena program, to the Range for review and acceptance.

Radiation Protection Officer Data—The spacecraft contractor submits data on the type and intensity of RF radiation that the spacecraft transmits during ground tests, processing, and launch at the Range. LM forwards this data to the Radiation Protection Officer for review and approval of the RF-related operations to be performed at the launch site.

Spacecraft Processing Procedures—Through the Athena program, the spacecraft contractor supplies the operator of the Payload Processing Facility with all onsite processing procedures for review and approval. The procedures must comply with the processing facility safety policies. The spacecraft contractor also provides all other launch site operating procedures through the Athena program to the Range for review and approval.

4.0 REQUIREMENTS AND ENVIRONMENTS

The spacecraft encounters a variety of environments during Athena processing, launch, and flight. All predicted environments derive from standards defined in the LM Test and Requirements Practices Manual, uses the standards of MIL-STD 1540. To the extent possible, actual configuration and related flight and test data contribute to the Maximum Predicted Environments (MPEs), and added margins account for dispersions and sample size. For data samples of three or more, we calculate a 95% Probability/50% Confidence (P95/50), assuming a log-normal distribution. For data samples less than three, a 3 dB margin accounts for unknown data dispersions. Industry standard sources and test data references determine attenuation factors for localized acoustic, vibration, and shock levels. Flight data validates these standards and the overall MPEs on a continuing basis.

The original vibration, acoustic, and shock MPEs developed for Athena were predicated on data from missile configurations flown in the Fleet Ballistic Missile (FBM) Program. With the extensive flight data gathered from the Demonstration Launch Vehicle, Lewis, Lunar Prospector, ROCSAT-1, IKONOS, and Kodiak Star missions, Athena data has gradually taken the place of FBM data.

4.1 PRELAUNCH ENVIRONMENTS

4.1.1 Loads and Load Factors

Transportation and handling loads incurred during ground operations and processing are enveloped by the flight environments. The heritage transportation and processing procedures and ground support equipment used on the Athena Program have been designed and developed to minimize the potential for damage as a result of ground processing. LM's unparalleled experience with payload integration and launch vehicle processing assures that spacecraft processing occurs on schedule and with minimal risk.

4.1.2 Cleanliness, Contamination Control, Temperature, and Humidity

At both Launch Complex 46 (LC-46) of Cape Canaveral Air Force Station (CCAFS) and the Kodiak Launch Complex (KLC), carefully controlling the environments surrounding the spacecraft during prelaunch operations—subsequent to removal of the spacecraft from the customer-supplied shipping container—preserves the integrity of the spacecraft. We typically use Astrotech Space Operations, Inc. at LC-46 of CCAFS and the PPF at Kodiak to support payload processing activities. These clean rooms comply with FED-STD-209 and ISO 14644-1; details appear in Table 4.1-1.

Table 4.1-1. Both CCAFS and KLC have Environmentally-Controlled Athena Payload Facilities

Launch Complex	Facility	Clean Room	Temperature Range	Relative Humidity	Filtration	ISO Class
46	**Astrotech**	Buildings 1, 1A, 2 high bays	22.2±2.8 °C (72±5 °F)	55±5%	Class 100,000	Class 8
		Building 3 storage bay	21.1-25.6 °C (70-78 °F)	≤55%		
Kodiak	**PPF**	Checkout cells	18.3±5.6 °C (65±10 °F)	40±10%	Class 100,000	Class 8
		Airlock 1	21.1±2.8 °C (70±5 °F)	40±10%	Class 100,000	Class 8
		Airlock 2	21.1±1.1 °C (70±2 °F)	45±10%	Class 100,000	Class 8

Meeting the requirements and using the processes and equipment specified in the mission-peculiar contamination control plan preserve the controlled environment. These controls are initiated at the Payload Processing Facility (PPF) and maintained during transport of the spacecraft to the launch pad and while it is mated to the Launch Vehicle (LV). While Class 100,000 (ISO Class 8) clean conditions are standard, Class 10,000 (ISO Class 7) clean conditions are also possible.

Following final spacecraft/payload assembly and checkout in the PPF, the spacecraft/payload is mated to the Payload Adapter (PLA) and encapsulated. In order to minimize temperature extremes, a "low-boy" trailer transfers the encapsulated assembly to the pad at night. A gaseous nitrogen purge maintains a positive pressure within the Payload Fairing (PLF) to prevent the intrusion of moisture or contaminants. The nitrogen purge is maintained until the encapsulated assembly is mated to the LV and conditioned air is supplied to the PLF. Table 4.1-2 shows various standards for the conditioned air supplied to the PLF. Internal ducting within the PLF prevents the conditioned air from directly impinging, in excess of the velocity shown, on any part of the encapsulated spacecraft. Five one-way vent valves in the PLA release the conditioned air to the Orbit Adjust Module.

Table 4.1-2. Standards for PLF

PLF Air Supply	Standard
Cleanliness	Class 5,000 (ISO Class 6)
Flow	5.67-21.24 m^3/min (200-750 ft^3/min)
Temperature	10-23.9 °C (50-75 °F)
Maximum Dew Point	4.4 °C (40 °F)
Payload Impingement Velocity	<4.57 m/s (15 ft/s)

4.1.3 Radiation and Electromagnetic Environments

The launch site must control radiation and electromagnetic environments to comply with Range Safety and for the protection of sensitive mission components. Signal levels emanating from, or impinging on, the Range, the LV, or the spacecraft must be known for all ground and flight modes of operation. Range Safety at each launch complex identifies, measures, and maps all fixed radiation sources that impinge on the ground and flight envelopes. Emission characteristics of Athena and spacecraft must be integrated with local characteristics to assure that safe margin-

limited levels are not exceeded for any part of the spectrum. Radiation from the LV or spacecraft must be coordinated with the Range at all times subsequent to arrival at the launch site. Therefore, the spacecraft contractor must supply the data necessary to support an Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) evaluation to preclude adversely affecting launch processing or Range-wide operations. Similarly, LM contributes the necessary data to support the design of sensitive payload components. For these reasons, each mission requires the preparation and implementation of an EMC Control Plan.

The Athena vehicle transmits at several frequencies to provide telemetry data for Range tracking of the LV, which begins operation before launch and remains active until after spacecraft separation, the Collision and Contamination Avoidance Maneuver (CCAM), and propellant depletion. Also, the Athena LV generates an electromagnetic environment at the spacecraft location within the PLF. The maximum induced electromagnetic environment resulting from all sources operating at CCAFS and impinging on LC-46 is 5 V/m from 14 kHz to 40 GHz, while the maximum induced electromagnetic environment resulting from all sources operating at KLC and impinging on LP-1 is 22 V/m from .0001 GHz to 21 GHz.

The electromagnetic radiation levels that the payload encounters are determined by the LV transmitters (telemetry and tracking), the launch site, and downrange emitters. Typically, the launch site represents the worst-case RF environment for the LV and payload. Radiation susceptibility testing has been performed on the Athena LV to levels that envelope the KLC environment. Susceptibility levels are established at 6 dB below the test levels to protect for multipath effects. These levels, attenuated by 20 dB for the PLF, represent the maximum environment for the payload and are shown in Figure 4.1-1.

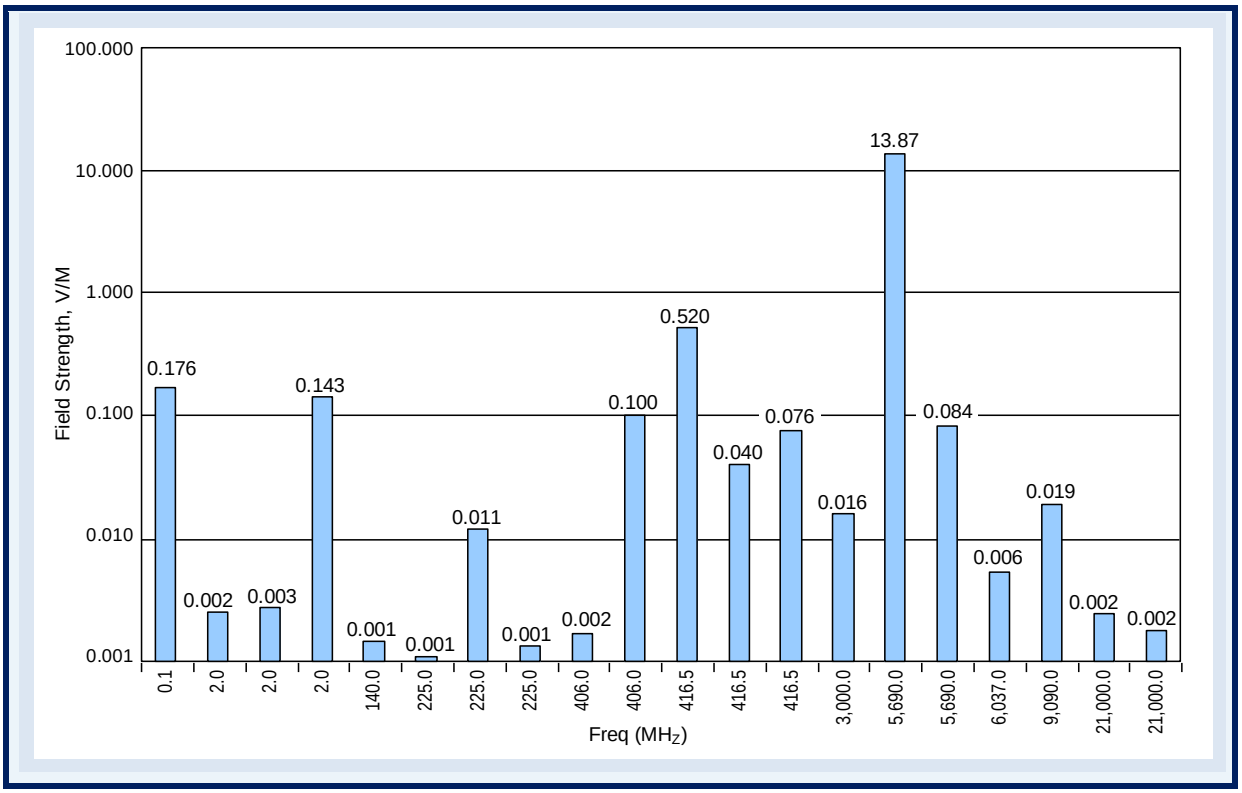


Figure 4.1-1. Athena Maximum Electromagnetic Radiation Levels Encountered on Payload at KLC

4.1.4 Electrostatic Potential and Grounding

The buildup of high-electrostatic discharge potential presents possible risks in prelaunch operations. The nature of the materials, size of surface areas, presence of electrical current sources, and weather conditions all contribute to the potential danger. To keep personnel, equipment, pyrotechnic devices, and sensitive electronics out of the discharge path, surfaces use proper electrical bonding, along with suitable electrical paths between the spacecraft and ground, throughout the preflight phase.

Also, electronic and electrical circuits require a common ground reference to operate together or communicate as designed. Consequently, the spacecraft must have ground attachment points to which properly-designed ground straps can attach during prelaunch processing. These attach points provide the path for grounding the spacecraft to a ground potential equal to that of the checkout equipment and the LV. To avoid possible damage or erroneous signal levels, the electrical resistance across the spacecraft-to-PLA interface must be less than 2.5 mΩ when installation is complete (MIL-B 5087B, Class R). Each spacecraft-to-LV Interface Control Document contains the developed point-to-point requirements for detailed electrical measurement values, including shielding.

4.2 LAUNCH AND FLIGHT ENVIRONMENTS

Launch and flight environments encompass everything that the spacecraft encounters from first-stage ignition through on-orbit separation. The predominant environments, from a spacecraft design perspective, are the quasi-steady state and oscillatory dynamic structural loads, shock, vibration, and pressure experienced as the spacecraft rockets through the atmosphere. The radiant effects of atmospheric heating of the PLF are comparatively less severe environmental concerns and are usually more amenable to design accommodation. Meteorological conditions, trajectory lofting, PLF jettison timing, and Attitude Control System (ACS) maneuvering are examples of variables that affect the environmental conditions and must be considered in each mission's environmental analyses.

4.2.1 Loads and Load Factors

Preliminary design load factors at the LV-to-spacecraft interface that envelope the maximum spacecraft response during critical flight events for Athena Ic and Athena IIc appear in Table 4.2-1. The values, in *g*'s, include an average spacecraft response because loads are partly dependent on the specific spacecraft configuration. These values only apply to preliminary spacecraft primary structure sizing. To avoid undesirable coupling between the LV and the spacecraft, the stiffness of the spacecraft structure should be such that fundamental fixed-base frequencies comply with the values shown in Table 4.2-2. For spacecraft not meeting this modal frequency criteria, structural dynamic spacecraft responses may exceed the preliminary design load factors shown in Table 4.2-1. In such cases, detailed coupled load analysis must quantify mission load factors on a mission-unique basis for potential mitigation through Center of Gravity (CG) adjustment, PLA structural modification, or other means. The leveraged effects of small changes in spacecraft configuration merit close budgeting of their CG and mass properties, plus stringent acceptance criteria, as a result of the potentially large cost and schedule impact of late accommodation.

Table 4.2-1. Preliminary Spacecraft CG Load Factors

Flight Event	Direction	Athena Ic Acceleration (*g*) steady-state	Athena Ic Acceleration (*g*) dynamic	Athena IIc Acceleration (*g*) steady-state	Athena IIc Acceleration (*g*) dynamic
Launch/First Stage Ignition	Axial	1.0	±5.0	1.0	±5.0
	Lateral		±1.8		±1.3
First Stage Motor Resonance and Gust	Axial	3.2	±3.5	1.8	±4.1
	Lateral	0.7	±1.3	0.2	±0.9
First Stage Maximum Acceleration	Axial	8.1		2.2	
	Lateral		±1.4		±1.4
Second Stage (Castor 120) Ignition	Axial			0.25	+6.2/-3.4
	Lateral			0.3	±1.5
Second Stage Motor Resonance and Gust	Axial			3.8	±5.0
	Lateral				±0.9
Second Stage Maximum Acceleration	Axial			0.3	±1.4
	Lateral				
Third Stage (Castor 30) Ignition (Athena Ic Second Stage)	Axial	0	+3.3/-1.3	0	+3.3/-1.3
	Lateral		±1.4		±1.4
Third Stage Maximum Acceleration (Athena Ic Second Stage)	Axial	7.0		7.0	
	Lateral		±1.0		±1.0

Notes:

- All loads have 99th percentile probability of nonexceedance
- Positive axial load factors act in the aft direction at the spacecraft's center of gravity
- Coupled Loads Analysis provides specific spacecraft responses
- Axial and lateral load factors should be applied simultaneously
- Analysis does not include a spacecraft dynamic uncertainty factor

Table 4.2-2. Athena Preliminary Dynamic Mode Frequencies

Mode	Athena Ic	Athena IIc
Axial (Hz)[1]	>30	>30
Axial (Hz)[2]	<45 and >70	<45 and >70
Lateral (Hz)[3]	>15	>12

Notes:

1. Axial mode frequency requirements avoid dynamic coupling between spacecraft and booster ignition-boosting functions
2. Minimizing spacecraft structure resonances in this range will reduce dynamic coupling with LV solid motor resonances
3. Lateral mode frequency requirements avoid dynamic coupling between spacecraft and first bending mode of the LV

4.2.2 Low-Frequency Vibration

For the Athena family, first- and second-stage Solid Rocket Motor (SRM) chamber resonances are the primary generators of low-frequency quasi-sinusoidal vibration. For the Castor 120® SRM, the first chamber resonant mode ranges from 45 Hz to 70 Hz. Based on previous flight experience and test firings, oscillation amplitudes for the Athena family peak at the spacecraft at 55 Hz as a result of this chamber resonance phenomenon. This has been incorporated into the Athena Ic and Athena IIc preliminary design load factors shown in Table 4.2-1. For each mission, coupled loads analysis determines the predicted sinusoidal vibration response of a specific spacecraft, caused by motor chamber resonance. Designing spacecraft structure fundamental frequencies to remain out of the frequencies shown in Table 4.2-2 greatly diminishes quasi-sinusoidal effects.

4.2.3 Random Vibration

Figure 4.2-1 and Table 4.2-3 show high-frequency broadband random vibration from transient sources at the Athena family LV-to-spacecraft interface. In general, launch and transonic acoustics drive the mechanically-transmitted random environment.

