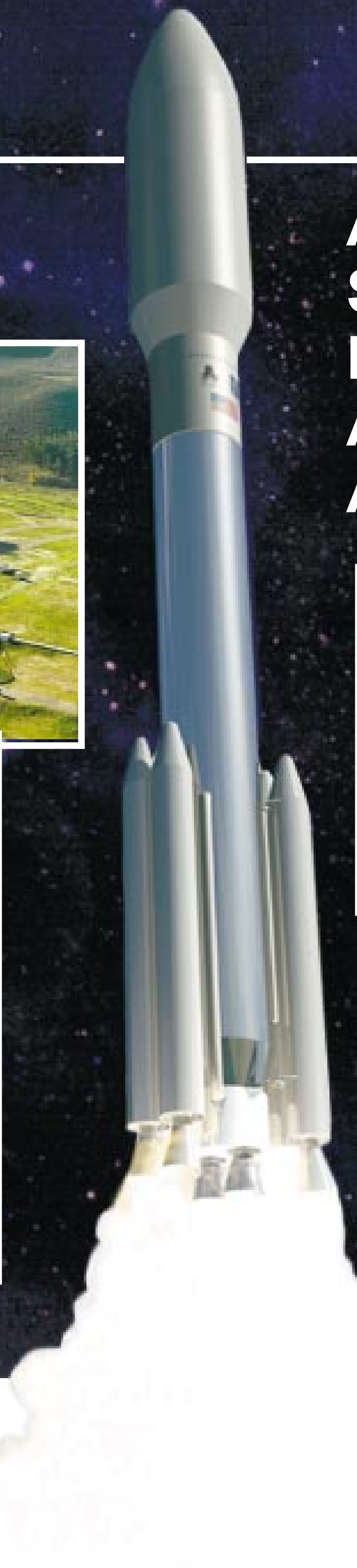
ATLAS

Atlas Launch System Mission Planner's Guide, Atlas V Addendum



ILS INTERNATIONAL LAUNCH SERVICES

LOCKHEED MARTIN

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ATLAS LAUNCH SYSTEM MISSION PLANNER'S GUIDE ATLAS V ADDENDUM (AVMPG)

APPROVALS

Michael C. Gass
Vice President
Program Director—Atlas Recurring Operations
Lockheed Martin Astronautics

John C. Karas
Vice President
EELV/Atlas V
Lockheed Martin Astronautics

Dennis R. Dunbar
Vice President
Programs and Technical Operations
International Launch Services

W. Gainey Best, II
EELV System Director
Lockheed Martin Astronautics

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INTERNATIONAL LAUNCH SERVICES
101 W. Broadway, Suite 2000
San Diego, CA 92101

FOREWORD

This *Atlas V Addendum* supplements the current version of the *Atlas Launch System Mission Planner's Guide (AMPG)* and presents the initial vehicle capabilities for the newly available Atlas V launch system. Atlas V's multiple vehicle configurations and performance levels can provide the optimum match for a range of customer requirements at the lowest cost. The performance data are presented in sufficient detail for preliminary assessment of the Atlas V vehicle family for your missions.

This guide, in combination with the *AMPG*, includes essential technical and programmatic data for preliminary mission planning and spacecraft design. Interface data are in sufficient detail to assess a first-order compatibility. This guide contains current information on Lockheed Martin's plans for Atlas V launch services. It is subject to change as Atlas V development progresses, and will be revised periodically. Potential users of Atlas V launch service are encouraged to contact the offices listed below to obtain the latest technical and program status information for the Atlas V development.

For technical and business development inquiries, contact:

COMMERCIAL BUSINESS INQUIRIES

Telephone: (691) 645-6400
Fax: (619) 645-6500
Postal Address:
International Launch Services, Inc.
P.O. Box 124670
San Diego, CA 92112-4670

Street Address:
International Launch Services, Inc.
101 West Broadway
Suite 2000
San Diego, CA 92101

U.S. GOVERNMENT BUSINESS INQUIRIES

Telephone: (303) 977-5250
Fax: (303) 971-2472
Postal Address:
Commercial Launch Services, Inc.
P.O. Box 179
Denver, CO 80201

Street Address:
Commercial Launch Services, Inc.
P.O. Box 179
MS DC1400
12999 Deer Creek Canyon Road
Littleton, CO 80127-5146

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ATLAS LAUNCH SYSTEM MISSION PLANNER'S GUIDE ATLAS V ADDENDUM (AVMPG) REVISIONS

Revision Date	Rev No.	Change Description	Approval
December 1999	8	• Section 1—Updates Include – Revised Summary Performance Values	
	8	• Section 2—Updates Include – Revised Summary Performance Values – Updated Sequence Timelines – Revised Ascent Profiles – Revised Performance Curves and Tables	
	8	• Section 3—Updates Include – Updated Load Limit Factors – Clarified Static Pressure (PLF Venting) Wording – Added Clarification to Contamination Control Wording	
	8	• Section 4—Updates Include – Clarified Configuration of Centaur Forward Load Reactor – Clarified Lateral Load Factors in Figure 4.1.2.3-2 in Section 4.1.2.3	
	8	• Section 5—No Changes	
	8	• Section 6—No Changes	
	8	• Section 7—No Changes	
	8	• Section 8—Updates Include – Added Section on Solid Rocket Booster Addition to Atlas V 400 Series	
	8	• Appendixes—No Changes	

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1.0 ATLAS V INTRODUCTION

The *Atlas Launch System Mission Planner's Guide (AMPG), Atlas V Addendum* is designed to provide current and potential Atlas launch services customers with information about the newly available Atlas V launch vehicle family and related spacecraft services. Revision 7 of the AMPG previously introduced the Atlas V launch vehicle family as system enhancements in Section 8. This Addendum expands and refines the Atlas V launch vehicle family information for the Series 400 and 500 configurations to include technical planning data that allow the user to assess the compatibility of the user's spacecraft with the various interfaces that comprise the Atlas V system.

1.1 ATLAS V SUMMARY

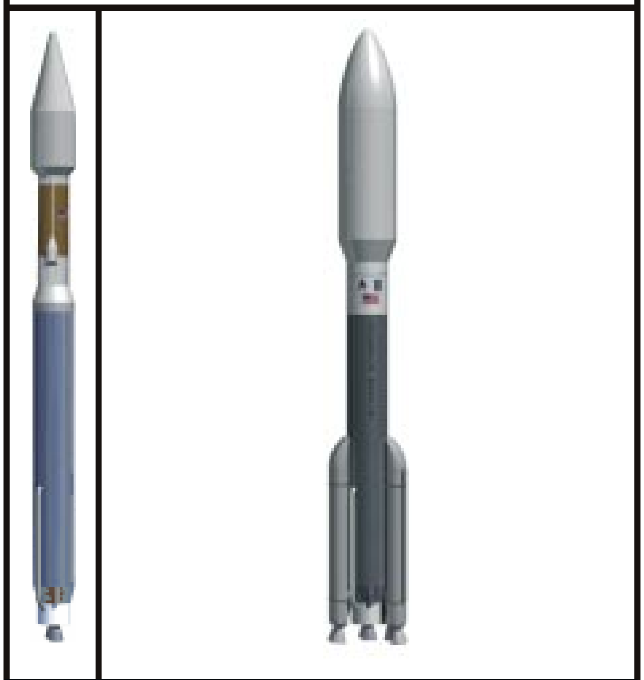
The Atlas V launch vehicle system is based on the newly developed 3.8-m (12.5-ft) diameter Common Core Booster^{TM} (CCB) powered by a single RD-180 engine. The Atlas V 400 series combines the CCB with either the large payload fairing (LPF) or the extended-length large payload fairing (EPF). The Atlas V 500 series combines the CCB with a larger and newly available 5-m-class-diameter payload fairing. To meet the growing needs of our payload users, the Atlas V 500 series can tailor performance by incorporating from zero to five solid rocket boosters (SRB). In addition, the 5-m payload fairing can be selected in either short or medium lengths to accommodate spacecraft volume growth. Selected performance capabilities for these configurations are shown in Figure 1.1-1.

The Atlas V 500 payload fairing (PLF) is a derivative of the composite PLF currently used on the Ariane 5 vehicle. Two lengths of the 5-m PLF are available: the 5-m Short, which is 20.7-m (68-ft) long or the 5-m Medium, which is 23.4-m (77-ft) long.

Both Atlas V 400 and 500 configurations incorporate a stretched version of the flight-proven Centaur upper stage (CIII), which can be configured as a single-engine Centaur (SEC) or a dual engine Centaur (DEC). A three-digit naming convention was developed for the Atlas V launch vehicle system to identify it's multiple configuration possibilities, and is indicated as follows: the first digit identifies the diameter class (in meters) of the payload fairing (4 or 5 m); the second digit indicates the number of solid rocket motors used (zero for Atlas V 400 and zero to five for Atlas V 500); the third digit represents the number of Centaur engines (one or two). For example, an Atlas V 531 configuration includes a 5-m PLF, three SRBs, and an SEC. An Atlas V 402 configuration includes a standard Atlas 4-m PLF and a DEC.

The Atlas V family of launch vehicles can be launched from either Cape Canaveral Air Station (CCAS) Launch Complex 41 (LC-41) or Vandenberg Air Force Base (VAFB) Space Launch Complex 3W (SLC-3W) to support various mission needs.

Atlas V



Atlas V 400	Atlas V 500					
401	501	511	521	531	541	551
Performance to GTO, kg (lb)						
4,950	3,970	5,270	6,285	7,200	7,980	8,670
(10,913)	(8,752)	(11,618)	(13,856)	(15,873)	(17,593)	(19,114)

Figure 1.1-1 The Atlas V Launch Vehicle Family

The Atlas V 400 and 500 series are under development for initial launch capability in the year 2002 from the Eastern Range.

1.2 LAUNCH SERVICES

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

1.3 LAUNCH SERVICES ORGANIZATION AND FUNCTION

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

1.4 ADVANTAGES OF SELECTING ATLAS V

All government and commercial agreements required to conduct Atlas V launch services are maintained for our customer. Agreements are in development to support Atlas V launches, covering Atlas V vehicle processing facilities, services, and range support at CCAS and at VAFB.

Our launch vehicles and services provide the following key advantages:

1) Atlas V flight vehicle and ground system hardware and processes that are derived from flight-proven Atlas systems;
2) Payload launch environments (e.g., shock, vibration, acoustic, thermal) that are the same as or better for the payload than those of other launch vehicles;
3) A streamlined launch processing approach to ensure launch schedules and maintain commitments;
4) Launch pads at CCAS and VAFB to accommodate low- and high-inclination satellite missions;
5) An experienced team that has launched more than 480 orbital missions over almost 40 years;
6) Mission design flexibility demonstrated in a diverse array of mission types, including all projected government missions in the EELV National Mission Model, low-Earth orbit missions, heavy-lift, geosynchronous orbits (GSO), U.S. planetary missions, and numerous geostationary transfer orbit (GTO) missions;
7) A flexible mission design capability providing maximum spacecraft onorbit lifetime through optimized use of excess launch vehicle capabilities;
8) The combined resources and experience of the Atlas launch services team to meet the challenging commercial and government launch services needs of the future.

1.5 ATLAS V LAUNCH SYSTEM CAPABILITIES AND INTERFACES

From the user's perspective, the Atlas V launch system is comprised of a number of hardware- and software-based subsystems and engineering, manufacturing, and operations processes designed to properly interface the spacecraft with our space transportation vehicle. The following paragraphs summarize the major interface and process components of the Atlas V system. Each section corresponds to a section in the *Atlas Launch System Mission Planner's Guide (Rev. 7)* where more detailed information on the same subject can be found.

1.5.1 Atlas V Launch System

The Atlas V 400 and 500 series configurations consist of a CCB, up to five strap-on solid rocket boosters (Atlas V 500 series), a stretched Centaur upper stage (CIII) with either single (SEC) or dual (DEC) engines, and a PLF. Figure 1.5.1-1 illustrates key components of the Atlas V launch vehicles. The Atlas V launch vehicle family includes the Atlas V 400 configuration that will incorporate either the standard Atlas LPF or EPF, and the Atlas V 500 configuration that will incorporate the 5-m Short or 5-m Medium payload fairings.

With the evolution of commercial and government launch services requirements, Lockheed Martin is focusing its resources on the continuing development of the Atlas V 400 and Atlas V 500 series launch vehicles for future missions. The Atlas V 400 and 500 series vehicles will be the cornerstone launch vehicles offered well into the next decade.

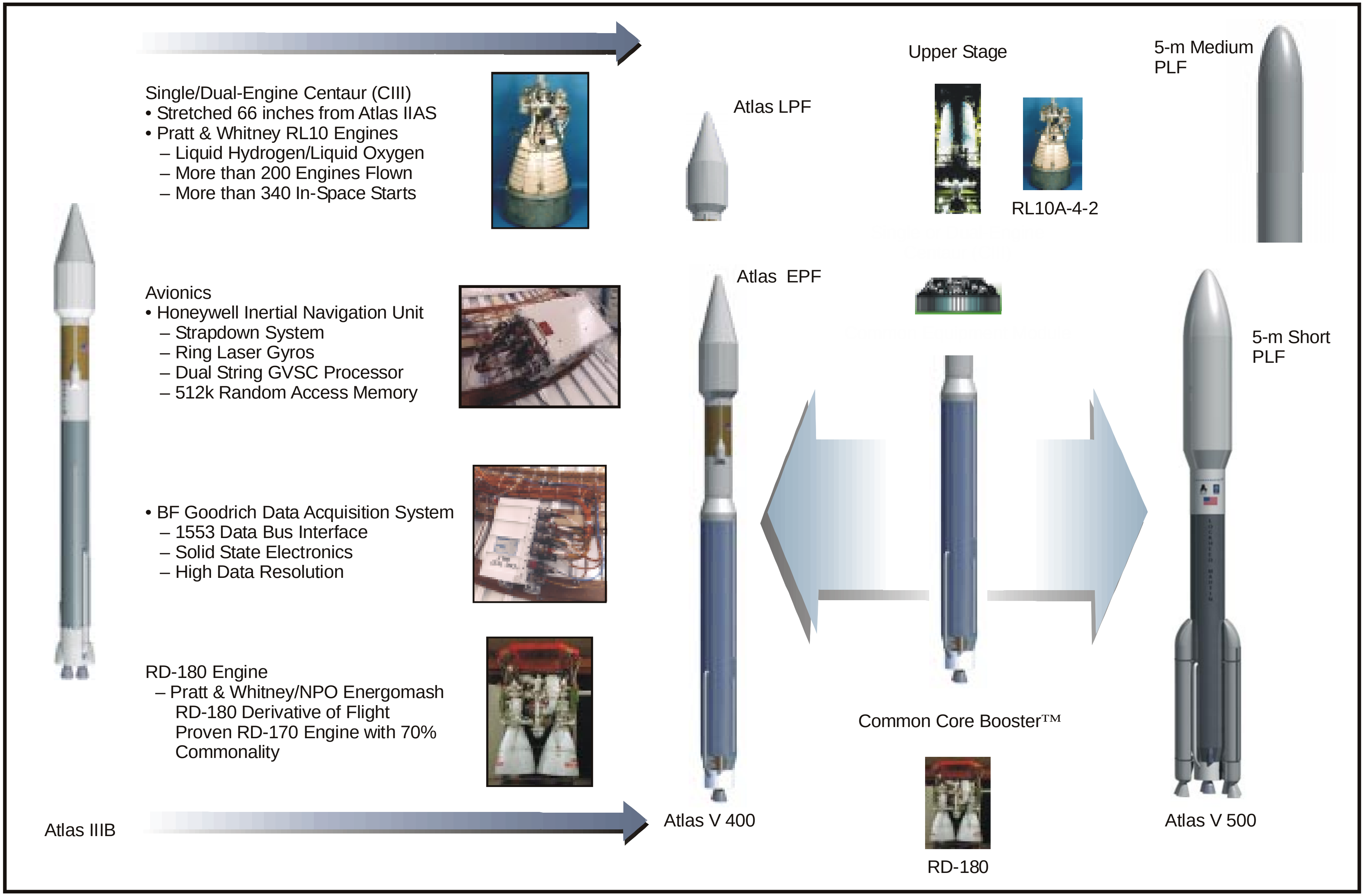


Figure 1.5.1-1 The Atlas V launch vehicle family offers flight-proven hardware.

The Atlas V 400 and 500 series vehicles are the latest evolutionary versions in development and will be phased into service beginning in 2002. Figure 1.5.1-2 summarizes the characteristics of the Atlas V 400 series, and Figure 1.5.1-3 summarizes the characteristics of Atlas V 500 series.

1.5.2 Atlas V Mission Design and Performance

The Atlas V system is designed to deliver payloads of various volumes and masses to precisely targeted orbits. A number of flight-proven mission trajectory and targeting options can be offered to maximize the benefits of the Atlas V system to the spacecraft mission. Section 2.0 discusses the launch vehicle mission and performance capabilities available for Atlas V 400 and 500 series missions.

For certain missions, additional performance is available using a dual engine configuration. A DEC currently flies on Atlas IIA, and IIAS vehicles, and is manifested on Atlas IIIB vehicles starting in 2000. The DEC performance increase is primarily from the additional thrust of the second engine, which is especially beneficial to large spacecraft flying to low-Earth orbits. The Atlas V 500 series vehicles also provide the capability to directly insert spacecraft into geosynchronous or geostationary orbits (GSO), avoiding the need for the spacecraft to purchase and integrate an apogee kick motor stage. This capability is enabled by encapsulation of the Centaur within the PLF, allowing the installation of the thermal protection required for the longer duration GSO missions. Lockheed Martin has extensive experience flying GSO missions with the Titan IV Centaur upper stage.

1.5.3 Atlas V Launch System Environments

The Atlas V launch system provides spacecraft preflight and flight environments that are enveloped by those available with other launch systems. All environments specified for the Atlas V launch system (e.g., shock, vibration, acoustic, thermal, electromagnetic) are based on engineering analyses of existing and evolved hardware, and will be validated with test and flight telemetry data from the Atlas V vehicle configurations. Verification that the launch service user’s flight environments remained within specified levels can be obtained with use of instrumentation that will measure spacecraft environments. The environments to which spacecraft are exposed are fully discussed in Section 3.0 of this Addendum.