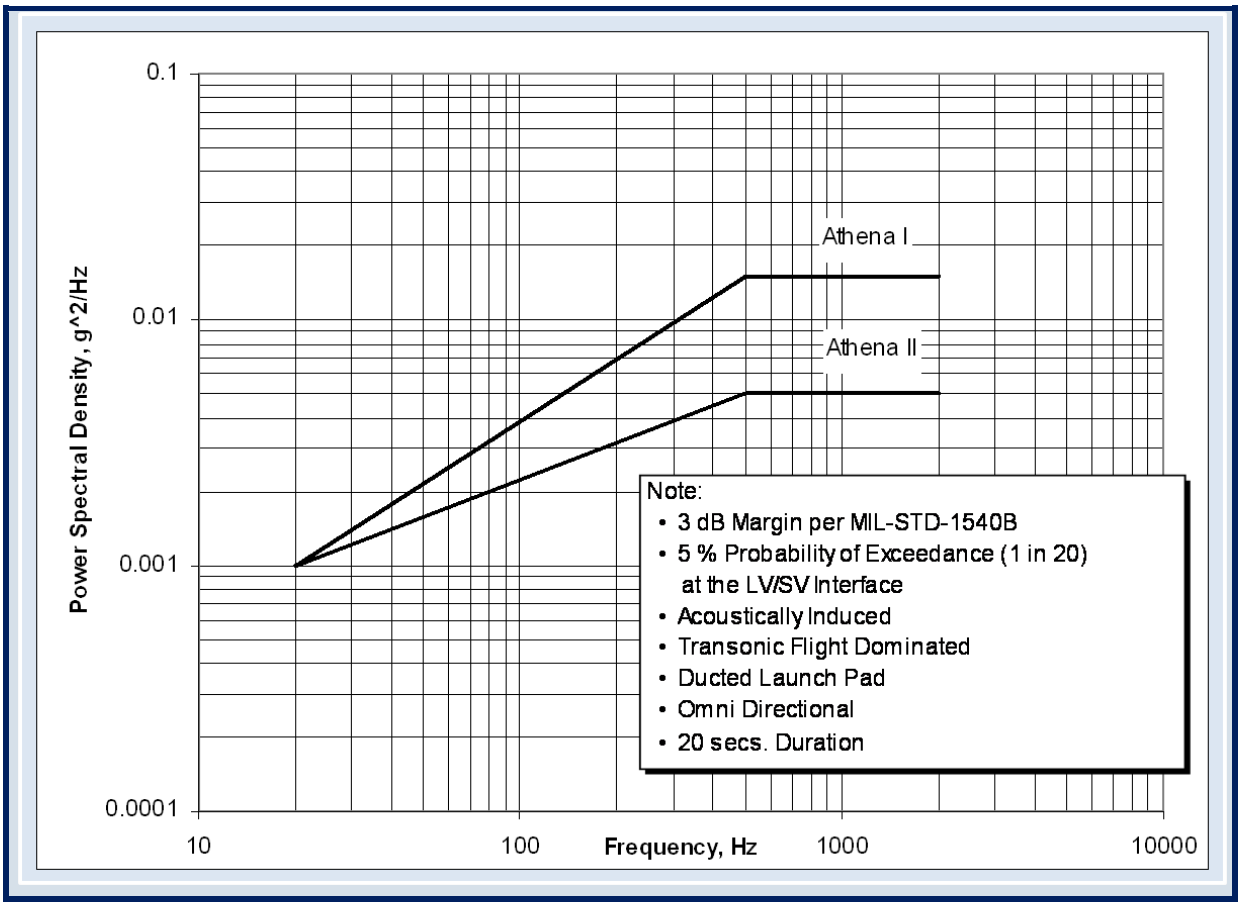


Figure 4.2-1. Maximum Flight-Level Payload Interface Vibration Environment

Table 4.2-3. Maximum Payload Interface Random Vibration Environment

Launch Vehicle	Frequency (Hz)	Power Spectral Density (g^2/Hz)
Athena Ic	20	0.001
	500	0.015
	2000	0.015
Athena IIc	20	0.001
	500	0.005
	2000	0.005

Notes:
- 3-dB margin per MIL-STD-1540B
- 5% probability of exceedance at LV/SV interface
- Acoustically-induced
- Transonic flight-dominated
- Ducted launch pad
- Omni-directional

4.2.4 Acoustics

Spacecraft experience an acoustic environment during launch and throughout flight. The acoustic pressure levels for frequencies present inside the PLF vary according to the dimensions of the PLF, the shape and size of the unfilled interior space, the pressure density of the environment, the venting design, and the size, shape, and surface material properties of the spacecraft components. The concern of the spacecraft designer is to limit exposure of those components to acoustic pressures within an acceptable range. The greatest acoustic sound pressure levels inside the PLF occur during the first 10 seconds after ignition and during transonic flight. Table 4.2-4 presents the envelope of the launch and transonic acoustic levels for an Athena IIc LV. The acoustic sound pressure-frequency data apply to the Athena Ic and Athena IIc with aluminum Model 92 PLFs. These acoustic levels are for an empty PLF without acoustic blankets; on a mission unique basis, adding acoustic blankets can reduce the acoustic levels. During the spacecraft integration process, revisions to the empty PLF acoustic data include a "fill factor" based on the volume the spacecraft occupies within the PLF. This changes the acoustic environment and is assessed given the volume for specific payloads.

Table 4.2-4. Payload Fairing Acoustic Levels

Athena IIc Acoustic Maximum Predicted Environment (Pad-Independent)		
1/3 Octave Sound Pressure Level Frequency (Hz)	**Sound Pressure Level Without Blankets (dB)**	**Sound Pressure Level With Blankets (dB)**
19.7	106.3	103.8
24.8	108.8	107.5
31.3	113.2	113.0
39.4	118.2	115.7
49.6	116.0	115.7
62.5	115.7	115.7
78.7	116.0	115.7
99.2	118.9	118.2
125.0	127.0	123.3
157.5	126.5	123.5
198.4	126.5	124.2
250.0	125.1	123.2
315.0	125.0	122.3
396.9	125.0	122.3
500.0	125.7	122.5
630.0	129.6	125.7
793.7	132.1	127.7
1000.0	124.3	119.9
1259.9	120.7	113.6
1587.4	115.2	109.9
2000.0	116.6	108.8
Overall Sound Pressure Level	**137.8**	**134.4**

Notes:

- Includes 50% fill effects
- Maximum Predicted Environment defined as 95% Probability/50% Confidence

4.2.5 Shock

During flight, the payload experiences several shock events, most of which are highly attenuated by the Athena structure. These events include stage ignitions, stage separations, PLF separation, and payload separation. The shock levels produced by these events are well-characterized because they have been measured by ground testing and/or during flight on previous Athena launches. Table 4.2-5 summarizes these shock environments. The Athena design may use a SoftRide adapter ring to make the shock response at the PLA below these levels. We determine the maximum shock environment, including the separation system shock, on a mission-unique basis as we define payload locations and separation systems in detail.

Table 4.2-5. Athena Maximum Flight-level Payload Interface Shock Response Spectrum

Shock Response Spectrum (g): Q=10	
Frequency, Hz	**Without Separation System and Without SoftRide System**
20	15
40	20
80	20
100	25
300	270
600	600
2,000	1,300

4.2.6 Thermal

During ascent, aerodynamic heating of the PLF results in a time-dependent radiant heating environment around the spacecraft. This heating is the dominant thermal energy source that the spacecraft encounters during its flight. After the PLF jettison, the remaining thermal environment involves a much lower level of Free Molecular Heating (FMH), plus solar heating, Earth thermal heating, Castor 30® SRM plume heating, and heating through conductive structural coupling. Mitigation methods available on a mission-unique basis include PLF-separation delay and implementation of a slow roll during coast phases.

Because the PLF heat absorption is the major contributor to the spacecraft's thermal environment, its overall effect depends largely on PLF configuration. For the standard Model 92 PLF, the mission trajectory and insulation configuration determine the skin temperature. Figure 4.2-2 and Figure 4.2-3 give the Athena Ic and IIc PLF maximum temperature profiles for stressing trajectories at various regions along the fairing internal surface.

PLF separation occurs at a time and altitude in the flight trajectory planned such that the FMH rate is less than 0.1 Btu/ft^2-sec. To meet mission-specific spacecraft thermal requirements, delaying the PLF separation provides lower FMH rates. During the transfer coast, implementing a slow roll (typically 1° to 3° per second) can moderate solar-generated heating and cooling.

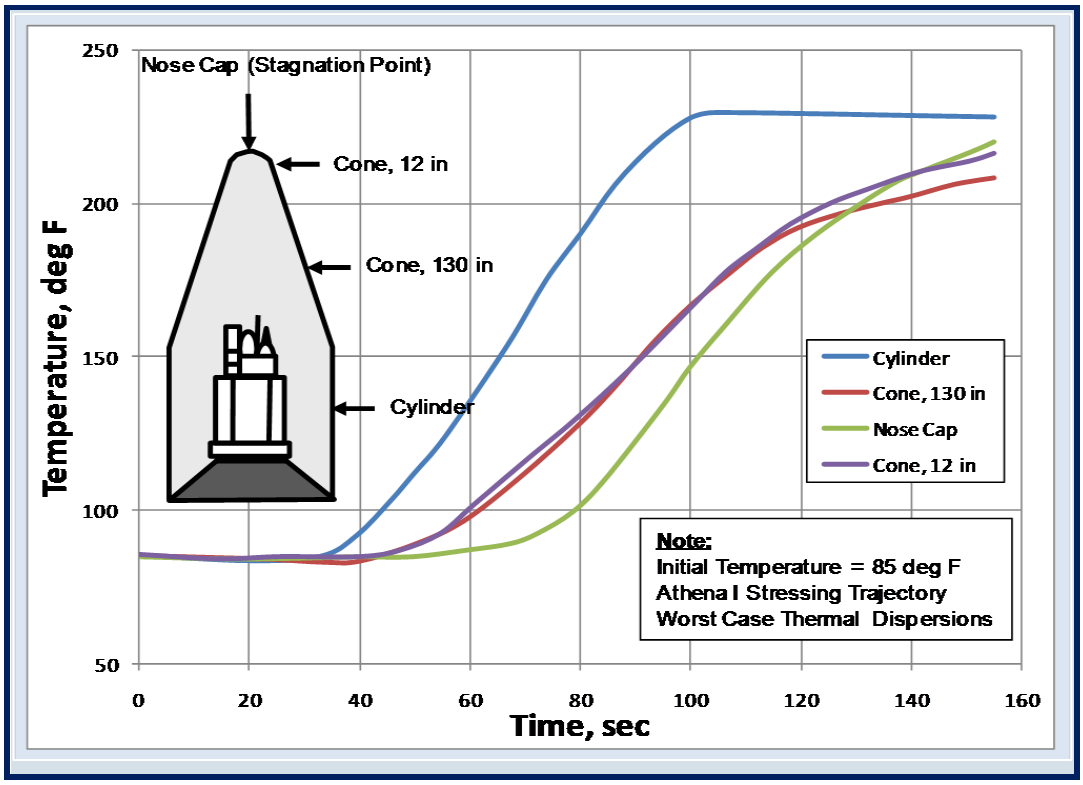


Figure 4.2-2. Athena Ic PLF Internal Temperature Profile

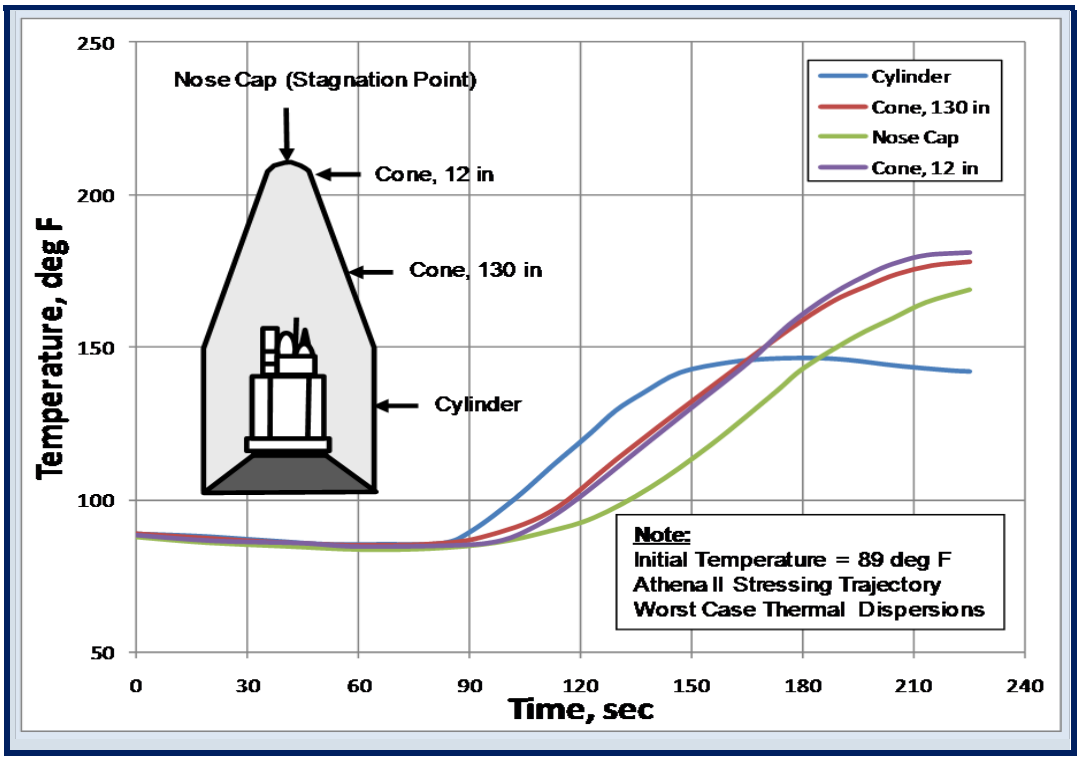


Figure 4.2-3. Athena IIc PLF Internal Temperature Profile

4.2.7 Atmospheric Pressure Venting

The pressure on the spacecraft diminishes from first-stage ignition, as a function of the trajectory profile, through PLF jettison. After PLF jettison, the pressure on the spacecraft diminishes as a function of altitude.

As the Athena LV ascends through the atmosphere, one-way vent valves in the PLA relieve pressure within the PLF. PLF internal pressure time histories for typical Athena Ic and Athena IIc flight trajectories are shown in Figure 4.2-4. The maximum steady-state venting rate prediction is typically 0.6 psi/s during ascent. However, a transient event occurs as the vehicle crosses into the transonic regime where the pressure decay rate increases to 1.0 psi/s for approximately 3 seconds.

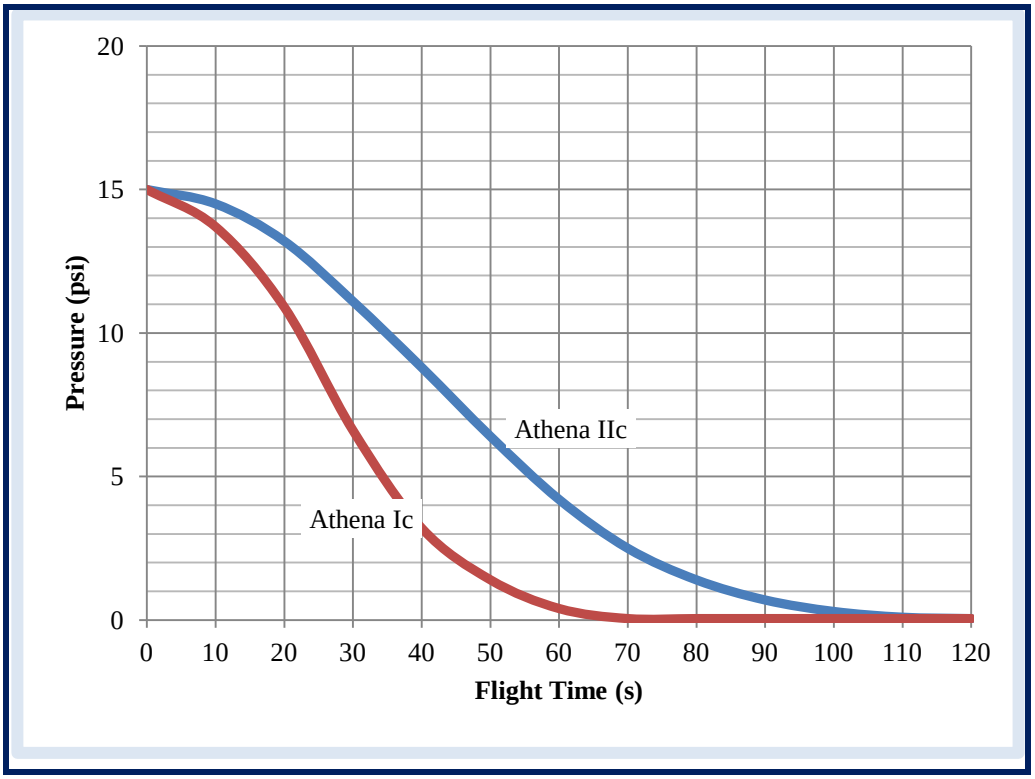


Figure 4.2-4. Payload Fairing Internal Pressure Time Histories

4.2.8 Contamination Control and Cleanliness

Effective contamination avoidance and mitigation techniques consist of containment, maneuvering, materials selection, and the addition of shielding, coatings, coverings, and sealants. The PLF protects the spacecraft from all sources of contamination by maintaining the clean environment established underground processing conditions discussed in Section 4.1.2. To avoid contaminating the spacecraft following PLF jettison and through spacecraft separation, the Athena LV includes features that either eliminate contamination or reduce it to acceptable levels. The PLF employs Zip Tube®, a patented clean separation system, along the base and separation joints of the two halves of the PLF. All contamination from detonable items is contained within the Zip Tube® to secure debris during PLF separation. Throughout orbit injection and spacecraft orientation, directing the thrusters away from the spacecrafts minimizes contamination by the ACS thruster plumes. During spacecraft deployment, the ACS does not begin the CCAM

maneuver until the deployed spacecraft is nominally 30 m (100 ft) away. This reduces potential contamination from the ACS thruster plumes.

In addition to our control of particulate contamination, we use low-molecular outgassing materials which contributes to the robustness of the Athena design. The PLF (including acoustic blankets, if required), PLA internal and forward-facing surfaces, and all LV equipment within this volume produce less than 0.1% volatile condensable materials (by weight) and total mass loss of approximately 1.0% after spacecraft encapsulation and through spacecraft separation.

5.0 SPACECRAFT AND LAUNCH FACILITIES

5.1 CAPE CANAVERAL AIR FORCE STATION

Athena launch services at Cape Canaveral Air Force Station (CCAFS) are conducted from Launch Complex 46 (LC-46). Figure 5.1-1 shows the principal facilities used for Athena payload and Launch Vehicle (LV) processing.

5.1.1 CCAFS Payload Processing Facilities

Astrotech Payload Processing Facility—The commercial Payload Processing Facility, owned and operated by Astrotech Space Operations, Inc., is the primary facility used for processing Athena-class civil, government, and commercial spacecraft at CCAFS; the customer may, of course, select an alternative facility. This facility contains separate nonhazardous and hazardous processing buildings, storage buildings, and offices that are described in detail in the Astrotech User's Guide available from the Astrotech website.

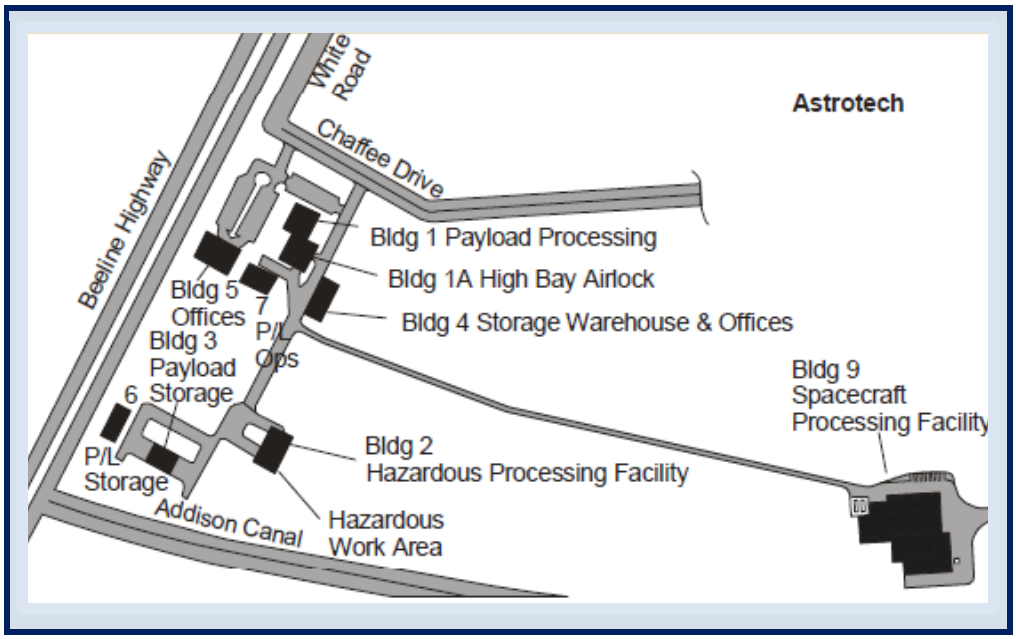


Figure 5.1-1. Payload and LV Processing Facilities

5.1.2 Launch Complex 46

LC-46 is located at 28° 28' North, 80° 32' West near the tip of Cape Canaveral, making it well-suited for low- to medium-inclination missions. An aerial view of LC-46 is shown in Figure 5.1-2. The Space Florida conversion of LC-46 for commercial launch use includes the addition of the Mobile Access Structure (MAS), a new launch pedestal, a flame trench, and a utility room.