1.5.4 Atlas V Vehicle and Ground System Interfaces

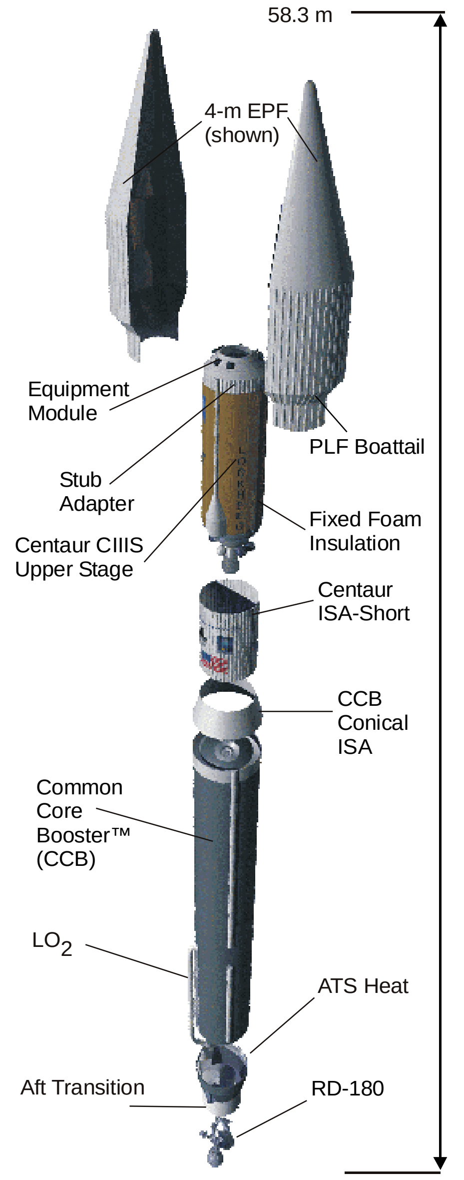
The Atlas V launch system offers a range of interface options to meet spacecraft mission requirements. The primary interfaces between the launch vehicle and spacecraft consist of the payload adapter, which supports the spacecraft on the launch vehicle and provides separation, and the payload fairing, which encloses and protects the spacecraft during ground operations and launch vehicle ascent. The Atlas program currently has eight standard payload adapters, all compatible with Atlas V 400 and Atlas V 500 configurations (subject to structural capability limitations specified in Section 4) (refer to Figure 1.5.4-1, in the *Atlas Launch System Mission Planner’s Guide [Rev. 7])*. Two standard Atlas payload fairings, the LPF and the EPF, are available for Atlas V 400 missions. A new 5-m (17.7-ft)-diameter payload fairing is available for Atlas V 500 missions in two lengths, 20.7 m (68 ft) and 23.4 m (77 ft). Section 4.0 describes these components and specifies our flight vehicle and ground system interfaces with the spacecraft.

1.5.5 Atlas Mission Integration and Management

Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

1.5.6 Spacecraft and Launch Facilities

Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7)* for spacecraft facilities. Launch facilities are TBS.



PAYLOAD FAIRING (PLF)

Features	**Large (Non Std)**	**Extended (Std)**
Diameter:	4.2 m	4.2 m
Length:	12.2 m	13.1 m
Mass:	2,087 kg	2,255 kg
Subsystems		
Fairing:	Aluminum Skin Stringer & Frame Clamshell	
Boattail:	Aluminum Skin Stringer & Frame Clamshell	
Separation:	Pyro Bolts & Spring Thrusters	

CENTAUR UPPER STAGE(CIII)

Features	
Size:	3.05-m Dia x 12.68-m Length with Extended Nozzle
Inert Mass:	1,914 kg/2,106 kg
Propellant:	20,672-kg LH_2 & LO_2
Guidance:	Inertial
Subsystems	
Structure:	Pressure Stabilized Stainless Steel Tanks Separated by Common Ellipsoidal Bulkhead
Propulsion:	1 or 2 Pratt & Whitney Restartable Engine(s)
— Model:	RL10A-4-2
— Thrust:	99.2 kN (SEC) 198.4 kN (DEC)
— I_{SP}:	450.5 s
(SEC)	1 Electromechanically Actuated 51-cm Columbium Fixed Nozzle 4 27-N Hydrazine Thrusters 8 40.5-N Lateral Hydrazine Thrusters
(DEC)	2 Hydraulically Actuated 51-cm Columbium Extendible Nozzles (12) 40.5-N Lateral Hydrazine Thrusters
Pneumatics:	Helium & Hydrogen Autogenous (Tank Pressurization)
Avionics:	Guidance, Navigation & Control, Vehicle Sequencing, Computer-Controlled Vent & Pressurization, Telemetry, Tracking, Range Safety Command, Electrical Power
Insulation:	Polyvinyl Chloride Foam (1.6-cm Thick), Modified Adhesive Bonding

CENTAUR INTERSTAGE ADAPTER (CISA SHORT)

Features	
Size:	3.05-m Dia x 3.13-m Length
Mass:	374 kg
Subsystems	
Structure:	Aluminum Lithium Skin Stringer & Frame
Separation:	Low-Cost Atlas Separation System

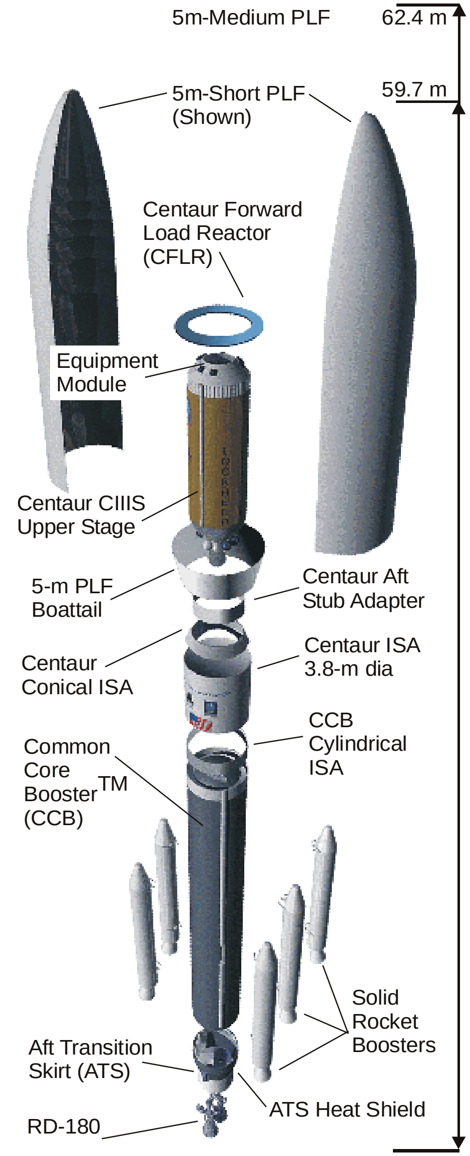
CCB CONICAL INTERSTAGE ADAPTER

Features	
Size:	3.05-m Dia (Top) x 1.65-m Length 3.83-m Dia (Bottom)
Mass:	420 kg
Structure:	Composite (Graphite Epoxy) with Aluminum Ring

COMMON CORE BOOSTER™ (CCB)

Features	
Size:	3.81-m Dia x 32.46-m Length
Inert Mass:	20,743 kg
Propellant:	284,089-kg LO_2 & RP-1
Guidance:	From Upper Stage
Subsystems	
Structure:	Structurally Stable Aluminum Isogrid Tanks; Integrally Machined Aft Transition Structure; Composite Heat Shield
Separation:	8 Retro Rockets
Propulsion:	Pratt & Whitney/NPO Energomash RD-180 Booster Engine (2 Chambers) SL 100% Thrust = 3,827 kN, I_{SP} = 311.3 s Vac 100% Thrust = 4,152 kN, I_{SP} = 337.8 s
Pneumatics:	Helium (Pressure Tanks), Computer-Controlled Pressurization System
Hydraulics:	Fluid—Integral with Engine Provides Gimbal Control
Avionics:	Flight Control, Flight Termination, Telemetry,

Figure 1.5.1-2 The Atlas V 400 launch system is capable of meeting a wide variety of mission requirements.



PAYLOAD FAIRING (PLF)

Features	**5m-Short (Std)**	**5m-Medium (Non-Std)**
Diameter:	5.4 m	5.4 m
Length:	20.7 m	23.4 m
Mass:	4,085 kg	4,649 kg
Subsystems		
Fairing:	Bisector; Sandwich Construction with Graphite Epoxy Face Sheets & an Aluminum Honeycomb Core	
Separation:	Vertical Separation by a Linear Piston & Cylinder Activated by a Pyrotechnic Cord; Horizontal Separation by an Expanding Tube Shearing a Notched Frame, Activated by a Pyrotechnic Cord	

CENTAUR UPPER STAGE (CIII)

Features	
Size:	3.05-m Dia x 12.68-m Length with Extended Nozzle
Inert Mass:	1,914-kg/2,106-kg
Propellant:	20,672-kg LH_2 & LO_2
Guidance:	Inertial
Subsystems	
Structure:	Pressure Stabilized Stainless Steel Tanks Separated by Common Ellipsoidal Bulkhead
Propulsion:	One or Two Pratt & Whitney Restartable Engine(s)
— Model:	RL10A-4-2
— Thrust:	99.2 kN (SEC) 198.4 kN (DEC)
— I_{SP}:	450.5 s
(SEC)	One Electromechanically Actuated 51-cm Columbium Fixed Nozzle Four 27-N Hydrazine Thrusters Eight 40.5-N Lateral Hydrazine Thrusters
(DEC)	Two Hydraulically Actuated 51-cm Columbium Extendible Nozzles (12) 40.5-N Lateral Hydrazine Thrusters
Pneumatics:	Common with Atlas V 40X
Avionics:	Common with Atlas V 40X
Insulation:	Common with Atlas V 40X