Figure 5.1-2. Arial View of Cape Canaveral, LC-46

The MAS is a large, moveable, open-frame structure that rolls up to, and back from, the launch mount. It provides access for vehicle buildup and checkout, as well as access to the satellite within the LV fairing.

The tower encloses the LV to protect it from wind and rain. An Athena Ground Service Equipment (GSE) clean tent can also enclose the specific satellite working area around the fairing access door. Satellite access typically ceases at T-10 hours, just before building rollback. A mobile crane performs vehicle stacking operations and, if required, can hoist GSE to upper platforms.

5.1.3 Support Facilities

Satellite Assembly Buildings (SAB)—The Athena LV program uses the CCAFS SAB, which contains a workshop, office space, GSE storage space, and an enclosed work area for the staging of certain flight hardware. The Launch Vehicle Control Van (LVCV) parks and operates at Hangar K, which provides personal amenities for those stationed in the LVCV during launch.

Propellant Servicing Facility—The Athena team uses the Propellant Servicing Facility for hazardous processing, including OAM fueling.

Liquid Fuels Storage Areas No. 1 and No. 2—The Athena team uses the Liquid Fuels Storage Area (LFSA) No. 1 for hydrazine fuel storage, and the LFSA No. 2 stores ordnance and pyrotechnic devices. Both are located on CCAFS.

5.1.4 Launch Control

Launch control during CCAFS operations is from the LVCV with management support in Hangar AE, and range control at the Range Operations Control Center (ROCC). Hangar AE and ROCC descriptions appear below, while Section 3.2.3 addresses the LVCV and its functions. During launch operations, fiber optic cables interconnect all three locations for data and communication transmittal.

Hangar AE—The Athena vehicle's Mission Control Center is in Hangar AE, a NASA facility located on CCAFS. Hangar AE also houses the Mission Director's Center (MDC), which normally provides consoles for up to two customer personnel, supplying them with equipment to monitor or participate in launch operations.

The VIP viewing area of the MDC offers seating for additional key customer personnel and dignitaries. This facility has bay windows overlooking the console area, two speakers connecting it to the public affairs net, and video capability during launch and ascent.

Range Operations Control Center—The ROCC is located on CCAFS and is the hub of Range operations. Launch operators monitor all vehicle events and parameters, and Range Safety personnel from the ROCC control Command Destruct. The Range Operations Controller, Senior Mission Flight Control Officer, and the Mission Flight Control Observer are the other primary Range personnel in the ROCC during launch operations.

5.2 KODIAK LAUNCH COMPLEX

The Athena program conducts high inclination missions—typically polar and Sun-Synchronous orbits—from Launch Pad 1 (LP-1) the Kodiak Launch Complex (KLC) on Kodiak Island, Alaska.

In Kodiak, transportation links are well established and fully capable of supporting the needs of both the LV and payload processing teams. Kodiak's remote location, while ideal for rocket launches, necessitates various transportation methods to convey the LV, spacecraft, and payloads to the KLC. Kodiak relies on both air and sea systems for food, fuel, and freight imports, along with exports for the profitable commercial fish exporting business. This economic dependence on frequent shipments is advantageous to the aerospace industry, because transportation providers ensure year-round access to Kodiak Island. Space mission components can arrive at Kodiak by air or sea, and the AAC has executed logistics plans to ship solid rocket motors directly from the port of Seattle, Washington to Kodiak. Also, the Kodiak airport is capable of accepting planes as large as a heavy transport C-5. The AAC coordinates with all state and local officials to allow LV transport from Kodiak to KLC, and the Pasaghsak Highway, connecting the city of Kodiak to KLC, is fully paved to expedite transportation. The AAC's advanced equipment and years of experience guarantee safe shipment of expensive and delicate assets to and from KLC.

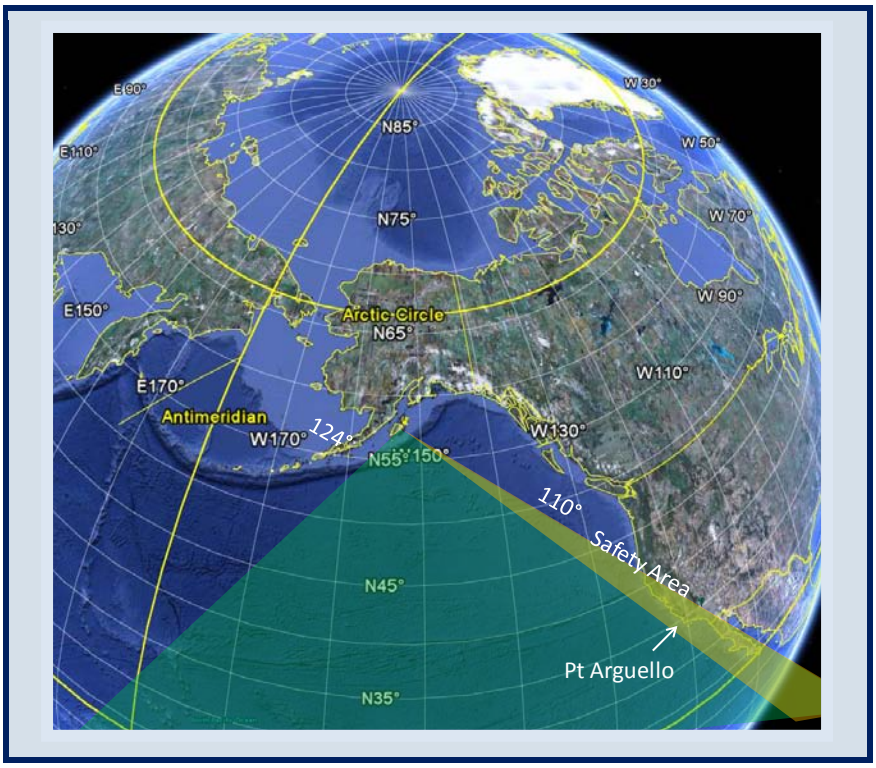


Figure 5.2-1. KLC Launch Azimuths

Kodiak's oceanic climate and predictable weather patterns represent a significant asset, distinguishing KLC as one of the best launch facilities available. Warm ocean currents moderate the weather in Kodiak, and KLC meteorologists understand local weather and can predict weather breaks with great accuracy, allowing on-schedule launches throughout the year. Kodiak's rainfall is largely stable regardless of month or season, and weather holds have impacted only 13.3% of KLC's launches, compared with 18.0% for typical Eastern Range launch sites and 22.0% for other Western Range sites. There is less fog than at VAFB and virtually no lightning, lessening the probability of weather delays. Summer temperatures rarely exceed 16 °C (60° F), and winter lows average approximately -1 °C (30° F); these moderate temperature extremes protect the LV, spacecraft, and payload from significant thermal stress. Furthermore, the KLC's summer daylight lasts up to 18 hours due to Kodiak's high northern latitude. Even in winter, the six hours of sunlight are adequate for any required activities.

With its impressive history of successful launches, the AAC has proven that it can support vehicle processing and launch operations year-round. About 47% of all KLC launches have occurred in winter, beginning with a USAF mission in November of 1998 and including the most recent launch—another USAF mission in November of 2010. Also, while KLC originally operated as a basic launch facility and required the customer to supply the majority of the necessary equipment, AAC has undertaken responsibility for most components of Range operations, managing ground safety, classified and unclassified communications, meteorology, instrumentation, launch operations, and governmental coordination. At 57° 36' 16" north latitude and with a clear flight path to the south, as shown in Figure 5.2-1, KLC is an excellent location for high inclination missions, such as those to polar and Sun-Synchronous orbits. The KLC grounds are shown in Figure 5.2-2.

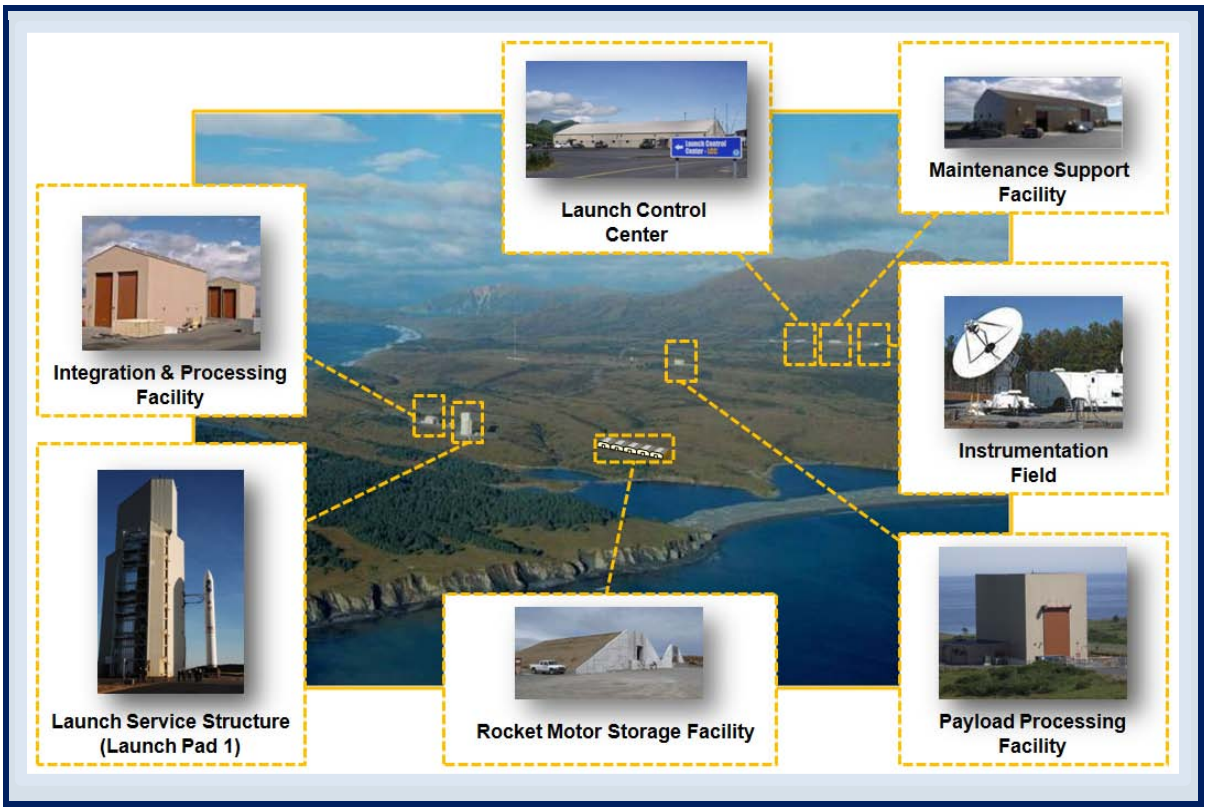


Figure 5.2-2. Kodiak Launch Facilities

5.2.1 KLC Payload Processing Facilities

The launch complex consists of a Maintenance Support Facility, Launch Control Center, Instrumentation Field, Integration and Processing Facility, Payload Processing Facility, Rocket Motor Storage Facility, Launch Service Structure, and Spacecraft Assemblies Transfer Facility. The Kodiak Launch Complex facilities are described in detail on the AAC website.

6.0 LAUNCH CAMPAIGN

6.1 VEHICLE INTEGRATION AND SITE PREPARATION

LM provides complete vehicle integration and launch services for its customers. A system of facilities, equipment, and personnel trained in launch vehicle/spacecraft integration and launch operations implements each mission. The following subsections summarize the types of support and services available.

6.1.1 Spacecraft-to-Launch Vehicle Integration

LM performs spacecraft-to-launch vehicle integration and interface verification testing, including:

1. Matchmate testing of interface hardware
   a) Prototype items
      i) Early verification of design
      ii) Accessibility to install equipment
      iii) Development of handling/installation procedures
   b) Flight items
      i) Verification of critical mechanical and electrical mating interfaces before hardware delivery to the launch site
      ii) Separation system installation
      iii) Bolt-hole pattern alignments and indexing
2. Electrical system interfaces
   a) Telemetry, command, and monitor interfaces
   b) Pyrotechnic signal interfaces
3. Launch site testing
   a) End-to-end test
   b) Spacecraft data flow

6.1.2 Launch Services

In addition to our basic responsibilities for Athena program management, component manufacture, vehicle integration, checkout, and launch, LM offers the following prelaunch and launch operations, integration, and documentation services:

1. Launch site operations support
   a) Prelaunch preparation of the LM-supplied Payload Adapter (PLA), Payload Fairing (PLF), and other spacecraft support hardware
   b) Transport of the encapsulated spacecraft to the launch pad and mating of the encapsulated assembly to the Launch Vehicle (LV)
   c) Support of LV and spacecraft interface tests
   d) Support of spacecraft on-stand launch readiness tests (if requested)
   e) Joint launch countdown preparation and implementation

2. Basic facility services and assistance in the installation of spacecraft ground support equipment at the launch site
   a) Installation of spacecraft power, instrumentation, and control equipment in the utility room and Launch Vehicle Control Van (LVCV)
   b) Provision of electrical power, water, gaseous helium (GHe), and gaseous nitrogen (GN2) cable circuits, and on-pad communications
   c) Supply of on-pad payload air conditioning
3. Coordination, preparation, and maintenance of the required Range support documents in accordance with the Universal Documentation System (UDS)
   a) Gaining the consent of the Cape Canaveral Air Force Station (CCAFS) or Kodiak Launch Complex (KLC) authorities requires documents prepared in accordance with the UDS. In addition, these documents allow LM and the customer to obtain essential Range assets and services required to support the launch operations associated with each mission. LM, with inputs from the customer, is responsible for preparing the Program Introduction Document (PID), the Program Requirements Document (PRD), and the Operations Requirements Document (ORD). In response to the PID, PRD, and ORD, the Range prepares the Statement of Capability (SC) document, the Program Support Plan (PSP), and the Operations Directive Document (ODD), respectively. Figure 6.1-1 illustrates this Range interchange process.

      Note: Requests for downrange tracking support are contained in the UDS products when United States Air Force assets offer this capability. Cases where NASA or foreign assets provide downgrade support require alternate documentation.
   b) Range ground safety and flight safety documentation, as required by the launch site Range Safety regulation
      i) Missile System Prelaunch Safety Package, which proffers detailed technical data on all LV and spacecraft hazardous items, forming the basis for launch site approval of hazardous ground operations at the launch site
      ii) Flight data safety package, which compiles detailed trajectory and vehicle performance data (nominal and dispersed trajectories, instantaneous impact data, 3-sigma maximum turn rate data, etc.), forming the basis for launch site approval of mission-unique targeted trajectory
4. Flight status reporting during launch ascent of flight telemetry data
   a) Marking event voice callouts of major flight events throughout launch ascent
   b) Providing orbital parameters (from LV guidance data)
   c) Confirmation of spacecraft separation, time of separation, and separation state vector (if separation within site of a tracking station)
5. Transmission of spacecraft data by interleaving a limited amount of spacecraft data into the LV data and downlinking it as part of the flight telemetry
6. Postflight processing of LV flight data, which provides quick-look and final flight evaluation reports of selected flight data on a timeline and quantitative basis, as negotiated with the customer.

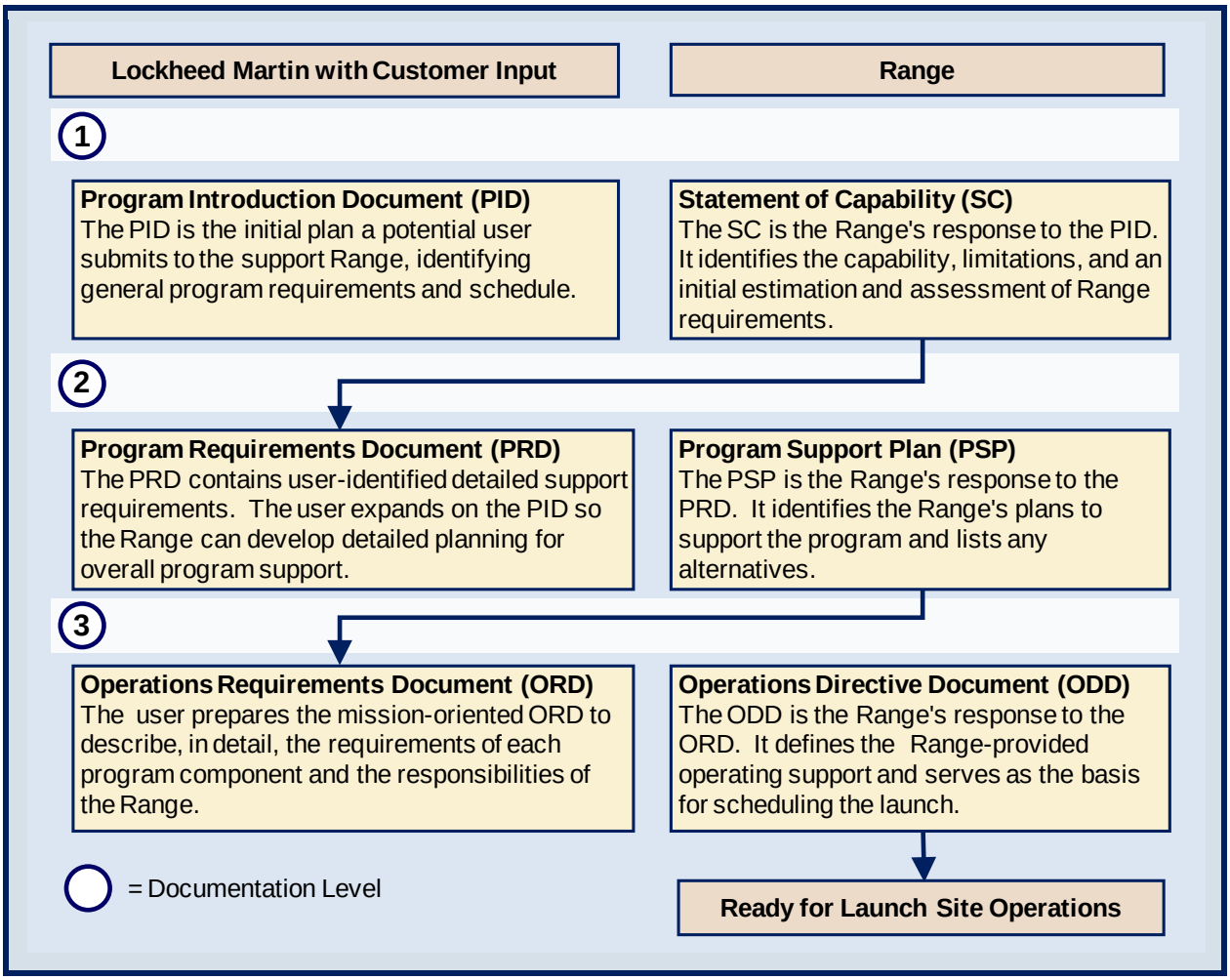


Figure 6.1-1. Range Interchange Process

6.1.3 Propellants, Gases, and Ordnance

All chemicals used must be in compliance with Federal, State, and local regulations. As part of Athena's standard service, up to 100 lbm (45 kg) of hydrazine is available to the spacecraft. Additionally, the site can offer limited quantities of GN_2, GHe, isopropyl alcohol, and de-ionized water before propellant loading, along with a hazardous materials disposal service. All propellants the spacecraft requires must observe and be handled in compliance with U.S. national aerospace standards and U.S. military specifications (MIL-STD P26536).