SOLID ROCKET BOOSTERS (SRB)

Zero-to-Five	Ground-Lit
Size:	155-cm Dia x 19.5-m Length
Mass:	46,494 kg (Each Fueled)
Thrust:	1,361 kN (Each)
I_{SP}:	275 s
Nozzle Cant:	3°

CENTAUR INTERSTAGE ADAPTER (C-ISA LARGE)

Features	
Size:	3.83-m Dia x 3.81-m Length
Mass:	1,266 kg
Subsystems	
Structure:	Composite Sandwich (Aluminum Core/Graphite Epoxy Face Sheets)

CCB CYLINDRICAL INTERSTAGE ADAPTER

Features	
Size:	3.83-m Dia x 0.32-m Length
Mass:	278 kg
Subsystems	
Structure:	Aluminum Machined Rolled-Ring Forging

COMMON CORE BOOSTER™ (CCB)

Features	**All Common with Atlas V 40X**
Size:	3.81-m Dia x 32.46-m Length
Propellant:	284,089-kg LO_2 & RP-1
Inert Mass:	21,173 kg for 55X Configuration
Guidance:	From Upper Stage
Subsystems	
Structure:	Structurally Stable Aluminum Isogrid Tanks; Integrally Machined Aft Transition Structure; Composite Heat Shield
Separation:	8 Retro Rockets
Propulsion:	Pratt & Whitney/NPO Energomash RD-180 Booster Engine (2 Chambers) SL 100% Thrust = 3,827 kN, I_{SP} = 311.3 s Vac 100% Thrust = 4,152 kN, I_{SP} = 337.8 s
Pneumatics:	Helium (Pressure Tanks), Computer-Controlled Pressurization System
Hydraulics:	Integral with Engine Provides Gimbal Control
Avionics:	Flight Control, Flight Termination, Telemetry, Redundant Rate Gyros, Electrical Power

Figure 1.5.1-3 The Atlas V 500 launch system is capable of meeting a wide range of mission requirements.

1.5.7 Atlas Launch Operations

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)* for general Atlas Launch Operation guidelines. Details of Atlas V Launch Operations are TBS.

1.5.8 Atlas V Enhancements

Section 8.0 is designed to provide the Atlas V user community insight into Lockheed Martin's plans for enhancing the Atlas V system to meet the world's launch services needs of the 21st century.

Enhancements include:

1) 117-in. interface for heavyweight satellites >9,072 kg (>20 klb),
2) Updated spacecraft-to-Atlas V 500 allowable shock,
3) Multiple satellite capabilities (Ref Sect. 8.1.1 of the *Atlas Launch System Mission Planner's Guide [(Rev. 7]),*
4) Heavy lift capabilities (Ref Sect. 8.2.1 of the *Atlas Launch System Mission Planner's Guide [(Rev. 7]).*

Contact information for additional information requests can be found in the Foreword of this Addendum.

1.5.9 Supplemental Information

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

1.6 ATLAS V CONCLUSION

The members of the Atlas V team are eager to assist in the definition and development of potential future Atlas V missions. Potential launch services customers may refer to the foreword of this document for information regarding the appropriate ILS/CLS representative to contact for their mission needs.

2.0 ATLAS MISSION DESIGN AND PERFORMANCE: ATLAS V

To ensure each vehicle meets design expectation, Atlas V launch vehicle performance is projected through engineering analyses using conservative estimates based on our experience with more than 1,000 Atlas and Titan launches. These engineering estimates of Atlas family performance capabilities reflect flight-qualified hardware performance characteristics and our knowledge of developed hardware. Table 2-1 illustrates the performance capabilities of the Atlas V 400 and 500 series families.

As suggested by the data in the table, Atlas V configurations are planned to launch from both Cape Canaveral Air Station (CCAS) in Florida and Vandenberg Air Force Base (VAFB) in California. This section further describes Atlas V 400 and 500 series mission and performance options available for both East and West Coast launches.

2.1 ATLAS V MISSION PERFORMANCE-LEVEL PHILOSOPHY

Lockheed Martin has significantly increased the performance levels available to the Atlas launch services customer with the introduction of the new Atlas V configurations (Table 2-1). In addition, we can meet performance requirements by tailoring mission and trajectory designs for specific missions. Lockheed Martin offers performance capability levels as part of its standard launch services package to meet evolving commercial satellite mission launch requirements.

2.2 ATLAS V MISSION DESCRIPTIONS

Atlas V is a reliable, versatile launch system capable of delivering payloads to a wide range of low- and high-circular orbits, elliptical transfer orbits, and Earth-escape trajectories. Each Atlas V 400 launch vehicle, available with either a large- or extended-length large payload fairing (LPF or EPF), is dedicated to a single launch services customer. The Atlas V 500 launch vehicles with greater performance and larger fairings are well suited for launching single large satellites, multiple smaller satellites populating LEO constellations (Ref Sect. 8.1 of the *Atlas Launch System Mission Planner's Guide* [*Rev. 7*]), or a mix of primary and secondary satellites. The trajectory design for each mission can be specifically

Table 2-1 Atlas V 400/500 Performance Capabilities Summary

	Atlas V 400	Atlas V 500					
		Number of Solids					
		0	1	2	3	4	5
Orbit Type	PSWC, kg (lb)						
GTO	4,950 (10,913)	3,970 (8,752)	5,270 (11,618)	6,285 (13,856)	7,200 (15,873)	7,980 (17,593)	8,670 (19,114)
GSO	N/A	N/A	N/A	2,680 (5,908)	3,190 (7,033)	3,540 (7,804)	3,890 (8,576)
LEO Polar	10,750* (23,699)*	9,050 (19,952)	10,645* (23,468)*	12,795* (28,208)*	14,530* (32,033)*	16,060* (35,406)*	17,365* (38,283)*
LEO 28.5° inc	12,500* (27,558)*	10,300* (22,707)*	12,590* (27,756)*	15,080* (38,029)*	17,250* (38,029)*	18,955* (41,788)*	20,520* (45,238)*

Note:
- PSWC: Payload Systems Weight Capability
- GCS: Guidance Commanded Shutdown
- GTO: ≥167 x 35,788 km (≥90 x 19,324 nmi), I = 27°, ωp = 180°
- GSO: 35,786-km Circ (19,323-nmi Circ), I = 0°
- LEO Polar: 185-km Circ (100-nmi Circ), I = 90°
- LEO 28.5° Inclination: 185-km Circ (100-nmi Circ), I = 28.5°
- GTO, GSO & LEO 28.5° Launch from CCAS, LEO Polar from VAFB

Atlas V 500
- GTO & GSO Performance Is with Single Engine Centaur (SEC)
- LEO 28.5° & LEO Polar Performance Is with Dual Engine Centaur (DEC)
- Quoted Performance Is with 5-m Short PLF

Atlas V 400
- GTO Performance Is with SEC
- LEO 28.5° & LEO Polar Performance Is with DEC
- Quoted Performance Is with EPF

Note: *Payload systems weight above 9,072 kg (20,000 lb) may require mission-unique accommodations.

tailored to optimize the mission's critical performance parameter (e.g., maximum satellite orbit lifetime, maximum weight to transfer orbit), while satisfying satellite and launch vehicle constraints.

Atlas mission ascent profiles are developed using one or more Centaur upper stage main engine burns. Each mission profile type is suited for one of the following missions types.

Direct Ascent Missions—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

Parking Orbit Ascent Missions—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

Geosynchronous Orbit (GSO) Mission—The GSO mission is a three-burn Centaur mission profile. This mission could be flown by an Atlas V 500 configuration. This type of profile combines the parking orbit ascent to a geosynchronous transfer burn with a long coast followed by the third burn. The first Centaur burn starts just after Common Core Booster™ (CCB)/Centaur separation and is used to inject the Centaur/spacecraft into a mission performance-optimal parking orbit. After a coast to the desired location for transfer orbit injection, the second Centaur engine burn provides the impulse to place the spacecraft into the transfer orbit. A long transfer orbit coast follows the second burn. The Centaur main engine is ignited for a third time near the apogee of the transfer orbit. This final burn provides the energy to circularize at synchronous altitude and reduces the inclination to 0°.

2.3 ATLAS V ASCENT PROFILE

To familiarize users with Atlas V mission sequences, information is provided in the following paragraphs regarding typical Atlas V mission designs. Figures 2.3-1, 2.3-2, and 2.3-3 show sequence-of-events data for a typical Atlas V 401 geosynchronous transfer orbit (GTO), Atlas V 551 GTO, and Atlas V 552 LEO park orbit ascent missions, respectively. Tables 2.3-1, 2.3-2, and 2.3-3 show the corresponding mission sequence data for the illustrated Atlas V ascent profiles. These data are representative; actual sequencing will vary to meet the requirements of each mission. Atlas V launch vehicles can be launched at any time of day to meet spacecraft mission requirements.

2.3.1 Booster Phase

2.3.1.1 Atlas V 400—The booster phase begins with ignition of the RD-180 engine system. The vehicle is held down during start and a portion of throttle up. A vehicle health check is made before achieving full throttle. After passing the health check, the vehicle is committed to launch, the hold-down bolts are blown, and throttle up is completed. After a short vertical rise away from the pad, the vehicle begins to roll from the launch pad azimuth to the appropriate flight azimuth. Above an altitude of 244 m (800 ft), the vehicle begins pitching over into the prescribed ascent profile. At about 2,438 m (8,000 ft), the vehicle enters a pitch and yaw angle-of-attack profile phase to minimize aerodynamic loads.