1. Sampling and Analysis—Personnel analyze fluid and gas samples as specified in the Interface Control Document
2. Propellant Handling and Storage—Short-term storage and delivery to the Hazardous Processing Facility of spacecraft propellants
3. Ordnance and Solid Motor Storage—Spacecraft ordnance and solid motors may be stored for approximately three months and spares may be stored for up to six months. The site offers other long-term storage on a space-available basis with advance notification. In addition, there is a safe facility for test and checkout (receiving, inspection, lot verification testing) of ordnance devices.

6.2 VEHICLE TEST REQUIREMENTS

The Test Requirements Specification (TRS) for the Athena vehicle plans and controls all testing performed during Athena design, development, manufacture, launch site checkout, and launch operations. This encompasses all LV testing, including the spacecraft mission-peculiar equipment and spacecraft-to-LV integrated tests. The TRS consists of six sections that define the test concepts, philosophy, and management policies shown in Figure 6.2-1. Subsections—comprised of the individual test plans for each Athena component, system, and integrated system—detail the test requirements and parameters necessary to achieve desired test objectives.

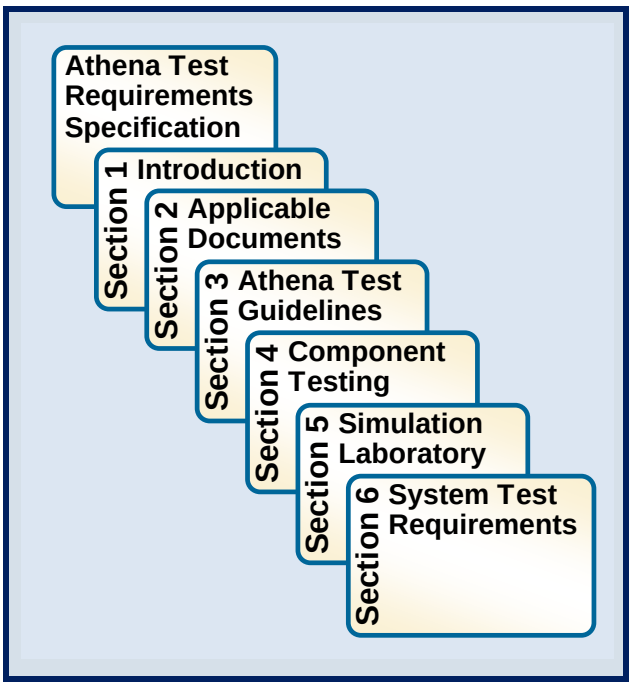


Figure 6.2-1. Test Requirements Specification

Test and Checkout Responsibilities—LM operations personnel are responsible for LV standalone operations and for performing integrated spacecraft/LV tests and operations. The spacecraft contractor is responsible for conducting spacecraft standalone tests and operations. Specifically, the LM launch site function completes the following major tasks in the test conduct arena:

1. LV integration with the spacecraft contractor activities associated with the LV and the launch complex
2. Providing overall launch pad operation integration and conducting the final countdown and launch
3. Organizing and chairing Mission Integration Working Groups between contractors, as necessary, to ensure integrated spacecraft/LV operation
4. Representing the LV operations at the spacecraft-, LV-, and launch base-related working group meetings, joint procedure critiques, and readiness reviews
5. Preparing and controlling all LV-prepared integrated spacecraft/LV test procedures and LV-unique test procedures
6. Providing integrated safety documentation and monitoring for compliance with the applicable Range Safety requirements
7. Formulating an integrated launch complex schedule
8. Supporting spacecraft prelaunch activities
9. Ensuring launch complex security
10. Ensuring launch complex safety
11. Conducting readiness reviews at key points during LV processing.

The spacecraft contractor is responsible for supplying all spacecraft-associated test equipment and the logistical and technical support required to support spacecraft launch operations at the launch site. The spacecraft contractor is responsible for the following major tasks in the test conduct arena:

1. Preparing and controlling spacecraft standalone procedures
2. Preparing, inputting, and approving spacecraft and LV integrated procedures
3. Attending all launch base-related working group meetings, integrated procedure critiques, and readiness reviews
4. Providing safety documentation (e.g. procedures, plans) and monitoring compliance with applicable Range Safety requirements
5. Planning and, if necessary, implementing spacecraft abort activities.

6.3 VEHICLE TEST PROCEDURES

Personnel perform all test operations according to documented test procedures, using the approved TRS subsections together with engineering drawings and specifications. Engineers formally review, approve, and release the procedures for testing of Athena flight hardware before completing the testing. Inspection verifies that the test operators performed the procedures properly, and personnel incorporate the results into each vehicle's permanent history file for use in determining acceptance for flight and final launch readiness.

Engineers also document test procedures for spacecraft mission-peculiar hardware and joint spacecraft/LV integrated tests and operations. The Athena team urges customers to discuss their launch operations needs with LM early in the mission planning phase so that the team can identify and plan the various interface and hardware tests. Customer personnel review and approve mission-peculiar test procedures that involve the spacecraft and participate as required in LV and spacecraft integrated tests.

6.4 VEHICLE VERIFICATION

The typical sequence of tests and activities performed during manufacture, prelaunch checkout, major launch readiness operations, and launch countdown of the Athena LV uphold LM's dedication to mission success.

6.4.1 Launch Vehicle Tests

Engineers perform flight vehicle acceptance tests after final assembly is complete. System-level functional testing ensures the fidelity of key mission components. LM performs a wide range of tests on the Orbit Adjust Module (OAM), which houses all of the avionics, at LM's Athena CCAFS facility in Florida before shipment to the launch site. These tests include a full, integrated systems test with supplementary Athena components simulated for completeness, in addition to system-level functional tests. The TRS controls all OAM testing.

SimLab Mission Software Validation—LM performs rigorous mission software validation in our Simulation Laboratory, SimLab, with the processor package and Inertial Measurement Unit (IMU) hardware. The mission software, loaded into the processor package, runs the "end-to-end" flight simulation. Our real-time trajectory simulation commands the four-axis Flight Analysis Motion Simulator (FAMS) at each point along the flight profile. The IMU, mounted on the FAMS, sends position and rate data to the processor package via a 1553 bus. The processor package sends commands to the Thrust Vector Control System (TVCS) of the Castor 120®

during first/second-stage flight. During second/third-stage flight, the processor package sends commands to the TVCS of the Castor 30®. The simulation includes the entire Attitude Control System (ACS) thruster flight phase. The processor package also sends telemetry downlink data for flight communication checkout. Finally, the TVCS feedback real-time nozzle angular positions arrive at the 6-DOF trajectory simulation in the computer to allow calculation of vehicle acceleration. The simulation computer integrates acceleration to predict vehicle motion and to drive the FAMS so that the IMU "thinks" it is flying the mission. Simulations faithfully implement PLF separation, OAM maneuvers, and spacecraft separation events. This end-to-end, real-time, closed-loop simulation fully checks out mission software and ascent performance before launch. Our Athena Independent Verification and Validation team reports the results of the end-to-end flight simulation to the Athena Program Office for review and assessment.

By using the above process, we validate the planned flight trajectory and mission-unique spacecraft separation sequence before each mission. For example, after programming the mission software into the flight-qualified processor package, a bit-by-bit comparison with the master software disk verifies the mission software. Embedding mission software in the vehicle's processor package allows us to quickly execute mission software changes when required.

The SimLab's computers perform all-digital, as well as real-time, hardware tie-in simulations. Real-time simulations allow programmers to incorporate late changes to the mission software without impacting the launch schedule. Programmers can implement changes in mission parameters, such as orbit inclination and separation altitude, in the mission software data tables so personnel can re-verify and revalidate the mission in the SimLab before launch.

6.4.2 Launch Site Prelaunch Operations

Figure 6.4-1 shows a typical Athena checkout and launch operations sequence. After arrival at the launch site, the Athena team inspects all LV items before stacking on the launch pad. The Castor 120® and Castor 30® are shipped directly to the launch site. Each motor undergoes a receiving inspection to confirm that the motors were not damaged during transport. The manufacturers ship the PLF, with nose cap, and PLAs directly to the launch site where personnel perform a receiving inspection.

Before shipment to the launch site, we subject the OAM, which houses all the avionics, to subsystem testing, hardware-in-the-loop mission software verification and validation in the LM SimLab, and multiple end-to-end system checks at an LM facility. At the launch site, after stacking the vehicle, we perform vehicle tests, concluding with a complete end-to-end system test and launch rehearsal. We perform the tests, listed in Table 6.4-1, to ensure proper operation of the subsystems. Customer and spacecraft contractor personnel participate in the end-to-end system test and launch rehearsal, as well as other spacecraft-specific tests.

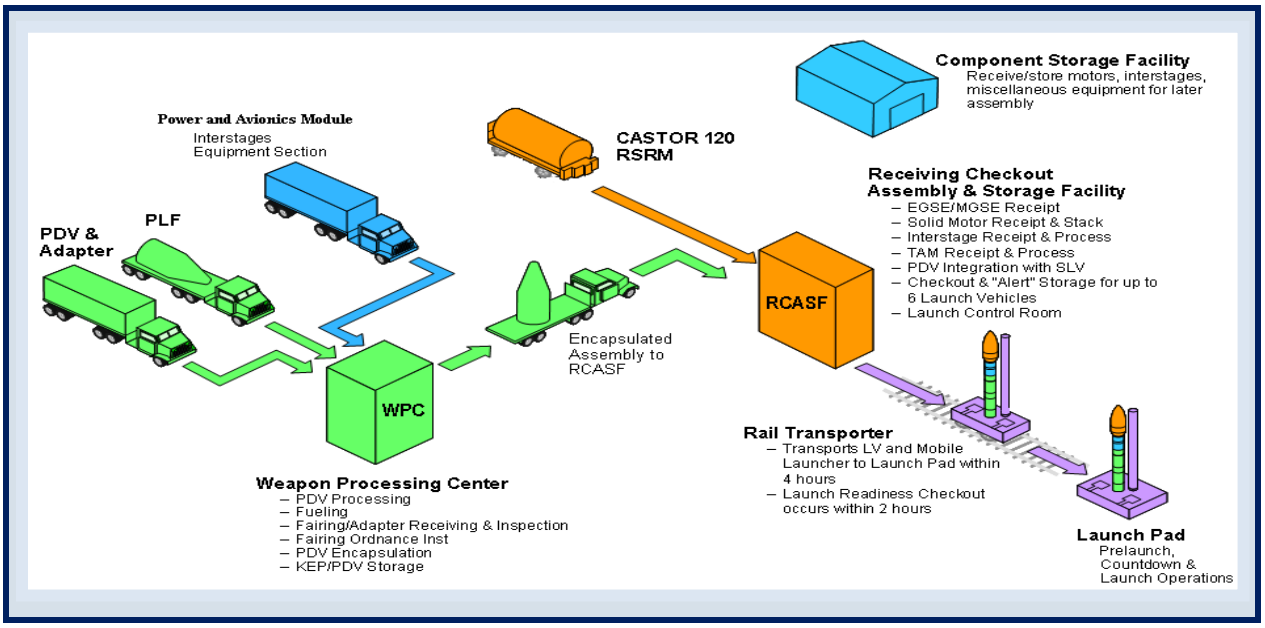


Figure 6.4-1. Athena Launch Operations

Table 6.4-1. Complete End-to-End Launch Site Tests

Launch Site Test	Objectives
Checkout Equipment Verification	Determine that the LVCV and the utility room equipment are ready to perform LV checkout
Power Distribution Test	Determine that the LV power is correctly applied through the LV cabling
Grounding, Bonding, and Shielding Test	Determine that the LV packages, cables, and components are correctly grounded through the LV cabling and structure
Telemetry RF Subsystem Test	Verify the operation of the telemetry RF subsystem
C-Band Transponder Subsystem Test	Verify the operation of the transponder subsystem
Command Destruct RF Subsystem Test	Verify the operation of the RF component of the destruct subsystem
Destruct System Test	Determine that the launch destruct system will operate properly during normal staging, abnormal staging, and command destruct scenarios
TVCS Test	Determine that the LV TVCS will respond properly to steering commands from the avionics package, activating the correct actuator with the appropriate polarity
ACS Test	Determine that the LV ACS will respond properly to steering commands from the avionics package, activating the correct valve with the appropriate polarity
IMU Gyro Compass Test	Determine that the LV IMU will gyro compass and track Earth rotation
Instrumentation System Sense Test	Determine that all instrumentation is connected properly and that data is processed through the correct telemetry channelization
Integrated System Test	Determine that the LV will fly a mission with all subsystems operating as in flight, with real flight timing and events controlling the sequence
Launch Countdown	Determine that the LV is ready for launch, perform the launch sequence

RF Tests—LM performs Radio Frequency (RF) tests on the telemetry, C-band transponder, and command destruct subsystems. We run these tests closed-loop to verify Athena equipment operation and conduct open-loop tests in which the Range receivers are utilized to verify the Range interface. We can accommodate RF testing of the spacecraft as a nonstandard item.

Subsystem Tests—We subject all subsystems to individual tests that verify post-shipping operational status. We bench-test the tracking and the command destruct subsystems, in compliance with Range requirements.

Integrated System Tests—We run an integrated system test on the LV to determine that all subsystems operate together as in flight. We perform this test sequence several times before the launch rehearsal.

Mission Dress Rehearsal—Conducting a Mission Dress Rehearsal (MDR) verifies the readiness of all ground and flight hardware, all support functions, and the launch countdown procedure and all Athena and spacecraft system launch operations personnel that have assigned launch countdown responsibilities. We perform full operations to the extent possible and simulate those operations with hazard implications (such as ordnance installation) where applicable. The MDR demonstrates that the integrated Athena ground, flight, and associated launch support functions, such as Range operations, are ready to support launch operations. The customer supports the LV simulated flight and MDR operations.

6.4.3 Integrated Operations

Integrated operations begin by preparing the LV and launch pad for the arrival of the spacecraft, followed by testing and processing.

Spacecraft Encapsulation—After the spacecraft is mated to the PLA, encapsulation occurs in the Payload Processing Facility (PPF) under the required cleanliness conditions. Engineers complete final preparation of the PLF and lower it into place over the spacecraft.

Transport to the Launch Mount—Personnel place the encapsulated assembly on an Athena program-provided transport trailer in the airlock of the PPF and connect a nitrogen purge through the bag enclosing the encapsulated assembly to prevent the intrusion of moisture or contaminants. Then the trailer leaves the PPF and proceeds at a prudent speed to the launch mount. At CCAFS, this typically occurs at night to minimize solar heat load during the 25-mile journey from Astrotech to LC-46. At KLC there is usually no such constraint, as the distance from the Integrated Processing Facility to the enclosed launch mount at SLC-6 is less than 0.5 miles.

Mating to the Athena LV—Upon arrival of the encapsulated assembly at the launch pad, we install the hoist adapters and lifting sling, release the assembly from the trailer, and lift it to the tower where it is mated to the OAM, as shown in Figure 6.4-2. A continuous nitrogen purge into the assembly preserves the clean, dry environment during transport and mating operations. Once mating is complete, the umbilical connects and supplies Class 5,000 (ISO Class 6) conditioned air at 5.66 to 21.24 m^3/min (200 to 750 f^3/min) and 10 to 24 °C (50 to 75 °F). Two doors in the PLF enable spacecraft access after the encapsulated assembly has been mated to the OAM.

Spacecraft Testing—After mating the encapsulated assembly to the Athena vehicle, spacecraft personnel can perform required spacecraft on-stack testing and activation checks. LM coordinates all activities to ensure that ongoing LV activities and spacecraft activities do not conflict. Spacecraft personnel have access to the spacecraft until T-12 hours.

Launch Vehicle Activities—After mating the encapsulated assembly to the Athena LV, LM continues activities to test and prepare the vehicle for flight, including:

1. Vehicle destruct units installation
2. Test vehicle Flight Termination System
3. Flight battery installation
4. Power-on, no-voltage test.

Figure 6.4-2. Encapsulated Assembly and OAM Mating Operation

Launch Countdown Rehearsal—A joint spacecraft/LV countdown rehearsal typically occurs on L-2 day. This procedure uses key elements from the respective countdowns, arranged on an abbreviated timeline, to acquaint launch team operations personnel with communications systems, reporting, and status, hold, and recycle procedures used in the launch countdown. Personnel critique the operation and incorporate recommendations to improve overall communications procedures. Spacecraft personnel participating in this rehearsal use their assigned operating stations to familiarize themselves with the equipment before the actual countdown operation.

6.4.4 Launch Countdown Operations

LM conducts the final launch countdown operations in two phases. Phase I carries the count from approximately T-26 hours to T-2 hours, and Phase II carries the count from T-2 hours to launch. The spacecraft contractor supports both phases of the launch countdown. A third launch countdown phase, Phase III, arises if a countdown anomaly or launch scrub requires contingency operations.

Phase I—Table 6.4-2 shows a list of the five task groups completed during prelaunch. During each task group, personnel perform several different operations.

Table 6.4-2. Prelaunch Phase I Countdown Tasks

Task	Event
Task 1	Verify launch support readiness • Call to stations • Countdown Clock initiation
Task 2	Prepare and commit to vehicle arming • Telemetry systems test • FTS end-to-end checks • FTS open-loop checks • S&C band RF checks • Missile liftoff test tone • RF coupler removal • Weather briefing
Task 3	Direct arming of LV and SV • LV power-off no-voltage tests • Complex clearing • LV arming • Continuity checks • Pad reopen
Task 4	Prepare final facility closeouts before Phase II initiation • LV closeout • SV configuration for flight and closeout • Umbilical release, retract cable rigging • MTS roll and securing • Camera bore sighting • LST readiness verification • Utility room arming • Final pad evacuation
Task 5	Verify LV RF systems on external power with buildings away • S-Band RF Checks • C-Band RF Checks

Phase II—Phase II consists of major events that prepare the LV and spacecraft for launch. Table 6.4-3 shows these events and their respective tasks.