For Atlas V 400, after reaching 24,380 m (80,000 ft) until approximately 36,576 m (120,000 ft), an alpha-bias angle-of-attack steering technique may be used to reduce steering losses while maintaining aerodynamic loading within acceptable limits. The booster phase steering profile through the end of alpha-biased steering is implemented through our launch-day wind-steering system, which enhances launch availability by reducing wind-induced flight loads.

At the end of alpha-biased steering, closed-loop guidance steering is enabled. Near the end of the CCB phase, the RD-180 engine is continuously throttled so that a 5.5 ±0.5-g axial acceleration level is not exceeded. The core engine cutoff sequence is initiated when a propellant low-level sensor system indicates that the booster is about to deplete all available propellants. At this time, the RD-180 is throttled down to minimum power level and the engine is shut down. The Atlas V 400 retains the payload fairing through the booster phase of flight.

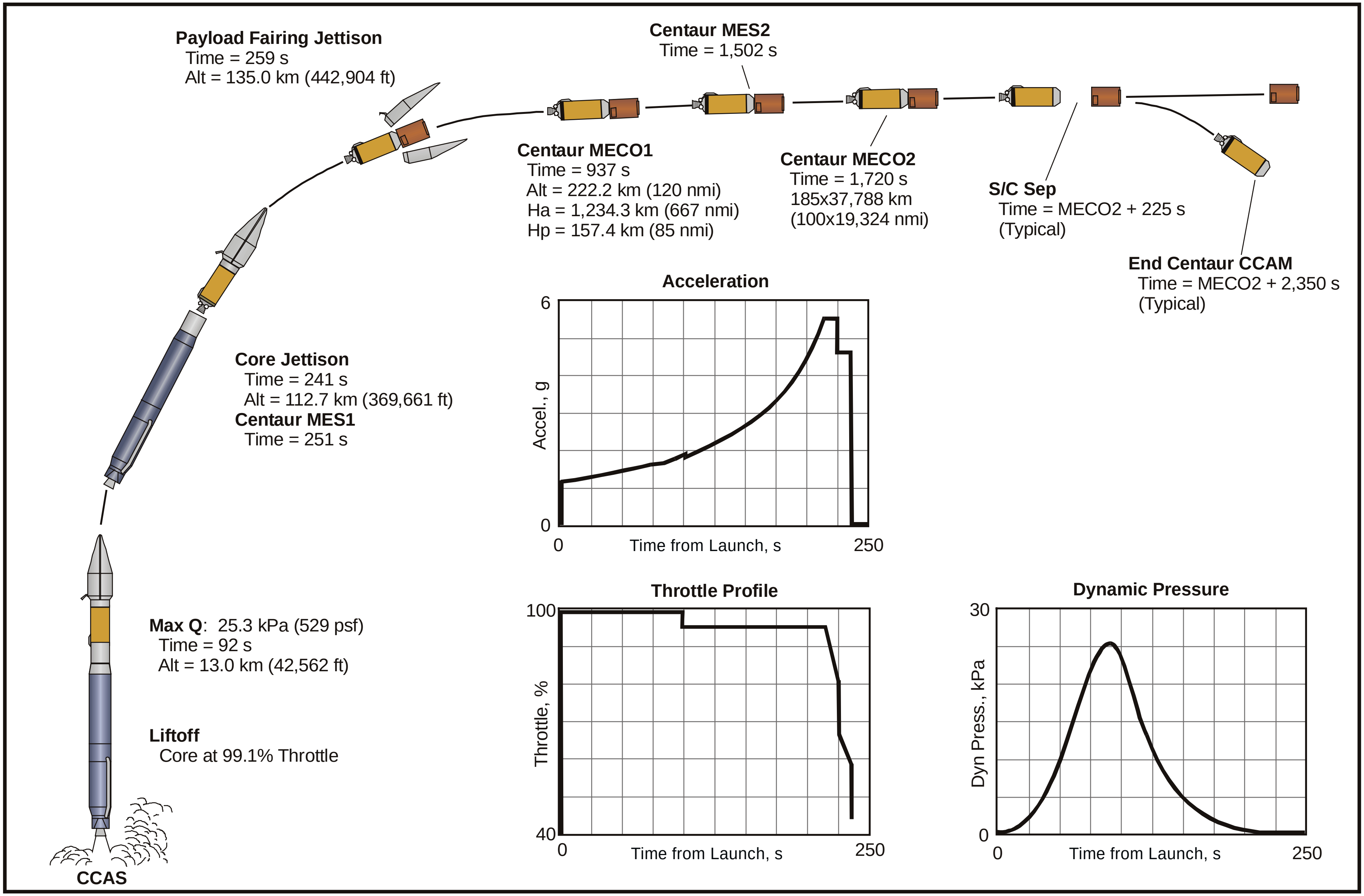


Figure 2.3-1 Typical Atlas V 401 GTO Ascent Profile

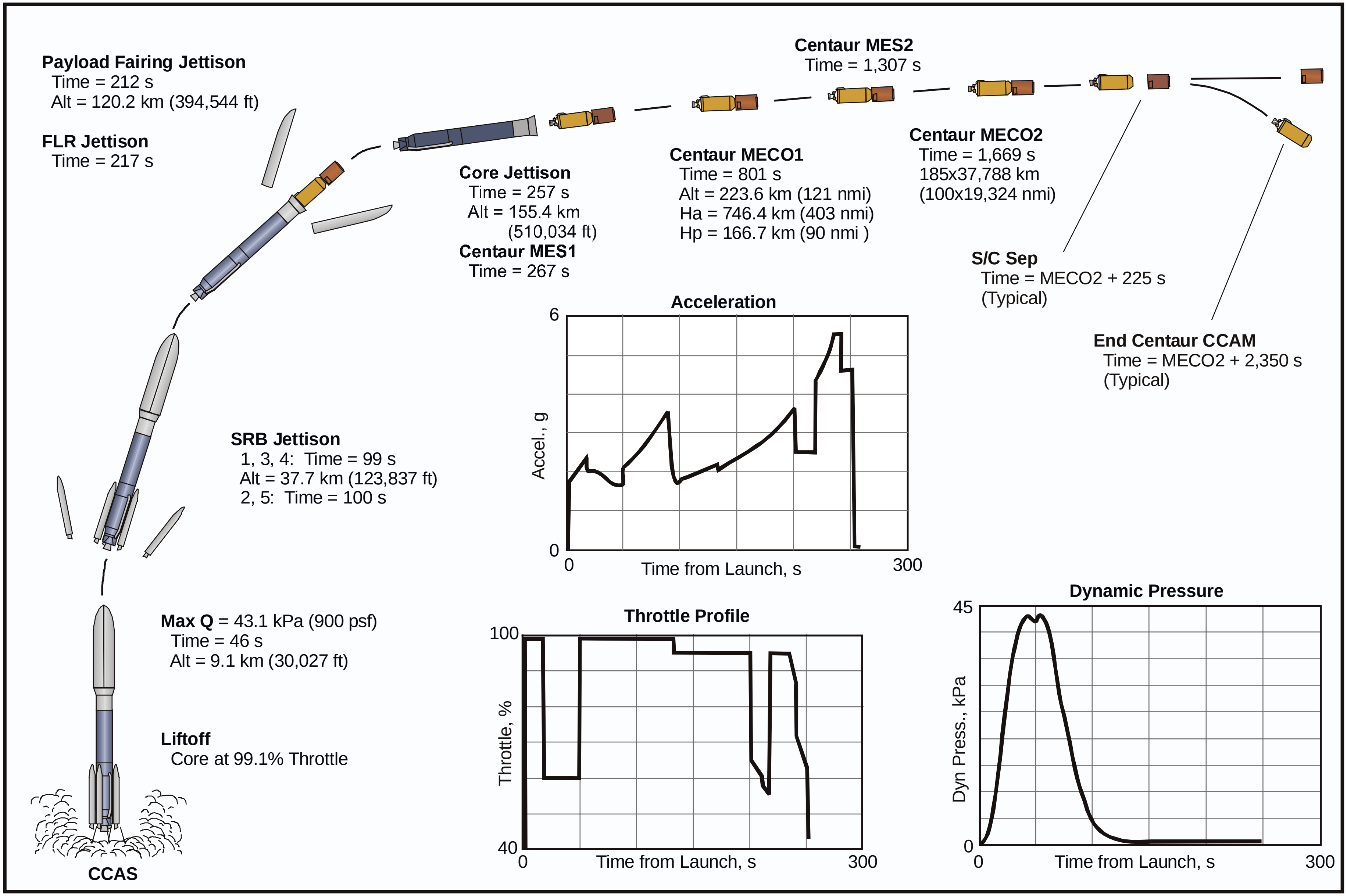


Figure 2.3-2 Typical Atlas V 551 GTO Ascent Profile

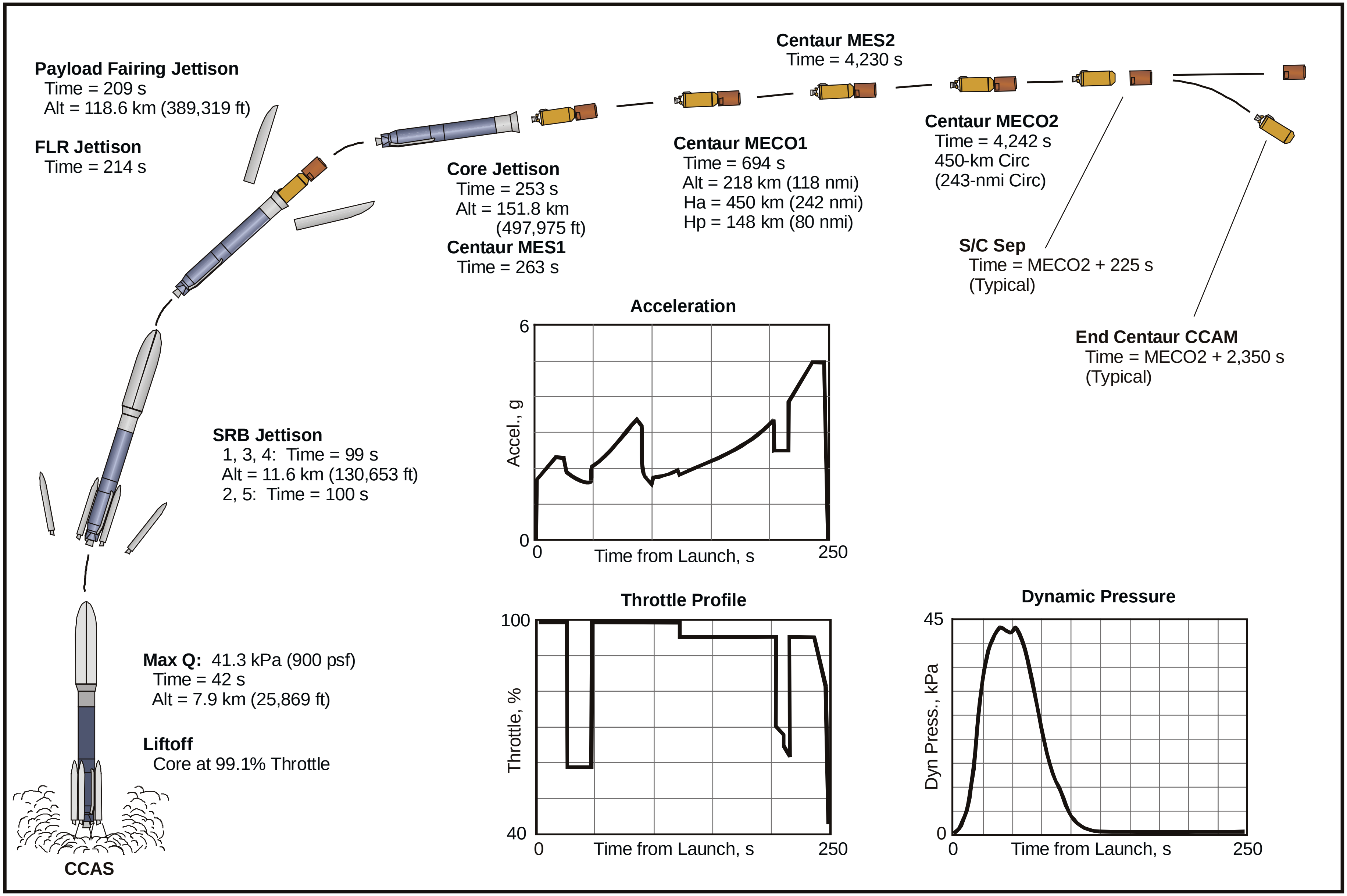


Figure 2.3-3 Typical Atlas V 552 LEO Ascent Profile

Table 2.3-1 Typical Atlas V 401 GTO Mission Launch Vehicle Sequence Time in Seconds

Atlas V 401 Event	Time from Liftoff, s
Guidance Go-Inertial	-11
Liftoff	0
Core Engine Cutoff	236
Core Jettison	241
Centaur Main Engine Start (MES1)	251
Payload Fairing Jettison (PFJ)	259
Centaur Main Engine Cutoff (MECO1)	937
Start Turn to MES2 Attitude	1,162
Centaur Main Engine Start (MES2)	1,502
Centaur Main Engine Cutoff (MECO2)	1,720
Start Alignment to Separation Attitude	1,730
Begin Spinup	1,840
Separate Spacecraft (SEP)	1,945
Start Turn to CCAM Attitude	2,045
Centaur End of Mission	4,070

2.3.1.2 Atlas V 500—The Atlas V 500 consists of a CCB combined with zero to five strap-on solid rocket boosters (SRB). The RD-180 start sequence is similar to the Atlas V 400 while still on the ground, and with the booster engine throttled to the desired power level, all SRBs are ignited to provide thrust for liftoff. The flight begins with a short vertical rise, after which the vehicle begins a roll to the target azimuth. At an altitude of 244 m (800 ft) and time from liftoff greater than 10 seconds, the vehicle begins its initial pitch-over phase.

At approximately 2,438 m (8,000 ft), the vehicle enters into a nominal zero-pitch and zero-yaw angle-of-attack phase to minimize aerodynamic loads. Zero pitch and yaw angle-of-attack steering phase is implemented through the launch-day wind-steering system, which enhances launch availability by reducing wind-induced flight loads.

Table 2.3-2 Typical Atlas V 551 GTO Mission Launch Vehicle Sequence Time in Seconds

Atlas V 551 Event	Time from Liftoff, s
Guidance Go-Inertial	-11
Liftoff	0
Strap-On SRM Jettison (SRM 1, 3, 4)	99
Strap-On SRM Jettison (SRM 2, 5)	100
Payload Fairing Jettison (PFJ)	212
Core Engine Cutoff	252
Core Jettison	257
Centaur Main Engine Start (MES1)	267
Centaur Main Engine Cutoff (MECO1)	801
Start Turn to MES2 Attitude	907
Centaur Main Engine Start (MES2)	1,307
Centaur Main Engine Cutoff (MECO2)	1,669
Start Alignment to Separation Attitude	1,679
Separate Spacecraft (SEP)	1,894
Start Turn to CCAM Attitude	1,994
Centaur End of Mission	4,019

Table 2.3-3 Typical Atlas V 552 LEO Mission Launch Vehicle Sequence Time in Seconds

Atlas V 552 Event	Time from Liftoff, s
Guidance Go-Inertial	-11
Liftoff	0