Table 6.4-3. Prelaunch Phase II Countdown Tasks

Nominal Time	Duration	Major Events
-135 min	10 min	Initialization; power off ambient checks, call to station, missile lift off switch test
-125 min	5 min	Ground power tests
-120 min	60 min	Ground power application, ground power ambient checks, mission software verification
-60 min	10 min	Flight termination tests on ground power
-50 min	34 min	Flight vehicle IMU alignment; final weather briefing
-16 min	11 min	Final system checks, transfer to airborne power, FTS test on airborne power, airborne power ambient checks
-5 min	210 sec	FTS arming, final go/no-go for launch
-1 min	60 sec	Automatic launch sequence, TVC-1 test
T_0		Ignition and launch

Note:
Nominal time is from launch (T_0)

6.5 LAUNCH CAPABILITY

The Athena vehicle is capable of launching at any time of the day, any day of the year. Spacecraft mission requirements typically determine launch window restrictions.

6.6 WEATHER LAUNCH CONSTRAINTS

Weather launch constraints include cloud conditions, lightning, thunderstorms, and ground and upper atmospheric winds. Launch site personnel have defined limiting conditions and developed operational approaches to ensure launch within safe limits. If significant weather and/or thunderstorm conditions exist in the proximity of the launch site or the planned vehicle flight path at the time of liftoff, the launch could be delayed. The LM launch conductor makes a go/no-go decision to launch based on various environmental factors such as lightning and winds.

The LM launch conductor does not allow the LV to launch if the weather station detects lightning within 8.5 km (10 nmi) of the launch site or flight path within 30 minutes of flight. In addition, lightning may postpone the launch countdown if it delays movement of the Launch Access Structure (LAS). The LV does not launch if sustained ground winds exceed 45 knots, omnidirectional, as measured approximately 60.7 m (200 ft) above the pad surface. Also, ground winds may postpone the launch countdown if they are of sufficient strength to delay movement of LAS. However, the Athena design maximizes launch availability and has the ability to fly through high velocity and upper atmospheric winds. Weather station personnel monitor winds during launch countdown and evaluate the observed conditions against criteria specified in the launch commit criteria. If upper atmospheric winds exceed these criteria, the launch is held.

6.7 LAUNCH POSTPONEMENTS

Phase III of the launch countdown is necessary if a launch countdown anomaly arises or the launch is scrubbed, forcing the vehicle into recycle mode. Pending resolution and mitigation of any anomalous condition that may threaten a successful mission, the Athena LV system can be recycled in minutes, hours or days depending on the reason for entering the recycle mode. The customer can access the spacecraft, if required, during scrub timelines. The Athena team

coordinates times of access with the spacecraft contractor during the course of normal integration activities.

7.0 MISSION INTEGRATION AND MANAGEMENT

7.1 INTEGRATION MANAGEMENT

Clear communication between spacecraft and Launch Vehicle (LV) contractors is vital to mission success. Established procedures and interfaces delineate areas of responsibility and authority. Both commercial and government missions have successfully used the mission integration and management process defined in this section. These identified processes and interfaces have enabled mission integration in as little as six months, with 24 months being a more typical schedule.

As an additional information resource, Appendix A of this document details the preferred approach and format for the exchange of data required for mission integration. When necessary, the launch team can accommodate deviations from these specified practices.

7.1.1 Launch Vehicle Responsibilities

Engineers at the LM facility in Denver, Colorado are primarily responsible for Athena design, integration, checkout, and launch. Teaming with LM on the Athena program is Alliant Techsystems, Inc. (ATK), providing the Castor 120® and Castor 30® motors and supporting hardware manufacture and structural assembly. As the spacecraft-to-LV integrating contractor, LM is responsible for payload integration (e.g. electrical, mechanical, environmental, and electromagnetic compatibilities; guidance system integration; mission analysis; software design; Range Safety documentation and support; launch site processing and coordination). LM produces all LV-related software for Athena launches and is responsible for the LV ascent trajectory, data acquisition, performance analysis, targeting, guidance analysis, and Range Safety analysis.

7.1.2 Spacecraft Responsibilities

Each spacecraft mission has unique requirements. The Athena team encourages interested users to discuss their particular needs with LM. Appendix A, Spacecraft Data Requirements, can serve as a guide to initiating dialogue. Shaded items in Appendix A should form the basis for the first face-to-face meeting between LM and the potential user to assist in determining spacecraft/LV compatibility. We encourage customers to contact LM to verify the latest launch information, including the following:

1. Hardware status and plans
2. Launch and launch complex schedules
3. Hardware production schedule and costs.

7.1.3 Integration Organization

For all missions, LM management assigns a Mission Manager. The Mission Manager is responsible for overall supervision of the particular customer activities at LM facilities and at the launch site and is the principal interface with the customer for all technical and LV and spacecraft interface and integration matters. The LM Mission Manager continues to direct the mission-peculiar engineering aspects of the program by performing the following major tasks during the launch campaign:

1. Providing technical management overview of the spacecraft/LV launch campaign to ensure compliance to the mission requirements and resolution of requirements issues

2. Ensuring that spacecraft/LV interface requirements needing verification during launch operations flow down to appropriate site checkout and test procedures and parameter/redline documents
3. Acting as engineering focal point, responsible for timely and thorough communication of all issues and decisions within LM engineering and the spacecraft community, and initiating Engineering Review Board activity as required
4. Integrating Interface Control Document (ICD) waiver/deviation requests and disposition with spacecraft community and integrating ICD change activity as appropriate
5. Managing mission integration schedule to ensure timely completion of LM engineering milestones for the launch campaign and reviewing and approving mission-peculiar technical documentation
6. Ensuring closeout of all mission-peculiar action items.

7.1.4 Working Groups and Responsibilities

In all phases of the mission, from Authority To Proceed to launch, specialized working groups coordinate interface activities between the spacecraft and LV contractors. These groups, which involve the spacecraft contractor as an active participant, develop schedules, monitor progress, and ensure the proper and on-time accomplishment of the technical and management tasks. Figure 7.1-1 shows the typical working groups and their responsibilities.

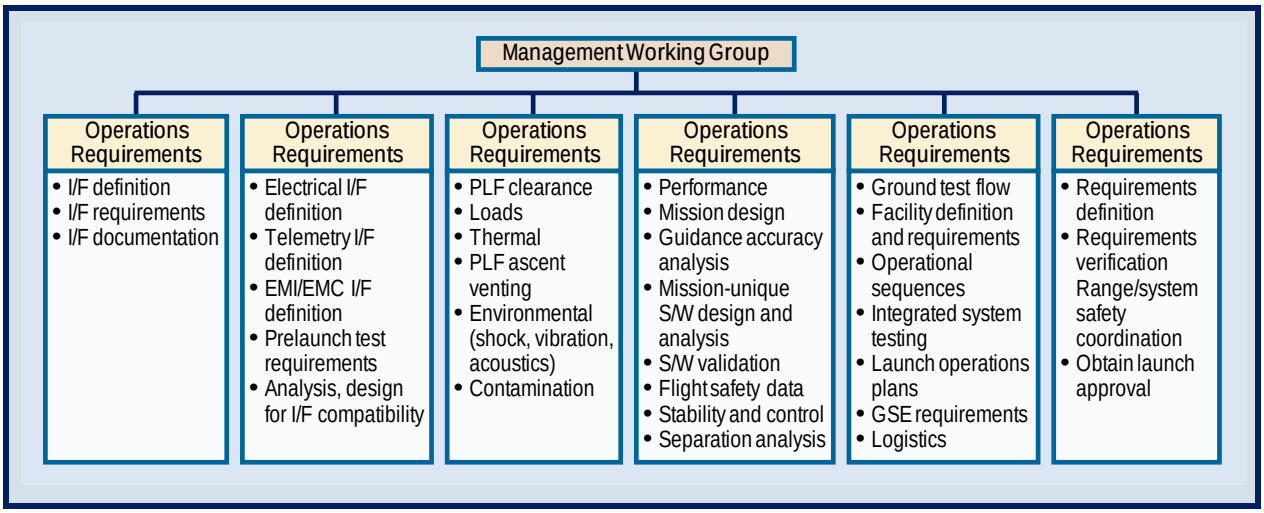


Figure 7.1-1. Mission Integration Working Groups and Responsibilities

Management Working Group—The technical and program managers compose the Management Working Group (MWG). Representatives from LM and the launch services customer attend the MWG, which convenes approximately quarterly. The LM MWG senior member is the Mission Manager, who is supported by members of the LM staff as required. This group is responsible for coordinating and managing the work of all participants throughout each phase of the mission, it establishes policies and integration guidelines, and it provides an overall program review. The group also manages the mission integration schedule, which monitors interface documentation, analyses documentation, hardware interchange, and systems and launch operations integrated tests.

Technical Working Groups—Technical Working Groups (TWGs), which operate under MWG authority, are organized by function. It should be noted that technical personnel frequently participate in multiple working groups, where qualifications allow, in order to minimize the personnel requirements of the participating contractor. In general, the TWGs convene as often as necessary to coordinate integration tasks and schedules. Meeting objectives include development of data exchange lists, a review of outstanding action items, a status of scheduled activities, and a discussion of outstanding issues or concerns.

7.1.5 Integration Program Reviews

Reviews focus management attention on significant milestones during the launch system design and launch preparation process. As with the working group meetings, users can tailor these reviews to meet their requirements; however, for a first-of-a-kind launch, they may include a preliminary and mission-peculiar Critical Design Review (CDR) and a Mission Readiness Review (MRR). In our extensive experience with various spacecraft contractors, we have found that one Mission-Peculiar Design Review (MPDR) can successfully meet the objectives that required both the Preliminary Design Review (PDR) and CDR in the past.

7.1.6 Integration Control Documentation

Program Master Schedule—LM develops this top-level schedule from the tasks and requirements identified during the initial integration meetings, all participating organizations and working groups use it to develop and update sub-tier schedules, and the MWG monitors its progress. It maintains visibility and control of all major program milestone requirements, including working group meetings, major integrated reviews, design and analysis requirements, and major launch operations tests.

Interface Control Document—This document defines spacecraft-to-LV and launch complex interfaces and catalogs all mission-peculiar technical and functional requirements. LM prepares the ICD, which is under configuration control after formal signoff.

7.2 MISSION INTEGRATION ANALYSIS

In support of most given missions, LM performs the standard integration analyses summarized in Table 7.2-1. This table indicates the specific output of the analyses to be performed, required spacecraft data, the timing of analysis completion during the appropriate integration cycle, and the application of the analyses to first-of-a-kind and follow-on missions. In this context, a follow-on mission is an exact copy of a previous mission, with no change to the functional requirements or physical interfaces. We can develop mission-peculiar analyses if needed.

Table 7.2-1. LM Standard Integration Analyses

Analysis	Spacecraft Data	Analysis Products	# Cycles	Schedule	First-of-Its-Kind	Follow-On
Coupled Loads	S/C dynamic math model	• S/C loads • Dynamic loss of clearance	2	Model delivery + 4 months	X	
Integrated Thermal	S/C geometric and thermal math models, power dissipation profile	• S/C component temperature • Prelaunch gas condition and set points	1	Model delivery + 6 months	X	
PLF Venting	S/C venting volume	• Press profiles • Depressurization rate	1	S/C data + 2 months	X	
Critical Clearance	S/C geometric model, S/C dynamic model	• S/C-to-PLF loss of clearance (dynamic + static)	2	S/C model delivery + 4 months	X	
PLF Jettison Clearance	S/C geometric model	• Payload clearance margin during PLF jettison event	1	Design Review	X	
S/C Separation and Clearance	S/C mass properties	• S/C separation clearance • S/C separation attitude, rate, spin-up verification	1	Design Review	X	
Post-separation clearance		• LV and S/C separation history	1	Design Review	X	
Pyro Shock	S/C interface definition	• S/C shock environment	1	Design Review	X	
Acoustics	S/C geometry fill factors	• S/C acoustics environment	1	Design Review	X	
EMI/EMC	• S/C radiated emissions curve • S/C radiated susceptibility curve • S/C reception, operation, and demise thresholds • S/C diplexer rejection	• Margin confirmations	1	Design Review	X	
Contamination	S/C contamination limits for sensitive, critical vertical and horizontal surfaces	• Contamination analysis • Contamination assessment	1	Design Review	X	
RF Link Compatibility and Airborne Telemetry Coverage	S/C transmitter and receiver characteristics	• Link margins • ARIA positioning requirements	1	Design Review	X	

Table 7.2–1. LM Standard Integration Analyses (continued)

Analysis	Spacecraft Data	Analysis Products	# Cycles	Schedule	First-of-Its-Kind	Follow-On
RF Link Compatibility and Ground Telemetry Coverage	S/C transmitter and receiver characteristics	• Link margins • Identify required hardware	1	Design Review	X	
Performance	S/C mass and mission requirements definition	• Trajectory analysis report	3	ATP + 3 months (Design Review Final Targeting)		X
Stability		• Control system margins • ACS use	1	L-2 months		
Mass Properties		• LV mass properties	1	Coincident with Performance Reports		X
Trajectory Analysis	S/C mass and mission requirements definition	• LV reference trajectory • Performance margin	1	Design Review	X	X
Guidance Analysis	Mission requirements	• VeGA • Mission targeting cap and accuracies	1	Design Review	X	
Injection Accuracy	Mission requirements	• LV system orbit injection accuracy	1	Design Review	X	
Launch Window	Window definition	• Window durations	1	Design Review	X	X
Wind Placard	S/C mass properties	• LV ground and flight winds restrictions	1	Design Review	X	
Range Safety	S/C breakup data and propulsion characteristics	• Trajectory data and tapes for Range approval	2	L-1 year (Preliminary) L-7 weeks (Final)		
Electrical Compatibility	Electrical interface requirements	• End-to-end circuit analysis	1	Design Review	X	X
Postflight		• Flight evaluation of mission data, LV performance, and environment	1	L+60 days		
Destruct System		• Confirmation of meeting Range Safety requirements	1	Design Review	X	
Mission Targeting	Orbit requirements	• VeGA I-loads	1	L-1 month		X
Flight Software	Mission requirements	• Flight software	1	L-3 weeks		X

7.2.1 Coupled Loads Analysis

LM performs mission-peculiar coupled loads analyses where LV and payload parameters may be affected. Included are:

1. Spacecraft loading and loss of clearance evaluation for the critical flight events of all motor ignition and resonance events
2. Flight wind launch availability assessment
3. Payload Fairing (PLF) jettison evaluation applicable to a mission spacecraft.

Analysis of all events uses state-of-the-art finite element models of the launch vehicle coupled with a customer-supplied dynamic math model of the spacecraft. Appendix A of this document contains a description of the type and format of the dynamic model.

7.2.2 Integrated Thermal Analysis—Preflight and Flight

LM performs an integrated LV and spacecraft analysis of the thermal environments the spacecraft experiences under prelaunch conditions and for flight mission phases up to spacecraft separation. Analyses include assessment of vehicle aeroheating, PLF surface temperature ranges, maximum and minimum prelaunch air conditioning temperatures and velocities, and spacecraft-to-LV interface temperature ranges, all intended to allow missions design that keeps predicted spacecraft temperatures within allowable limits.

The Integrated Thermal Analysis (ITA) utilizes customer-supplied spacecraft geometric and thermal math models and a detailed spacecraft power dissipation timeline. LM performs PLF aeroheating and Free Molecular Heating (FMH) analyses to verify compliance with customer ICD thermal requirements and thermal requirements derived from the ITA. Also, engineers select PLF jettison time to meet the spacecraft FMH constraint. Athena missions ensure a benign spacecraft thermal environment by determining jettison time based on a flight program calculation of 3-sigma maximum qV during flight.

7.2.3 Payload Fairing Venting Analysis (Ascent Phase)

LM performs a venting analysis on the PLF to determine the mission-peculiar pressure profiles in the payload compartment during LV ascent. Engineers use existing models, previously validated with flight data, for this analysis. The analysis incorporates the customer-supplied spacecraft venting configuration and any mission-specific PLF requirements (e.g. thermal shields). The customer receives analysis outputs such as PLF pressure profiles and depressurization rates as a function of flight time.

7.2.4 Critical Clearance Analysis (Loss of Clearance)

Engineers perform a spacecraft-to-LV loss of clearance analysis with the coupled dynamic loads analysis. The clearance loss, as a result of the dynamic response of the spacecraft and LV during major events, combines with static deflections, manufacturing stack-up tolerances, and misalignments. LM compares these values with the allowable payload envelope.

7.2.5 Payload Fairing Jettison and Loss of Clearance Analyses

LM performs verification of payload clearance during PLF jettison using the effects of thermal preload, disconnect forces, shear pin forces, actuator forces, and dynamic response in a fully 3-D nonlinear analysis.

7.2.6 Spacecraft Separation Analysis

Extensive Monte Carlo analysis of the pre-separation dynamics, using a 3-DOF simulation of the vehicle, demonstrates compliance with all spacecraft attitude pointing and angular rate and spin rate requirements under nominal and 3-sigma dispersions. A two-body 6-DOF Monte Carlo simulation of the LV and spacecraft separation event using finalized spacecraft mass properties verifies that the Orbit Adjust Module (OAM) will not re-contact the spacecraft after separation system release. This analysis demonstrates the minimum relative separation velocity, ensuring that adequate separation distance is achieved before initiating any post-separation OAM maneuvers.

7.2.7 Spacecraft Post-separation Clearance Analysis

After the spacecraft has separated from the LV, the Athena OAM performs a Collision and Contamination Avoidance Maneuver (CCAM). The CCAM design positively precludes physical re-contact with the spacecraft and eliminates the possibility of significant impingement of OAM effluents on the spacecraft. The typical CCAM maneuver involves turning the OAM normal to the spacecraft flight plane and firing the hydrazine thruster to depletion in an attempt to de-orbit the OAM as much as possible and to prevent hydrazine tank rupture.

7.2.8 Pyroshock Analysis

The spacecraft pyroshock environment is maximized for the spacecraft separation event. PLF separation and LV staging are also significant events, but the distances of the shock sources from the spacecraft and LV interface make them less severe for the spacecraft than activation of the payload separation system.

7.2.9 Acoustic Analysis

Analysis of the acoustic environment of the payload compartment accounts for effects of noise reduction of the PLF and payload fill factors. Verification includes flight measurements taken from flight and ground acoustic tests of representative PLF/payload configurations.

7.2.10 Electromagnetic Interference/Electromagnetic Compatibility Analysis

LM maintains an Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) plan to facilitate integration of all avionics equipment. This plan covers requirements for bonding, lightning protection, wire routing and shielding, and procedures. LM analyzes both intentional and unintentional Radio Frequency (RF) sources to confirm 6-dB margins with respect to all general EMI/EMC requirements. In addition, engineers perform an Electro-Explosive Device (EED) RF susceptibility analysis to ensure compliance with the Range requirements. This analysis confirms the 20-dB margin with respect to the EED no-fire power.