Strap-On SRM Jettison (SRM 1, 3, 4)	99
Strap-On SRM Jettison (SRM 2, 5)	100
Payload Fairing Jettison (PFJ)	209
Core Engine Cutoff	248
Core Jettison	253
Centaur Main Engine Start (MES1)	263
Centaur Main Engine Cutoff (MECO1)	694
Start Turn to MES2 Attitude	3,830
Centaur Main Engine Start (MES2)	4,230
Centaur Main Engine Cutoff (MECO2)	4,242
Start Alignment to Separation Attitude	4,252
Separate Spacecraft (SEP)	4,467
Start Turn to CCAM Attitude	4,567
Centaur End of Mission	6,592

The zero pitch and yaw angle-of-attack phase is terminated at 24,384 m (80,000 ft). For Atlas V 500, an alpha-bias angle-of-attack steering technique may be used after reaching 24,380 m (80,000 ft) until approximately 33,528 m (110,000 ft) to reduce steering losses and maintain aerodynamic loading within acceptable limits. At the end of alpha-biased steering, closed-loop guidance steering is enabled.

The strap-on SRB jettison sequence is initiated after burnout. At 99 seconds into flight, the first three SRBs are jettisoned. The last SRBs are then jettisoned, 100 seconds into flight.

For Atlas V 500 missions, the payload fairing is jettisoned during the CCB phase. Before payload fairing jettison, the core RD-180 engine is throttled down to maintain acceleration at 2.5 g. Typically, the PLF is jettisoned when the 3-sigma free molecular heat flux falls below 1,135 W/m^2 (360 Btu/ft^2-hr). For sensitive spacecraft, payload fairing jettison can be delayed later into the flight with some performance loss.

After payload fairing jettison, the core RD-180 engine is throttled back up. Near the end of the CCB phase, the RD-180 engine is continuously throttled so that a constant axial acceleration level is not exceeded.

The core engine cutoff sequence is initiated when a propellant low-level sensor system indicates that the core booster is about to deplete all available propellants. At this time, the core RD-180 engine is throttled down to minimum power level and the engine is shut down.

2.3.2 Centaur Phase

2.3.2.1 Atlas V 400—The Atlas V 400 Centaur can use either a dual engine configuration (DEC) or single engine (SEC) configuration. Centaur main engine start (MES) occurs after the CCB stage is jettisoned. For typical Atlas V 400 missions, the payload fairing is jettisoned 8 seconds after MES1, by which time the 3-sigma free molecular heat flux has typically fallen below 1,135 W/m^2 (360 Btu/ft^2-hr). For sensitive spacecraft, payload fairing jettison can be delayed later into the flight with some performance margin loss.

For direct ascent missions, the Centaur main engine burn injects the spacecraft into the targeted orbit and then performs a series of preseparation maneuvers. With parking orbit ascent missions, the first Centaur burn (typically the longer of the two) injects the spacecraft into an elliptical performance-optimal parking orbit. After first-burn main engine cutoff (MECO1), the Centaur and spacecraft enter a coast period. During the coast period (about 10 minutes for a typical geosynchronous transfer mission), the Centaur aligns its longitudinal axis along the velocity vector. Should a spacecraft require attitude maneuvers during longer coast phases, Centaur can accommodate roll axis alignment requirements and provide commanded roll rates from 0.5 to 1.5°/s in either direction during nonthrusting periods. Accommodation of larger roll rates can be evaluated on a mission-unique basis. Before the second Centaur burn main engine start (MES2) the vehicle is aligned to the ignition attitude and the engine start sequence is initiated.