7.2.11 Contamination Analysis

Starting from PLF encapsulation through spacecraft separation, personnel identify and analyze contamination sources, including the LV. This assessment offers a first-order contamination analysis to allow the spacecraft user to determine final on-orbit contamination budgets. LM also implements a contamination control plan that ensures hardware cleanliness from the manufacturing phase through launch operations by specifying and implementing material control, ground support hardware cleanliness, and contamination monitoring.

7.2.12 RF Link Compatibility and Telemetry Coverage Analysis (Airborne)

LM conducts an airborne analysis on all RF links between ground stations and the Athena LV: the S-band telemetry system, the active C-band vehicle tracking system, and the Flight Termination System. LM uses a program that accounts for airborne and ground station equipment characteristics and vehicle position and attitude. Engineers analyze the transmit frequencies and their harmonics for potential interference to each active receiver. The spacecraft contractor contributes details of the active transmitters and receivers to the analysis of strong site sources, such as C-band radar. When missions require Advanced Range Instrumentation Aircraft, LM analyzes the mission support positions of the aircraft to maximize link capabilities.

7.2.13 RF Link Compatibility and Telemetry Coverage Analysis (Ground)

LM conducts a ground link analysis on the spacecraft RF systems to ensure that a positive link exists between the spacecraft and the spacecraft checkout equipment to check out the spacecraft telemetry and command system.

7.2.14 Performance Analysis

Our trajectory simulation program, POST II, evaluates the capability of the Athena LV to place the spacecraft into the required orbit(s). Our configuration, performance, and weight status report—tailored to accommodate the needs of specific missions—details vehicle performance capability and provides a comprehensive listing of the vehicle configuration, mission-peculiar ground rules and inputs, and vehicle masses for performance analysis. We offer the detailed trajectory simulation used for the performance assessment as an appendix to this report.

7.2.15 Stability and Control Analysis

Linear stability analysis—primarily frequency response—and nonlinear time-varying 6-DOF simulation determine the Athena autopilot configurations; establish gain and filter requirements for satisfactory rigid body, slosh, and elastic mode stability margins; verify vehicle/launch stand clearances; and demonstrate OAM Attitude Control System maneuver and attitude-hold capabilities. We evaluate uncertainties affecting control system stability and performance through a rigorous stability dispersion analysis. Applying tolerances to vehicle and environmental parameters and performing analysis with frequency response methods allows the team to ensure that the Athena autopilot maintains robust stability throughout the defined mission.

7.2.16 Mass Properties Analysis

LM performs mass properties analysis, reporting, and verification to support performance evaluation, structural loads analysis, control system software configuration development, ground operations planning, airborne shipping requirements, and customer reporting requirements.

7.2.17 Trajectory Analysis and Design

The LM trajectory design process ensures that all spacecraft, LV, and Range imposed environmental and operational constraints are met during flight, while simultaneously providing performance efficient flight designs. It provides the basis, by the simulation of non-nominal vehicle and environmental parameters, for injection accuracy analysis. Telemetry coverage assessment, RF link margins, PLF venting, and in-flight thermal analyses also rely on the reference mission design. The status report documents the process and includes detailed insight into the tradeoffs used for the trajectory design.

7.2.18 Guidance Analysis

Engineers perform analyses to demonstrate that designs satisfy spacecraft guidance and navigation requirements. Analyses encompass targeting, standard and extreme vehicle dispersions, and guidance accuracy. The targeting analysis verifies that the guidance program achieves all mission requirements across launch windows throughout the launch opportunity. Standard vehicle dispersion analysis demonstrates that guidance algorithms are insensitive to 3-sigma vehicle dispersions by showing that the guidance program compensates for these dispersions while minimizing orbit insertion errors. Selecting extreme vehicle dispersions and failure modes stresses the guidance program and demonstrates that the guidance software capabilities far exceed the vehicle capabilities.

7.2.19 Injection Accuracy Analysis

The guidance accuracy analysis combines vehicle dispersions and guidance hardware and software error models to evaluate total guidance system injection accuracy. Hardware errors model the off-nominal effects of the guidance system gyros and accelerometers. Software errors include Inertial Measurement Unit computation errors and vehicle dispersion effects, and simulations use positive and negative dispersions of more than 30 independent vehicle and atmospheric parameters to perturb vehicle performance.

7.2.20 Launch Window Analysis

Launch window analyses verify that the launch team understands each of the LV and spacecraft launch constraints. LM requests that customers determine the opening and closing times for the maximum launch window the spacecraft can support, and provide all more complicated window constraints, such as precise control of the Right Ascension of the Ascending Node, for our analysis.

7.2.21 Wind Placard Analysis (Prelaunch, Flight)

The Athena team has performed stress analyses of the Athena configurations to determine loading for both ground and flight wind conditions. We use this information, combined with launch site wind statistics, to determine the wind placards and subsequent launch availability for any given launch date.

7.2.22 Range Safety Analyses

LM performs the flight analyses required to comply with Range Regulations for both the request for preliminary Flight Plan Approval (FPA) and the more detailed submittal for final FPA. These submittals occur approximately one year before launch for the initial request and approximately 45 days before launch for the second. The Athena team provides reports and magnetic tapes of the required information to the Range agency and includes nominal and non-nominal trajectories and the impact locations of jettisoned hardware. During spacecraft integration, we prepare a Range support plan to document our planned coverage.

7.2.23 End-to-End Electrical Compatibility Analysis

LM conducts an end-to-end electrical circuit analysis to verify proper voltage/current parameters as well as any required timing/sequencing interfaces between all the spacecraft and LV airborne interfaces (through to the end function). This analysis requires data from the spacecraft, such as pin assignments, wiring interfaces, and first level circuit detail of avionics to verify spacecraft to LV compatibility. As part of the ICD verification process, we document this analysis and use it to generate inputs for all necessary launch site interface testing.

7.2.24 Postflight Data Analysis

For Athena missions, LM uses available flight test data to obtain the individual stage payload performance capabilities. Principal inputs into the postflight analysis include times of key vehicle mark events and flight telemetry data of the actual variables as functions of time from the onboard flight computer. The actual vector states of radius and velocity at stage shutdown, compared to the predicted nominal values, provide sufficient knowledge to obtain the LV stage performance.

Other main outputs of the analysis are the average thrust and specific impulse of the stages. The postflight report provides an assessment of the injection conditions in terms of orbital parameters and deviations from the target values, details spacecraft separation attitude and rates, and documents the payload environments—including interface loads, acoustics, vibration, and shock—to the extent that the LV instrumentation permits. In addition, the postflight performance report presents historical data for past flights of similar family and the statistics of the outputs of principal interest.

7.2.25 Destruct System Analysis

LM updates the airborne segment of the detailed description of the Athena Range Safety system, including a full analysis of system safety and reliability for each mission, as required. The analysis contains the qualification status of each component and a summary of component and system-level testing. The analysis also addresses worst-case component, battery, cordage, connectors, firing, squib parameters, and timing. It evaluates the tolerance to single-point failure, RF pattern capability, critical resistance, RF sensitivity, Voltage Standing Wave Ratio, and insertion loss. We ensure our Range Safety system is compliant with the program and range requirements.

7.2.26 Mission Targeting

Engineering analysts conduct mission targeting to define the target orbit parameters that guide the LV into the desired orbit. This process requires a target specification from the spacecraft agency and results in the publication of the Velocity Guidance Algorithm I-loads, integrated into the mission-peculiar flight software, and used to load the flight processor package and the mission-peculiar discrete command events.

7.2.27 Mission-Peculiar Flight Software

Our mission-peculiar software activity is a controlled process that ensures the generation and release of the flight software to support the launch schedule. The flight software baseline encompasses all the functionality needed to fly most typical Athena missions, and our modular software design minimizes the impact of changes resulting from mission-peculiar requirements. At LM, we use a mature system of development and controls, in-place and operational for all missions, to customize a reliable, tested product specifically designed to satisfy new mission requirements.

A complete software validation test program uses the specific mission trajectory to validate the flight software for nominal, 3-sigma dispersed, severe stress, and failure-mode environments before flight. We complete testing and validation in our Hardware-in-the-Loop Laboratory, which includes flight-like avionics components.

7.3 POLICIES

Management, integration, and production policies ensure efficient integration and launch of the customer's payload.

7.3.1 Launch Vehicle Logos

As part of our standard launch service, the Athena program offers customers the option of placing a mission or company logo almost anywhere on the cylindrical section of that mission's PLF hardware. Delivery of the customer PLF logo design is a schedule milestone required to support nominal assembly spans for PLF fabrication. In certain circumstances, LM may accommodate logo changes or modifications the customers propose after this milestone.

7.3.2 Launch Scheduling

LM completes contracts and schedules missions into available launch opportunities, typically 24 months in advance. Early contract completion increases the probability that a desired schedule position will be available. Figure 7.3-1 is our preliminary Athena schedule.

Scheduling and rescheduling launches in the manifest requires the equitable treatment of all customers. Sequential scheduling of launches in the queue, the customer's position in the queue, and vehicle processing flow time dictate earliest launch date(s). LM endeavors to fill each position in the queue. Consequently, once in queue, the customer must coordinate closely with the Athena team for rescheduling purposes.

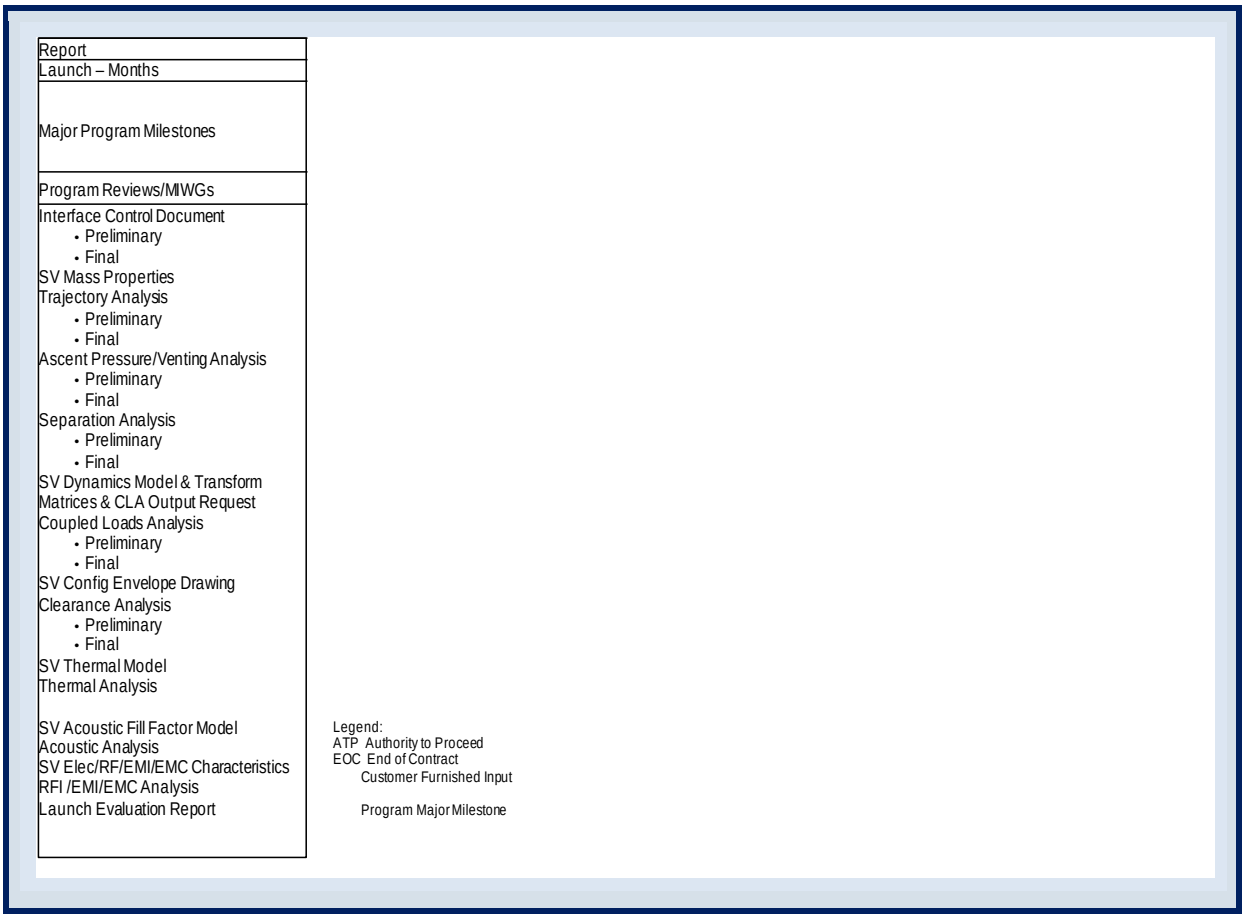


Figure 7.3-1. Preliminary Athena Mission Schedule

7.3.3 Spacecraft Launch Window Options

The Athena vehicle can launch at any time of the day, year round. However, the launch time should consider seasonal weather patterns while setting launch windows, when possible. Also, the Athena team can accommodate any launch window duration, but we recommend a window of between 45 minutes and 120 minutes. Shorter windows increase the risk of a launch delay if they are exceeded due to weather or technical problem resolution. Crew rest requirements may limit windows longer than four hours.

8.0 SYSTEM ENHANCEMENTS

Athena system enhancements discussed in this section are available to the customer to support specific mission requirements. The Athena team will inform the customer about cost savings or additions associated with these enhancements.

8.1 MODEL 120 PAYLOAD FAIRING

LM has investigated the use of a 120-in. (3,048-mm) diameter Payload Fairing (PLF), designated the Model 120. Engineers have designed the Model 120 PLF for use on the Athena IIc to accommodate larger and heavier payloads. The Model 120 PLF can support specific mission requirements in approximately 18 months.

8.1.1 Payload Fairing Usable Volume

The PLF dynamic envelope accounts for structural tolerances, as well as static and dynamic deflections. Clearance at the aft end of the envelope is necessary to accommodate the "boat tail" during PLF jettison. Figure 8.1-1 shows the dynamic envelope of the Model 120 PLF with the Model 66 Payload Adapter (PLA). Any of the three standard PLAs—Models 38, 47, and 66—is compatible with the Model 120 PLF.

8.2 ALTERNATE LAUNCH SITES

LM is investigating the use of alternate launch sites to achieve additional inclinations using launch azimuths not available from our launch sites at Cape Canaveral Air Force Station and Kodiak Launch Complex, and to enhance launch site flexibility. We are considering Wallops Flight Facility (WFF) and Vandenberg Air Force Base (VAFB), among others.

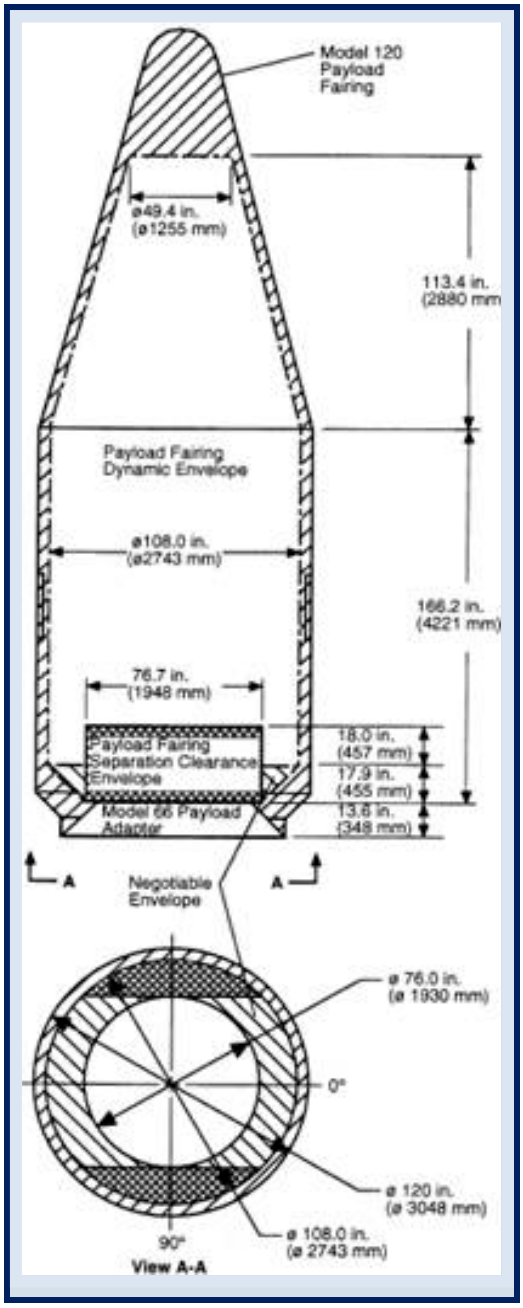


Figure 8.1-1. Model 120 PLF

APPENDIX A—SPACECRAFT DATA REQUIREMENTS

The items listed in this appendix are the preliminary information required for spacecraft integration and launch activities. Additional information may be required for specific spacecraft.

A.1 INTERFACE CONTROL DOCUMENT INPUTS

Table A.1-1 indicates the spacecraft information required to assess the compatibility of the spacecraft with the Athena Ic and IIc. The customer usually provides data in the form of an Interface Requirements Document (IRD) and are the basis for preparing the Interface Control Document (ICD). Shaded items should be provided for a preliminary compatibility assessment, while all items should be completed for a detailed assessment. The shaded items are typically supplied for the spacecraft before a proposal is offered for Athena Launch Services. These lists are generalized and apply to any candidate mission. In cases in which Lockheed Martin (LM) has previous experience with the spacecraft bus or spacecraft contractor, less information can be initially provided, (assuming the spacecraft contractor is willing to use a "same as mission" designation for purposes of assessing preliminary compatibility. A complete IRD is typically supplied within 30 days of contract signing.