At a guidance-calculated start time, the Centaur main engine is reignited and the vehicle is guided to the desired orbit. After reaching the target, the main engine is shut down (MECO2) and Centaur begins its alignment to the spacecraft separation attitude. Centaur can align to any attitude for separation. Preseparation spinups of up to 5.0 ±0.5 rpm about the roll axis can be accommodated. In addition, a pitch/yaw plane transverse spin mode can be used.

After Centaur/spacecraft separation, Centaur conducts a collision and contamination avoidance maneuver (CCAM) to prevent recontact and minimize contamination of the spacecraft. A blowdown of remaining Centaur propellants follows.

2.3.2.2 Atlas V 500—The Atlas V 500 Centaur can use either a dual engine (DEC) or single engine (SEC) configuration. After the Atlas V core/Centaur separation, the Centaur stage ignites its main engine (MES1). For direct ascent missions, the Centaur main engine burn injects the spacecraft into the targeted orbit and then performs a series of preseparation maneuvers. With parking orbit ascent missions, the Centaur first burn injects the spacecraft into an elliptical performance-optimal parking orbit.

After Centaur first-burn main engine cutoff (MECO1), the Centaur and spacecraft enter a coast period. During the coast period (about 8 minutes for a typical geosynchronous transfer mission), the Centaur normally aligns its longitudinal axis along the velocity vector. Because typical parking orbit coasts are of short duration, most spacecraft do not require special pointing or roll maneuvers. Should a spacecraft require attitude maneuvers during coast phases, Centaur can accommodate all roll axis alignment requirements and provide commanded roll rates from 0.5 to 1.5°/s in either direction during nonthrusting periods. Accommodation of larger roll rates can be evaluated on a mission-peculiar basis. Before the second Centaur burn main engine start (MES2), the vehicle is aligned to the ignition attitude and the engine start sequence is initiated.

At a guidance-calculated start time, Centaur main engines are reignited and the vehicle is guided to the desired orbit. After reaching the target, main engines are shut down (MECO2) and Centaur begins its alignment to the spacecraft separation attitude. Centaur can align to any attitude for separation. Preseparation spinups to 5.0 ±0.5 rpm about the roll axis can be accommodated. In addition, a pitch/yaw plane transverse spin mode can also be used.

After Centaur/spacecraft separation, Centaur conducts its collision and contamination avoidance maneuver (CCAM) to prevent recontact and minimize contamination of the spacecraft.

2.3.3 Injection Accuracy and Separation Control

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.3.3.1 Attitude Orientation/Stabilization—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.3.3.2 Atlas V Separation Pointing Accuracies—Pointing accuracy just before spacecraft separation is a function of guidance system hardware, guidance software, and autopilot attitude control capabilities. In the nonspinning precision pointing mode, the system can maintain attitude errors of less than 0.7° and attitude rates before separation of less than 0.2, 0.2, and 0.25°/s about the pitch, yaw, and roll axes, respectively (Table 2.3.3.2-1). Although the attitude and rates of a nonspinning spacecraft after separation (after loss of contact between the Centaur and the spacecraft) are highly dependent on the mass properties of the spacecraft, attitude can typically be maintained within 0.7°/s per axis. Body axis rates are typically less than 0.6°/s in the pitch or yaw axis and 0.5°/s in the roll axis. Separation conditions for a particular spacecraft are assessed as part of a mission-specific separation analysis.

Centaur can also provide a transverse spin separation mode in which an end-over-end tumble is initiated before separating the payload. A rotation rate of up to 7°/s is possible about the pitch or yaw axis for typical spacecraft.

Table 2.3.3.2-1 Summary of Guidance and Control Capabilities

Coast Phase Attitude Control	
• Roll Axis Pointing, °, Half Angle	≤5.0
• Passive Thermal Control Rate, °/s (Clockwise or Counterclockwise)	0.5 to 1.5
Separation Parameters Prior to Separation Command (with No Spin Requirement)	
• Pitch, Yaw & Roll Axis Pointing, (per Axis), °	≤0.7
• Body Axis Rates, °/s	
– Pitch	±0.2
– Yaw	±0.2
– Roll	±0.25
Separation Parameters Following SC Separation (with No Spin Requirement)	
• Pitch, Yaw & Roll Axis Pointing, (per Axis), °	≤0.7
• Body Axis Rates, °/s	
– Pitch	±0.6
– Yaw	±0.6
– Roll	±0.5
Spacecraft Separation Parameters Prior to Separation Command (with ≤5-rpm Longitudinal Spin Requirement)	
• Spin Rate Accuracy, rpm	±0.5
• Spin Axis Pointing Accuracy, °, (Half-Angle)	1.75
Spacecraft Separation Parameters Following SC Separation (with ≤5-rpm Longitudinal Spin Rqmt)	
• Nutation, °, Half Angle	≤5.0
• Momentum Pointing, °, Half Angle	≤3.0
• Spin Rate, °/s	≤30.0±3.0
Separation Parameters at SC Separation Command (with Transverse Spin Requirement)	
• Transverse Rotation Rate, °/s	≤7.0
Note: Capabilities Are Subject to Spacecraft Mass Properties Limitations	

For a mission requiring preseparation spinup, conditions just before spacecraft separation combine with any tip-off effects induced by the separation system and any spacecraft principal axis mission alignments to produce postseparation momentum pointing and nutation errors. Here, nutation is defined as the angle between the actual space vehicle geometric spin axis and the spacecraft momentum vector. Although dependent on actual spacecraft mass properties (including uncertainties) and the spin rate, momentum pointing and maximum nutation errors following separation are typically less than 3.0 and 5.0°, respectively.

2.3.3.3 Separation Velocity—The relative velocity between the spacecraft and the Centaur is a function of the mass properties of the separated spacecraft and the separation mechanism. Our separation systems provide a minimum relative velocity of 0.27 m/s (0.9 ft/s) for spacecraft weights up to 4,536 kg (10,000 lb) and are designed to preclude recontact between the spacecraft and Centaur.

2.4 PERFORMANCE GROUND RULES

Atlas V performance ground rules for various missions with launch from CCAS in Florida or VAFB in California are described in this section.

2.4.1 Payload Systems Weight Definition

Performance capabilities quoted throughout this document are presented in terms of payload systems weight (PSW), which is defined as the total mass delivered to the target orbit, including the separated spacecraft, the spacecraft-to-launch vehicle adapter, and all other hardware required on the launch vehicle to support the payload (e.g., payload flight termination system, harnessing). The launch vehicle trajectory, spacecraft mass, and mission target orbit can affect the performance contributions of each mission-peculiar item.

2.4.2 Payload Fairings

2.4.2.3 Atlas V 400—Atlas V 400 performance shown in this document is based on use of the 4.2-m (13.75-ft)-diameter EPF, unless noted otherwise.

Higher performance is available for those payloads that fit in the 0.9-m (3-ft) shorter LPF. Typical performance gains are vehicle configuration and trajectory design-dependent, but for GTO (Atlas V 401) and LEO (Atlas V 402) missions, the gains are approximately 32 kg (71 lb) and 53 kg (117 lb), respectively. Additional fairing information may be found in Section 4.1.

2.4.2.4 Atlas V 500—Atlas V 500 configuration performance is based on use of the 5-m short PLF. For spacecraft that require greater volume, the 5-m medium PLF is available. For Atlas V 500 configurations that use the 5-m medium PLF, the typical range of performance degradation is 59.3 kg (131 lb) for the Atlas V 511 and 521, to 66.6 kg (147 lb) for the Atlas 501 GTO missions. Additional fairing information can be found in Section 4.1.

2.4.3 Launch Vehicle Performance Confidence Levels

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.4.4 Centaur Short-Burn Capability

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.4.5 Centaur Long-Coast Capability

The standard Atlas V 400 and 500 series designs incorporate items supporting park orbit coast times up to 65 minutes. These items include 150-amp-hr main vehicle battery, shielding on the Centaur aft bulkhead, and three helium bottles. Longer duration missions can be supported by the 500 series with the addition of a fourth helium bottle, an additional second hydrazine load, addition of two 250-amp-hr main vehicle batteries, and an LH_2 tank sidewall radiation shield. Thus equipped, the 500 series can support a full three-burn GSO mission.

2.4.6 Heavy-Payload Lift Capability

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.5 GEOSYNCHRONOUS LAUNCH MISSION TRAJECTORY AND PERFORMANCE OPTIONS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.6 MISSION OPTIMIZATION AND ENHANCEMENT

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.6.1 Inflight Retargeting (IFR)

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.6.2 Minimum Residual Shutdown (MRS) (Atlas V)

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)* for a description of MRS. The Atlas V performance variations associated with MRS are in Table 2.6.2-1 and in the performance curves in Sections 2.12 and 2.13 for the Atlas V 400 and Atlas V 500, respectively. MRS has been successfully executed for 24 Atlas missions and has become the typical operations mode for GTO-type missions.

Table 2.6.2-1 Atlas V 401 and 551 3-sigma Performance Variations with MRS

Perigee Velocity Dispersions	2.33-sigma	3-sigma
Atlas V 400	99.7 m/s (327 ft/s)	123.4 m/s (405 ft/s)
Atlas V 500	93.0 m/s (305 ft/s)	116.7 m/s (383 ft/s)

2.6.3 Right Ascension of Ascending Node (RAAN) Control

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.7 MISSION PERFORMANCE DATA

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7),* Sections 2.7.1 through 2.7.8, for Atlas V orbit capability descriptions. Performance data presented in this addendum are only for selected Atlas V vehicles, consistent with the *Atlas Launch System Mission Planner's Guide (Rev. 7)* Sections 2.7.1, 2.7.2, 2.7.4, and 2.7.7.