Table A.1-1. Spacecraft Information Worksheet (Part 1 of 3)

Spacecraft Name:	Spacecraft Manufacturer:
Spacecraft Owner:	Spacecraft Model No.:
Name of Principal Contact:	Number of Launches:
Telephone Number:	Date of Launches:
Date:	

SPACECRAFT DESIGN PARAMETER	ENGLISH UNITS	METRIC UNITS
TRAJECTORY REQUIREMENTS		
• Spacecrafts Mass	_____ lbm	_____ kg
• Minimum Spacecrafts Lifetime	_____ yrs	_____ yrs
• Final Orbit Apogee	_____ nmi	_____ km
• Final Orbit Perigee	_____ nmi	_____ km
• Final Orbit Inclination	_____ deg	_____ deg
• Propulsion—Propellant Type, Orbit Insertion		
• Propulsion—Propellant Type, Stationkeeping		
• Propulsion—Multiple Burn Capability (Y/N)		
• Propulsion—Propellant Mass	_____ lbm	_____ kg
• Propulsion—Effective I_{sp}	_____ s	_____ s
• Maximum Apogee Allowable	_____ nmi	_____ km
• Minimum Perigee Allowable	_____ nmi	_____ km
• Argument of Perigee Requirement	_____ deg	_____ deg
• Right Ascension of Ascending Node Requirement	_____ deg	_____ deg
• Apogee Accuracy Requirement	_____nmi	_____ km
• Perigee Accuracy Requirement	_____ nmi	_____ km
• Inclination Accuracy Requirement	_____ deg	_____ deg
• Argument of Perigee Accuracy Requirement	_____ deg	_____ deg
• Right Ascension of Ascending Node Accuracy Requirement	_____ deg	_____ deg
MECHANICAL INTERFACE		
• Spacecraft Mechanical Drawing (Launch Configuration)		
• Spacecraft Effective Diameter	_____ in.	_____ mm
• Spacecraft Height	_____ in.	_____ mm
• Spacecraft/Launch Vehicle Interface Diameter	_____ in.	_____ mm
• Payload Sep System Supplier (Spacecraft or Launch Vehicle)		
• Payload Adapter Supplier (Spacecraft or Launch Vehicle)		
• Maximum Spacecraft Cross-Sectional Area	_____ ft^2	_____ m^2
• Number & Size Payload Fairing Access Doors	_____ in. x in.	_____ mm x mm
• Preseparation RF Transmission Requirement	_____ band	_____ band

Note: For a preliminary compatibility assessment, all dark blue shaded items should be completed.
For a detailed compatibility assessment, all items should be completed.

Table A.1–1. Spacecraft Information Worksheet (Part 2 of 3)

SPACECRAFT DESIGN PARAMETER	ENGLISH UNITS	METRIC UNITS
ELECTRICAL INTERFACE		
• Spacecraft Electrical Drawing		
• Number of Launch Vehicle signals Required		
• Number of Separation Discretes Required		
• Number of Umbilicals & Pins/Umbilical		
• Curve of Spacecraft-Induced Electric Field-Radiated Emissions	_____ MHz	_____ dBμ V/m
• Curve of Spacecraft-Radiated Susceptibility	_____ MHz	_____ dBμ V/m
• Number of Instrumentation Analogs Required		
THERMAL ENVIRONMENT		
• Prelaunch Ground Transport Temperature Range	_____ °F	_____ °C
• Prelaunch Launch Pad Temperature Range	_____ °F	_____ °C
• Maximum Prelaunch Gas Impingement Velocity	_____ ft/s	_____ m/s
• Maximum Ascent Heat Flux	_____ Btu/hr·ft^2	_____ W/m^2
• Maximum Fee-Molecular Heat Flux	_____ Btu/hr·ft^2	_____ W/m^2
• Maximum Fairing Ascent Depressurization Rate	_____ psi/s	_____ mbar/s
• Spacecraft Vented Volume(s)	_____ ft^3	_____ m^3
• Spacecraft Vent Area(s)	_____ in.^{2}	_____ cm^2
• Prelaunch Relative Humidity Range	_____ %	_____ %
• Pre-separation Spacecraft Power Dissipation	_____ Btu/hr	_____ W
• Maximum Free-Stream Dynamic Pressure	_____ psi	_____ mbar
DYNAMIC ENVIRONMENT		
• Maximum Allowable Flight Acoustics	_____ dB OA	_____ dB OA
• Allowable Acoustics Curve		
• Maximum Allowable Sine Vibration	_____ G_{RMS}	_____ G_{RMS}
• Allowable Sine Vibration Curve	_____ G_{RMS}	_____ G_{RMS}
• Maximum Allowable Shock	_____ g	_____ g
• Allowable Shock Curve		
• Maximum Acceleration (Static + Dynamic) Lateral	_____ g	_____ g
• Maximum Acceleration (Static + Dynamic) Longitudinal	_____ g	_____ g
• Fundamental Natural Frequency—Lateral	_____ Hz	_____ Hz
• Fundamental Natural Frequency—Longitudinal	_____ Hz	_____ Hz
• cg—Thrust Axis (Origin at Separation Plane)	_____ in.	_____ mm
• cg—Y Axis	_____ in.	_____ mm
• cg—Z Axis	_____ in.	_____ mm
• cg Tolerance—Thrust Axis	_____ ±in.	_____ ±mm
• cg Tolerance—Y Axis	_____ ±in.	_____ ±mm
• cg Tolerance—Z Axis	_____ ±in.	_____ ±mm
CONTAMINATION REQUIREMENTS		
• Fairing Air Cleanliness	_____ Class	_____ Class
• Maximum Deposition on Spacecraft Surfaces	_____ oz/ft^2	_____ mg/m^2
• Outgassing—Total Weight Loss	_____ %	_____ %
• Outgassing—Volatile Condensable Material Weight Loss	_____ %	_____ %
SPACECRAFT DESIGN SAFETY FACTORS		
• Airborne Pressure Vessel Burst Safety Factor		
• Airborne Pressure System Burst Safety Factor		
• Structural Limit (Yield) Safety Factor		
• Structural Ultimate Safety Factor		
• Battery Burst Safety Factor		
SPACECRAFT QUALIFICAITON TEST PROGRAM		
• Acoustic Qualification	_____ +dB	_____ +dB
• Sine Vibration Qualification Safety Factor		
• Shock Qualification Safety Factor		
• Loads Qualification Safety Factor		

Note: For a preliminary compatibility assessment, all dark blue shaded items should be completed.
For a detailed compatibility assessment, all items should be completed.

Table A.1–1. Spacecraft Information Worksheet (Part 3 of 3)

SPACECRAFT DESIGN PARAMETER	ENGLISH UNITS	SI UNITS
ORBIT INJECTION CONDITIONS		
• Range of Separation Velocity	_____ ft/s	_____ m/s
• Max Angular Rate at Separation—Roll	_____ rpm	_____ rpm
• Max Angular Rate Uncertainty—Roll	_____ ±rpm	_____ ±rpm
• Max Angular Rate at Separation—Pitch & Yaw	_____ rpm	_____ rpm
• Max Angular Rate Uncertainty—Pitch & Yaw	_____ ±rpm	_____ ±rpm
• Max Angular Acceleration	_____ rad/s^2	_____ rad/s^2
• Max Pointing Error Requirement	_____ deg	_____ deg
• Max Allowable Tip-Off Rate	_____ deg/s	_____ deg/s
• Coefficients of Inertia—I_{XX} (X=Thrust Axis)	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{XX} Tolerance	_____ ±slug ft^2	_____ ±kg m^2
• Coefficients of Inertia—I_{YY}	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{YY} Tolerance	_____ ±slug ft^2	_____ ±kg m^2
• Coefficients of Inertia—I_{ZZ}	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{ZZ} Tolerance	_____ ±slug ft^2	_____ ±kg m^2
• Coefficients of Inertia—I_{XY}	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{XY} Tolerance	_____ ±slug ft^2	_____ ±kg m^2
• Coefficients of Inertia—I_{YZ}	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{YZ} Tolerance	_____ ±slug ft^2	_____ ±kg m^2
• Coefficients of Inertia—I_{XZ}	_____ slug ft^2	_____ kg m^2
• Coefficients of Inertia—I_{XZ} Tolerance	_____ ±slug ft^2	_____ ±kg m^2

Note: For a preliminary compatibility assessment, all dark blue shaded items should be completed.
For a detailed compatibility assessment, all items should be completed.

Table A.1-2, Table A.1-3, Table A.1-4, Table A.1-5, Table A.1-6, Table A.1-7, and Table A.1-8 delineate spacecraft data required after contract signature to start integration of the spacecraft. The asterisks in these tables indicate data desired at an initial meeting between LM and the customer. This data will provide the detailed information required to fully integrate the spacecraft with the launch vehicle and determine such items as optimum mission trajectory, and verify compatibility of the launch vehicle environments and interfaces.

Table A.1-2. Mission Requirements

TYPE OF DATA	SCOPE OF DATA
Number of launches*	
Frequency of launches*	
Spacecraft orbit Parameters including tolerances (park orbit, transfer orbit)*	• Apogee altitude • Perigee altitude • Inclination • Argument of perigee • RAAN
Launch window constraints **• Pre-separation function*** **• Separation parameters (Including tolerances)***	• Pre-arm • Arm • Spacecraft equipment deployment timing, and constraints • Acceleration constraints (pitch, yaw, roll) • Attitude constraints • Spin-up requirements • Desired spin axis • Angular rate of spacecraft • Orientation (pitch, yaw, roll axes) • Acceleration constraints
Any special trajectory requirements	• Boost phase • Coast phase • Free Molecular Heating constraints • Thermal maneuvers • Separation within view of telemetry and tracking ground station • Telemetry dip-out maneuvers
Note: *Information desired at initial meeting between LM and customer after contract award	

Table A.1-3. Spacecraft Characteristics (Part 1 of 2)

TYPE OF DATA	SCOPE OF DATA
Configuration Drawings*	• Drawings showing the configuration, shape, dimensions, and protrusions into the mounting adapter (ground launch and deployment configurations) • Coordinates (spacecraft relative to launch vehicle) • Special clearance requirements
Apogee Kick Motor*	• Manufacturer's designation • Thrust • Specific impulse • Burn action time • Propellant offload limit
Mass Properties (Launch and Orbit Configurations)*	• Weight—specify total, separable, and retained masses • Center of Gravity—specify in 3 orthogonal coordinates parallel to the booster roll, pitch, and yaw axes for total, separable, and retained masses • Changes in cg resulting from deployment of appendages • Propellant slosh models
Moments of Inertia (Launch and Orbit Configurations)	• Specify about the axes through the spacecraft cg that are parallel to the Athena roll, pitch, and yaw axes for total, separable, and retained masses
Structural Characteristics	• Spring ratio of structure, elastic deflection constants, shear stiffness, dynamic model, bending moments and shear loads at spacecraft-to-launch-vehicle interface and limitations to include acoustic, shock, acceleration, temperature, and bending moments
Dynamic Model for 3-D Loads Analysis	• Generalized stiffness matrix • Generalized mass matrix • Description of the model, geometry, and coordinate system • Loads transformation matrix **Note**: Models must include rigid body and normal modes
Handling Constraints	• Spacecraft orientation during ground transport • Spacecraft handling limits (e.g., acceleration constraints)
Spacecraft Critical Orientation During:	• Location and direction of antennas checkout, prelaunch, and orbit • Location, look angle, and frequency of sensors • Location and size of solar arrays

Table A.1–3. Spacecraft Characteristics (Part 2 of 2)

TYPE OF DATA	SCOPE OF DATA
Safety Items	**General Systems Description** • Basic spacecraft mission • Prelaunch through launch configuration • Orbital parameters • Electrical and electronic subsystems • Non-ionizing radiation subsystems (RF/laser) • Ionizing radiation subsystems • Hazardous materials • Thermal control subsystems • Acoustical subsystems **Note:** hazard identification/controls/verification method summaries required for each subsystem **GSE Descriptions** • Mechanical GSE • Propellant/propulsion GSE • Pressure GSE • Ordnance GSE • Electrical GSE • RF/laser GSE • Ionizing radiation GSE • Hazardous materials GSE **Note:** hazard identification/controls/verification method summaries required for each item **Ground Operations** • Hazardous ground operations • Procedures • Transport configuration **Note:** identify each item/operation applicable to PPF, HPF, or launch site for each data submittal
Thermal Characteristics	• Spacecraft thermal math model • Emissivity • Conductivity • Resistivity • Thermal constraints (maximum and minimum allowable temperature) • Heat generation (e.g. sources, heat, time of operation)
Contamination Control	• Requirements for ground-supplied services • In-flight conditions (e.g. during ascent and after PLF jettison) • Surface sensitivity (e.g. susceptibility to propellants, gases, and exhaust products)
RF Radiation	• Characteristics (e.g. power levels, frequency, and duration for checkout and flight configuration) • Locations (e.g. location of receivers and transmitters on spacecraft) • Checkout requirements (e.g. open-loop, closed-loop, prelaunch, ascent phase)
Note: *Information desired at initial meeting between LM and customer after contract award	

Table A.1-4. Aerospace Vehicle Equipment Mechanical Requirements

TYPE OF DATA	SCOPE OF DATA
Mechanical Interfaces	• Base diameter of spacecraft interface* • Structural attachments at spacecraft interface* • Required accessibility to spacecraft in mated condition* • Extent of equipment remaining with adapter after spacecraft separation* • Degree of environmental control required • Spacecraft pressurization, fueling system connector type and location; timeline for pressure/fuel system operation • Spacecraft/adapter venting requirements
PLF Requirements	• Heating constraints • Venting characteristics (e.g. quantity, timing, and nature of gases vented from payload) • RF re-radiation system (RF band, spacecraft antenna location, etc.) • PLF separation (e.g. altitude, cleanliness, shock, aeroheating, and airload constraints) • Acoustic environment constraints • Special environmental requirements
Preflight Environment	• PLF separation (e.g. altitude, cleanliness, shock, aeroheating, and airload constraints) • Acoustic environment constraints • Special environmental requirements • Requirements - Cleanliness - Temperature and relative humidity - Air conditioning - Air impingement limits • Monitoring and verification requirements
Umbilical Requirements*	• Separation from launch vehicle • Flyaway at launch • Manual disconnect
Materials	• Special compatibility requirements • Outgassing requirements
Note: *Information desired at initial meeting between LM and customer after contract award	

Table A.1-5. Aerospace Vehicle Equipment Electrical Requirements (Electrical)

TYPE OF DATA	SCOPE OF DATA
Power Requirements (Current, Duration, Function Time, and Tolerances)*	• 28-VDC power • Other power • Over-current protection
Command Discrete Signals	• Number* • Sequence • Timing (including duration, tolerance, repetition rate, etc.) • Voltage (nominal and tolerance) • Frequency (nominal and tolerance) • Current (nominal and tolerance) • When discretes are for EED activation, specify minimum, maximum, and nominal fire current; minimum and maximum resistance; minimum fire time; operating temperature range and manufacturer's identification of device
Other Command and Status Signals	• Status displays • Abort signals • Range safety destruct • Inadvertent separation destruct
Ordnance Circuits	• Safe/arm requirements
Telemetry Requirements	• Quantity of spacecraft measurements required to be transmitted by Athena telemetry and type (e.g. temperature, vibration, pressure, etc.); details concerned with related system including operating characteristics (response definition of system), and locations and anticipated time of operation • Impedance, capacitance, operating range and full-scale range of each measurement • Signal conditioning requirements (e.g. input impedance, impedance circuit load limits, over-current protection, and signal-to-noise ratio) • Discrete events (bi-level) • Analog measurements • Minimum acceptable frequency response for each measurement • Minimum acceptable system error for each measurement (sampling rate is also governed by this requirement) • Period of flight for which data from each measurement are of interest (e.g. from liftoff to space vehicle separation)*
Bonding	• Bonding requirements at interface (MIL-B-5087, Class R for LV) • Material and finishes at interface (for compatibility with LV adapter)
EMC	• Test or analyze spacecraft emissions and susceptibility • EMC protection philosophy for low-power, high-power, and pyrotechnic circuits • LV and site emissions (provided by LM)
Grounding Philosophy	• Structure (e.g. use of structural as ground and current levels) • Electrical equipment (e.g. grounding method for signals and power supplies) • Single-point ground (e.g. location and related equipment)
Interface Connectors	• Connector item (e.g. location and function)* • Connector details • Electrical characteristics of signal on each pin
Shielding Requirements	• Each conductor or pair • Overall • Grounding locations for termination
Note: *Desired for initial integration meeting with LM after contract award	

Table A.1-6. AGE/Facility Mechanical Requirements

TYPE OF DATA	SCOPE OF DATA
Spacecraft Launch Vehicle Integration	• Sequence from spacecraft delivery through mating with the LV • Handling equipment requirements • LM-provided protective covers or work shields requirements • Space envelope, installation, clearance, and work area requirements • Special encapsulation requirements • Support services requirements
Spacecraft Checkout AGE and Cabinet Data	• List of all AGE and locations where used • Installation criteria for AGE items: - Size and weight - Mounting provisions - Grounding and bonding requirements - Proximity to spacecraft when in use - Period of use - Environmental requirements - Compatibility with Range Safety requirements and LV propellants - Access space to cabinets required for work area, door swing, slideout panels, etc. - Cable entry provisions and terminal board types in cabinets and/or interface receptacle locations and types - Power requirements and characteristics of power for each cabinet
Spacecraft Environmental Protection (Preflight)	• Environmental protection requirements (including cleanliness) by area: - Spacecraft room - Transport to Launch Pad - Mating - Inside PLF - During countdown • Air-conditioning requirements for applicable pad area - Temperature range - Humidity range - Particle limitation - Impingement velocity limit - Flow rate • Indicate if space vehicle is not compatible with LV propellants and what safety measures will be required • Environmental monitoring and verification requirements
Space Access Requirements	• Access for space vehicle mating and checkout • Access during transportation to the Launch Pad and erection onto the Athena • Access for checkout and achieving readiness before fairing installation • Access after fairing installation (location, size of opening, and inside reach required) • Access during final countdown (if applicable) • AGE requirements for emergency removal
Umbilicals	• Ground servicing umbilicals by function and location in excess of Athena standard umbilical • Structural support requirements and retraction mechanisms • Installation (supplier, installer, timeline)
Commodities Required for Both Spacecraft, AGE, and Personnel	• Gases, propellants, chilled water, cryogenics in compliance with ozone-depleting chemicals requirements • Source (spacecraft or LV) • Commodities for Personnel
Miscellaneous	• Spacecraft guidance alignment requirements

Table A.1-7. AGE/Facility Electrical Requirements

TYPE OF DATA	SCOPE OF DATA
Space Vehicle Electrical Conductor Data	Spacecraft system schematic showing all connectors required between spacecraft equipment, spacecraft terminal board position or receptacle pin assigned to each conductor; electrical characteristics of each connector including maximum end-to-end resistance, shielding, capacitance, and spare conductors
Electrical Power (AGE and Facility)	• Frequency, voltage, watts, tolerance, source • Isolation requirements • Identify if values are steady or peak loads • High-voltage transient susceptibility
RF Transmission	• Antenna Requirements (e.g. function, location, physical characteristics, beam width, direction, line-of-sight) • Frequency and power transmission • Operation
Cabling	Any cabling, ducting, or conduits to be installed in the Mobile Service Tower; supplier, installer, checkout, and removal personnel
Monitors and Controls	• Specify which spacecraft signals are to be monitored during readiness and countdown • Transmission method (e.g. space craft and LV telemetry) • Location of data evaluation center, evaluation responsibility, measurement limits, and go/no-go constraints; identify where in the operational sequence measurements are to be monitored and evaluated; specify frequency and duration of measurements • Video output characteristics of Telepaks (if available) for closed-loop prelaunch checkout at Launch Pad; data to include location and type of interface connector(s), characteristics of signal at source (voltage level, output impedance, output current limitation, maximum frequency of data train, and output loading requirements)

Table A.1-8. Test Operations

TYPE OF DATA	SCOPE OF DATA
Hardware Needs (Including Dates)	• Electrical simulators • Structural simulators • Master drill Gauge*
Interface Test Requirements	• Structural test • Fit test • Compatibility testing of interfaces (functional) • EMC demonstration • LV/spacecraft RF interference test • Environmental demonstration test
Launch Operations	• Detailed sequence and time span of all spacecraft-related launch site activities including AGE installation, facility installation and activities, spacecraft testing and servicing • Recycle requirements • Restrictions including launch site activity limitations, constrains on LV operations, security requirements, personnel access limitations, safety precautions • Special requirements including handling of radioactive materials, security, access control • Support requirements including personnel, communications, and data reduction • Launch and flight requirements for real-time data readout, postflight data analysis, data distribution, postflight facilities
Note: *Desired for initial integration meeting with LM after contract award	

A.2 SPACECRAFT DESIGN REQUIREMENTS

Table A.2-1 lists specific requirements that should be certified by analysis and/or test by the spacecraft agency to be compatible for launch with the Athena. Should the spacecraft not meet any of these requirements, LM will work with the customer to resolve the incompatibility.

Table A.2-1. Spacecraft Design Requirements

SPACECRAFT DESIGN REQUIREMENTS	COMMENTS
MECHANICAL • PLF envelope • PLA and separation system	
ELECTRICAL • Command and Control interfaces • Telemetry interfaces • Spacecraft separation signals • Spacecraft separation connectors • Spacecraft destruct option	
STRUCTURE AND LOADS • Design load factors • First lateral modes and first axial loads • Spacecraft mass versus CG range • Design Factor of Safety per applicable Range Safety documentation	
ENVIRONMENT • Radiation and electromagnetic • Quasi-sinusoidal vibration • Random vibration • Acoustic levels in the PLF • Shock induced by first-stage ignition and separation events • Ascent aerodynamic heating • PLF depressurization rates • Spacecraft test requirements	
SAFETY • All spacecraft propellant fill-and-drain valves and all pressurant fill-and-vent valves readily accessible when spacecraft is fully assembled and serviced in launch configuration (encapsulated and on Launch Pad) • Requirements in Range Safety regulation	It is advisable to accommodate normal servicing/de-servicing and potential emergency back-out situation for new spacecraft design
MISCELLANEOUS • Spacecraft propellants and pressurant specifications	
Note: Compliance with ozone-depleting chemicals regulation is required	

A.3 SPACECRAFT INTEGRATION INPUTS

Table A.3-1 provides a list of typical spacecraft inputs required for the integration process, the approximate need date, and a brief description of the contents. Further details on some items are provided in the following sections.

A.3.1 Computer-Aided Design Data Transfer Requirements

Computer-Aided Design (CAD) data must be provided according to the specified formats. LM supports two CAD systems: Structural Dynamics Research Corporation's (SDRC) I-DEAS 6.1 or higher and Computervision's (CV) CADDS 4X or CADDS 5. When the CAD data do not come from SDRC or CV, LM prefers to receive an Initial Graphics Exchange Specification (IGES) 4.0 or higher file from a 3-D wireframe system or wireframe extracted from solids.

Table A.3-1. Spacecraft Inputs to Integration Process

S/C DATA INPUT	TYPICAL NEED DATE	COMMENTS
Interface Requirements Document	Program Kickoff	
Initial Target Specification	Program Kickoff	Spacecraft weight, target orbit, separation attitude
Range Safety Mission Orientation Briefing Input	6 weeks before meeting date	Top-level description of the spacecraft and mission design
CAD Model	30 days after Program Kickoff	
Coupled Loads Model	6 months before Design Review	
Preliminary Launch Windows	5 months before Design Review	Target orbit
In-Flight Breakup Data	L-14 months	
Intact Impact Breakup Data	L-14 months	
Preliminary Spacecraft MSPSP	L-14 months	
Spacecraft EMI/EMC Certification Letter	L-6 months	
Spacecraft EED Analysis	L-6 months	
Procedures Used at CCAFS	L-5 months	
Procedures Used at Astrotech	2 months before spacecraft arrival at Astrotech	
Final Target Specification	L-90 days	Date depends on mission design
Spacecraft Environment Quality Test Reports	As available	

The following criteria should be met before transferring CAD or IGES data that do not come from SDRC:

Master Series Model Files—There are two options that can be used in transferring data using SDRC Master Series model files. Both incorporate the use of the "export" command. The following criteria should be met before transferring SDRC Master Series data:

Option 1—Using Archive Files

1. Verify the current revision of software being used. Model files and associated archive files are only upward compatible.
2. Export the model file to an archive file. The archive file is an ASCII file and will contain all assemblies, subassemblies, and parts within the model file. It is recognized by the filename and its ".arc" extension.

Option 2—Using Model Files

1. Verify the current revision of software being used. Model files and associated archive files are only upward compatible. Model files can only be copied between binary-compatible platforms.
2. Export the model file from a project. By exporting the model file (using a file name other than the current model file name), it creates the "mf1," "mf2" and "erf" files that contain all assemblies, subassemblies, and parts within the model file; the "erf" file contains all the attributes of the model file. All three files are necessary for "importing" back into Master Series.

Pre-Master Series Model Files

1. All entries should be visible (unblanked) and fontless (e.g. no center lines, phantom lines, thick lines).
2. Critical construction planes or working coordinate systems should be converted to independent entities.
3. Critical sculpted surfaces should be accompanied by a mesh of checkpoints lying on the surface at a minimum density of at least three points between each patch boundary.
4. Solids coming from systems other than SDRC or CV should be converted to 3-D wireframe and surface entities for the IGES file.

The following criteria should be met before transferring SDRC I-DEAS data:

1. Write a universal file in metric units.
2. Send the model files with the universal file if Level 6.1 was used.
3. All subsystems should reflect a common orientation so that a minimum of orientation work is required when bringing subsystems into upper level systems.
4. If the universal file is written from a larger model file and the "ALL" modifier was not used, the universal file should include pertinent data that could be helpful outside of the systems that are included. This includes working construction geometry, colors, etc.

The following criteria should be met before transferring CV data:

1. Single model files containing 30,000 entities or more should be divided into smaller model files, all having the same origin.

2. Single CADDS 5 models (containing _pd, _fd, vp_links, draw files, and execute routines) should be contained in the same subdirectory structure. The entire directory structure should then be transferred as a single compressed file.
3. No subfigures should be in the model, unless the subfigures are included in the data transfer.

Data Transfer—The preferred transfer method for all data files from any CAD system is file transfer protocol (FTP) via the Internet. This can be accomplished by allowing a LM representative to establish a temporary account on the contractor's computer and allowing retrieval of the files from that system once notified of their completion. An alternative would involve the contractor establishing a temporary account on a LM system and using FTP to transfer the files to the LM machine once completed. In either case, the transfer type should be set to "binary."

If FTP is not feasible, the data can also be supplied directly from UNIX-based systems and written to tape with the default block size of 512 using the tape archive (tar) command syntax as follows:

tar cvf/dev/rmt0 partfiles

The spacecraft contractor should verify that the files contain the correct data by reading the files back onto the originating CAD system from tape before transmittal to LM.

The following information must be sent with the CAD data file regardless of the transfer method:

1. Name and phone number of the computer system administrator/operator
2. Name and phone number of the contact person (who is familiar with the model) if problems or questions arise
3. Size of file (Mb)
4. Number of lines in IGES file
5. List of entities, including total count and types
6. Spacecraft axis and coordinate system
7. Spacecraft access requirements for structure that is not defined on CAD model (i.e., fill and drain valve locations)
8. Multiview plot of the drawing(s)
9. SDRC Data (identify top-level system and bin number; specify all subsystems and their bin numbers if model is not fully assembled into one top-level system)
10. Tapes
11. Data format (e.g. ASCII, CVASCII)
12. Tape drive brand name (e.g. Sun quarter-inch cartridge [QIC], Hewlett-Packard [HP] digital audio tape [DAT], Digital Equipment Corporation [DEC], 8 mm)
13. Blocking factor
14. Number of records.

A.3.2 Coupled Loads Analysis Model Requirements

The customer-supplied dynamic mathematical model of the spacecraft should consist of generalized mass and stiffness matrices and a recommended modal damping schedule. The

desired format is Craig-Bampton, constrained at the space vehicle-to-LV interface in terms of spacecraft modal coordinates and discrete interface points. The dynamics model should have an upper frequency cutoff of 70 Hz. The Output Transformation Matrices (OTM) should be in the form that, when multiplied by the spacecraft modal and interface generalized coordinate responses, will recover the desired accelerations, displacements, or internal loads. One of the OTMs should contain data that will allow calculation of loss of clearance between the PLF and critical points on the spacecraft. Typically, the size of the OTMs is 200 to 500 rows for accelerations, 50 to 200 rows for displacements, and 300 to 1,000 rows for internal loads.

A.3.3 Target Specifications

Target specifications normally include the final mission transfer orbit (apogee and perigee radius, argument of perigee, and inclination); spacecraft mass properties; and launch windows. The final target specifications are due to LM no less than 60 days before launch.

A.3.4 Spacecraft Electromagnetic Interference and Electromagnetic Compatibility Certification Letter and Electroexplosive Device Analysis

A final confirmation of spacecraft transmitter and receiver parameters and emission and susceptibility levels of the electronic systems is required six months before launch. This includes consideration of emissions from such electronic equipment as internal clocks, oscillators, and signal or data generators and susceptibility of both electronics and items such as electroexplosive devices to cause upset, damage, or inadvertent activation. These characteristics are to be considered according to MIL-STD-1541 requirements to ensure that appropriate margins are available during launch operations. LM will use the spacecraft data to develop a final analysis and certification for the combined spacecraft/LV and site environment.

A.3.5 Safety Data

The spacecraft must show compliance with AFSPCMAN 91-710 to receive Range Safety approval to launch from Cape Canaveral Air Force Station or Kodiak Launch Complex. Spacecraft documentation required for submittal to Range Safety is briefly described below. Details of the spacecraft submittals will be coordinated in mission integration working group meetings and other channels during the integration process.

Missile System Prelaunch Safety Package—The Missile System Prelaunch Safety Package (MSPSP) is the data package that describes, in detail, all hazardous and safety-critical systems or subsystems and their interfaces in the spacecraft and its ground support equipment. In addition, the MSPSP provides verification of compliance with AFSPCMAN 91-710. The MSPSP must be approved by Range Safety before the arrival of any spacecraft elements on the launch site.

Spacecraft Launch Site Procedures—All hazardous spacecraft procedures must be approved by Range Safety or by the Astrotech Safety Officer, depending on where the procedures will be used, before they are run. Because the approving authority must also concur in the nonhazardous designation of procedures, all spacecraft launch site procedures must be submitted for review. The LM System Safety group is the customer point of contact for launch site safety authorities.

Radiation Protection Officer Data—Permission must be secured from the Range Radiation Protection Officer before a spacecraft is allowed to radiate RF emissions on pad. The required data includes descriptions of the equipment involved, the procedures that will be used, and data forms on the personnel who will be running the procedures.

Spacecraft Breakup Data Requirements—The data described in the following three subsections are required to perform analyses that satisfy 45th Space Wing/SEY requirements for submitting a request for Range Safety flight plan approval.

Inadvertent Spacecraft Separation and Propulsion Hazard Analysis—This set of data is related to inadvertent separation of the spacecraft during early ascent and the potential for launch area hazard that could exist in the event the spacecraft engine(s) fire. Typical spacecraft propulsion system data provided by the customer include the maximum tanked weight, maximum loaded propellant weight, maximum axial thrust (all motors), and maximum resultant specific impulse.

Intact Impact Analysis—This set of data is related to the ground impact of the spacecraft. The intact impact analysis assumes ground impact of a fully loaded, fueled, intact spacecraft and assumes the propellants combine and explode. Typical spacecraft data provided by the customer include the types and weights of explosive propellants; estimates of the number of pieces of the spacecraft that could break off resulting from an explosion; and locations, size, weight, and shape of each piece.

Destruct Action Analysis—This set of data is related to the flight termination system destruction of the launch vehicle. The destruct action analysis assumes in-flight destruction of the vehicle by detonation of the Range Safety charge. Typical spacecraft data provided by the customer include an estimate of the number of spacecraft pieces that could break off as a result of commanded vehicle destruction and estimates of their size, weight, shape, and mounting location on the spacecraft.

APPENDIX B—ACRONYM LIST

AAC .....Alaska Aerospace Corporation
ACS.....Attitude Control System
AFR.....Air Force Regulation
ALC.....Assistant Launch Conductor
ARIA.....Advanced Radio Instrumentation Aircraft
ASO.....Astrotech Space Operations
ATK .....Alliant Techsystems, Inc.
ATP .....Authority To Proceed
AWG.....American Wire Gauge
BC .....Bolt Circle
C/AW .....Caution and Area Warning
CCAFS.....Cape Canaveral Air Force Station
CCAM.....Collision and Contamination Avoidance Maneuver
CCTV.....Closed-Circuit Television
CDR .....Critical Design Review
CFE .....Customer-Furnished Equipment
CG .....Center of Gravity
CLS .....Commercial Launch Services
CRT.....Computer Remote Terminal
CSC.....Computer Security Center
CSO.....Complex Safety Officer
DLV .....Demonstration Launch Vehicle
DOF.....Degree Of Freedom
EOC.....End of Contract
EED.....Electro-Explosive Device
EGSE.....Electrical Ground Support Equipment
EIA.....Electrical Industries Association
EMC.....Electromagnetic Compatibility
EMI .....Electromagnetic Interference
EOC.....End Of Contract
ER .....Eastern Range
ERB.....Engineering Review Board
ERR.....Eastern Range Regulation
ESMCR.....Eastern Space and Missile Center Regulation
EWR.....Eastern/Western Range Regulation
FAMS.....Flight Analysis Motion Simulator
FBM .....Fleet Ballistic Missile
FMA.....Final Mission Analysis
FMH.....Free Molecular Heating
FPA .....Flight Plan Approval
FRR.....Flight Readiness Review

FS .....First Stage
FSO .....Flight Safety Officer
FSPO .....Flight Safety Performance Officer
FSS .....Fixed Service Structure
FTS.....Flight Termination System
GHe .....Gaseous Helium
GN2.....Gaseous Nitrogen
GNC .....Guidance, Navigation, and Control
GPS .....Global Positioning System
GSE .....Ground Support Equipment
GSO.....Guidance System Observer
GTO .....Geosynchronous Transfer Orbit
HEPA .....High-Efficiency Particulate Air
HPF .....Hazardous Processing Facility
HVAC .....Heating, Ventilation, and Air Conditioning
HVDS.....Hazardous Vapor Detection System
HWIL .....Hardware In-the-Loop
ICD.....Interface Control Document
IF .....Instrumentation Facility
I/F .....Interface
ILC .....Initial Launch Capability
IMU.....Inertial Measurement Unit
IPF.....Integration and Processing Facility
ITA.....Integrated Thermal Analysis
ITC .....Instrument Technology Center
ITD.....Integrated Technology Center
ITS.....Integrated Test Station
IV&V .....Independent Verification and Validation
KLC.....Kodiak Launch Complex
KSC.....Kennedy Space Center
L .....Launch day
LC .....Launch Conductor
LC-46 .....Launch Complex 46
LCC.....Launch Control Center
LEO.....Low Earth Orbit
LEV.....Launch Equipment Vault
LFSA.....Liquid Fuels Storage Area
LM.....Lockheed Martin
LOCC.....Launch Operations Control Center
LRR.....Launch Readiness Review
LSS.....Launch Service Structure
LST .....Launch Support Team
LV .....Launch Vehicle

LVCV.....Launch Vehicle Control Van
LVMP .....Launch Vehicle Mission-Peculiar
MAS.....Mobile Access Structure
MAS.....Mobile Antenna System
MCC.....Mission Control Center
MDC .....Mission Director's Center
MDR .....Mission Dress Rehearsal
MFCO .....Mission Flight Control Officer
MGSE .....Mechanical Ground Support Equipment
MI.....STD- Military Standard
MOC .....Mobile Operations Center
MPDR .....Mission-Peculiar Design Review
MPE .....Maximum Predicted Environment
MRR.....Mission Readiness Review
MSF.....Maintenance Support Facility
MSPSP .....Missile System Prelaunch Safety Package
MTS .....Mobile Telemetry System
MWG .....Management Working Group
NASA.....National Aeronautics and Space Administration
OAM .....Orbit Adjust Module
OAFS .....Onizuka Air Force Station
ODD.....Operations Directive Document
OIS .....Operational Intercom System
ORD .....Operations Requirements Document
OSM.....Operations Safety Manager
PAS .....Payload Adapter System
P/AW.....Paging and Area Warning
PCM .....Pulse Code-Modulated
PDR.....Preliminary Design Review
PID .....Program Introduction Document
P/L.....Payload
PLA .....Payload Adapter
PLCP .....Propellant Leak Contingency Plan
PLF.....Payload Fairing
POST.....Program to Optimize Space Trajectories
PPF.....Payload Processing Facility
PRD.....Program Requirements Document
PSF.....Propellant Servicing Facility
PSP.....Program Support Plan
PTA .....Payload Technical Advisor
PTD .....Payload Technical Director
RF.....Radio Frequency
RMSF.....Rocket Motor Storage Facility

ROCC.....Range Operations Control Center
RPO.....Radiation Protection Officer
RSD.....Rotating Service Door
RSS .....Rotating Service Structure
RTS .....Remote Tracking Site
SC.....Statement of Capability
S/C.....Spacecraft
S&C.....Stability and Control
SCAPE .....Self-Contained Atmospheric Protective Ensembles
SCAT .....Spacecraft and Assemblies Transfer
SCS .....Signal Conditioning Set
SFA .....Spaceport Florida Authority
SLC-6.....Space Launch Complex 6
SRM .....Solid Rocket Motor
SS .....Second Stage
SV .....Space Vehicle
S/W .....Software
T .....Time of launch
T&C .....Telecommunications and Control
TGS .....Telemetry Ground Station
TIM .....Technical Interchange Meeting
TOY .....Time-Of-Year
TPC .....Technical Power Cutoff
TRS .....Test Requirements Specification
TS.....Third Stage
TSO.....Telemetry System Observer
TVC.....Thrust Vector Control
TVCS .....Thrust Vector Control System
TWG .....Technical Working Group
UDS.....Universal Documentation System
UPS .....Uninterruptible Power Supply
USAF .....United States Air Force
VAC .....Volts, Alternating Current
VAFB.....Vandenberg Air Force Base
VDC .....Volts, Direct Current
VeGA .....Velocity Guidance Algorithm
VIP .....Very Important Person
VSWR.....Voltage Standing Wave Ratio
WFF .....Wallops Flight Facility
WG.....Working Group
WR .....Western Range
WRR .....Western Range Regulation
WSMCR.....Western Space and Missile Center Regulation