2.8 ATLAS IIA PERFORMANCE DATA

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.9 ATLAS IIAS PERFORMANCE DATA

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.10 ATLAS IIIA PERFORMANCE DATA

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.11 ATLAS IIIB PERFORMANCE DATA

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

2.12 ATLAS V 400 PERFORMANCE DATA

Figures 2.12-2a, 2.12-2b, 2.12-4a, 2.12-4b, 2.12-7a, and 2.12-7b and Tables 2.12-1 and 2.12-2 illustrate the performance of Atlas V 400 vehicle configurations to orbits described in Section 2.7 of the *Atlas Launch System Mission Planner's Guide (Rev. 7).* Note that Figures 2.12-1, 2.12-3, 2.12-5, and 2.12-6 are TBS.

2.13 ATLAS V 500 PERFORMANCE DATA

Figures 2.13-2a, 2.13-2b, 2.13-3a, 2.13-3b 2.13-4a, 2.13-4b, 2.13-5a, 2.13-5b 2.13-7a, and 2.13-7b and Tables 2.13-1, 2.13-2a, and 2.13-2b illustrate the performance of Atlas V 500 vehicle configurations to orbits described in Section 2.7 of the *Atlas Launch System Mission Planner's Guide (Rev. 7).* Note that Figures 2.13-1 and 2.13-6 are TBS.

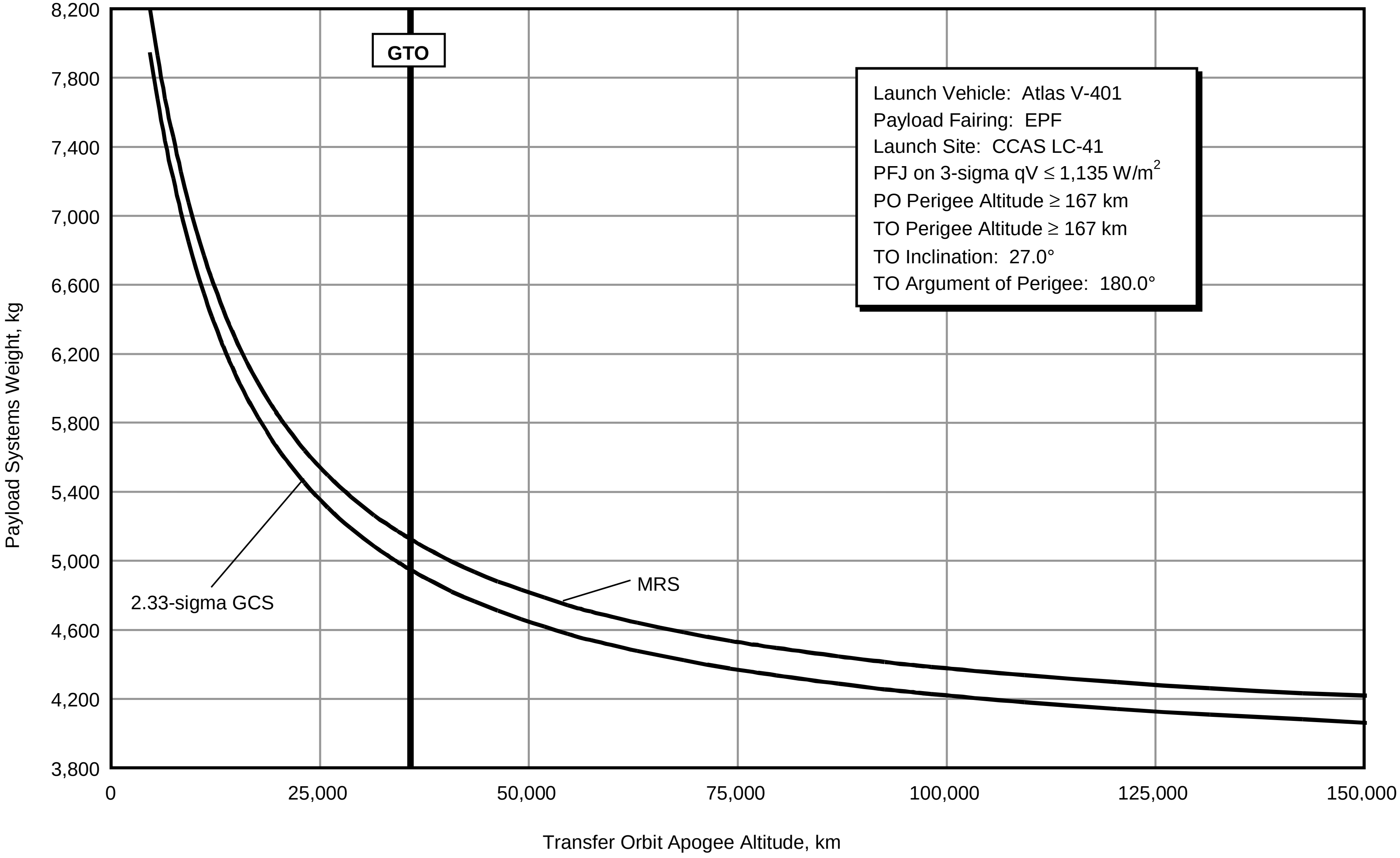


Figure 2.12-2a Atlas V 401 CCAS Performance to Elliptical Transfer Orbit (Metric)

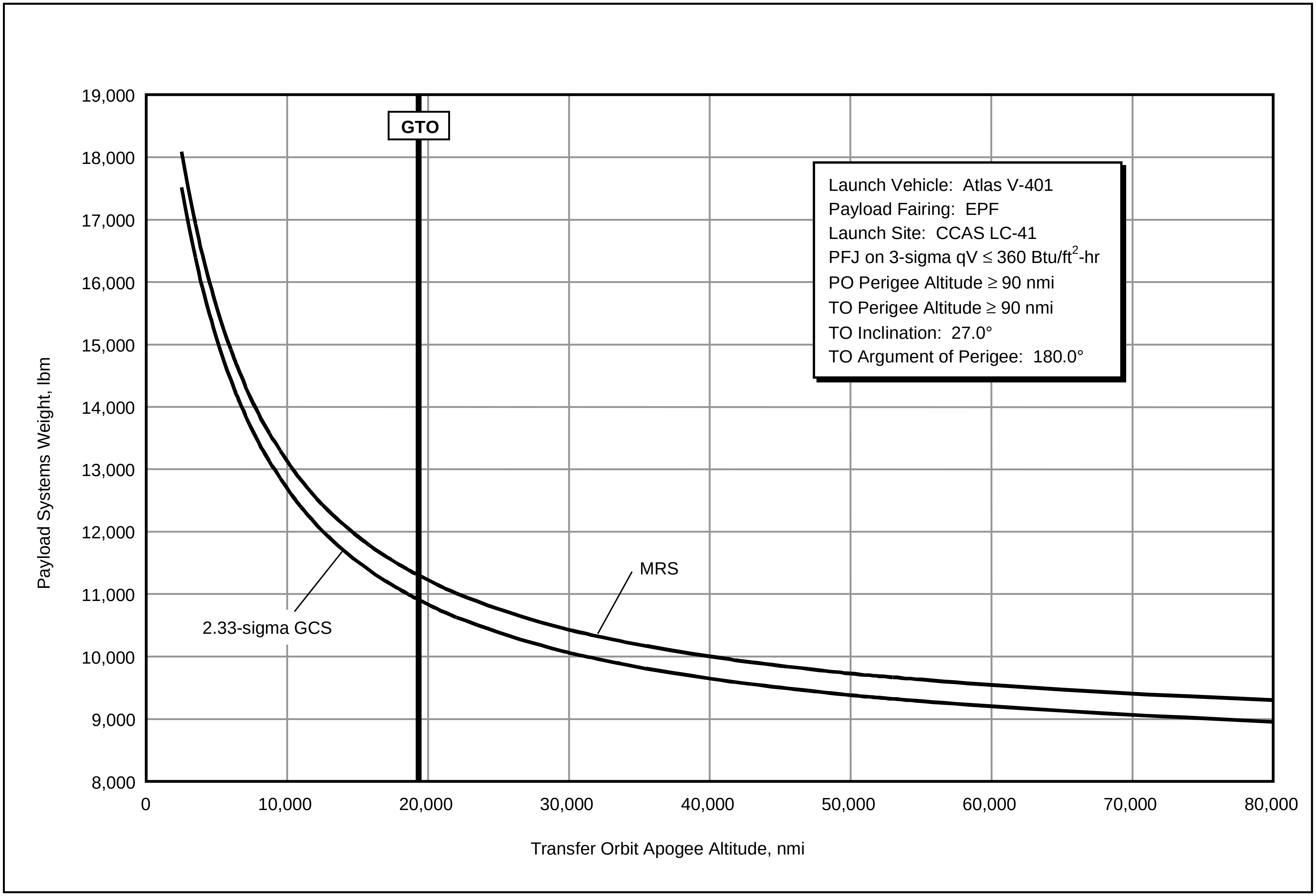


Figure 2.12-2b Atlas V 401 CCAS Performance to Elliptical Transfer Orbit (English)

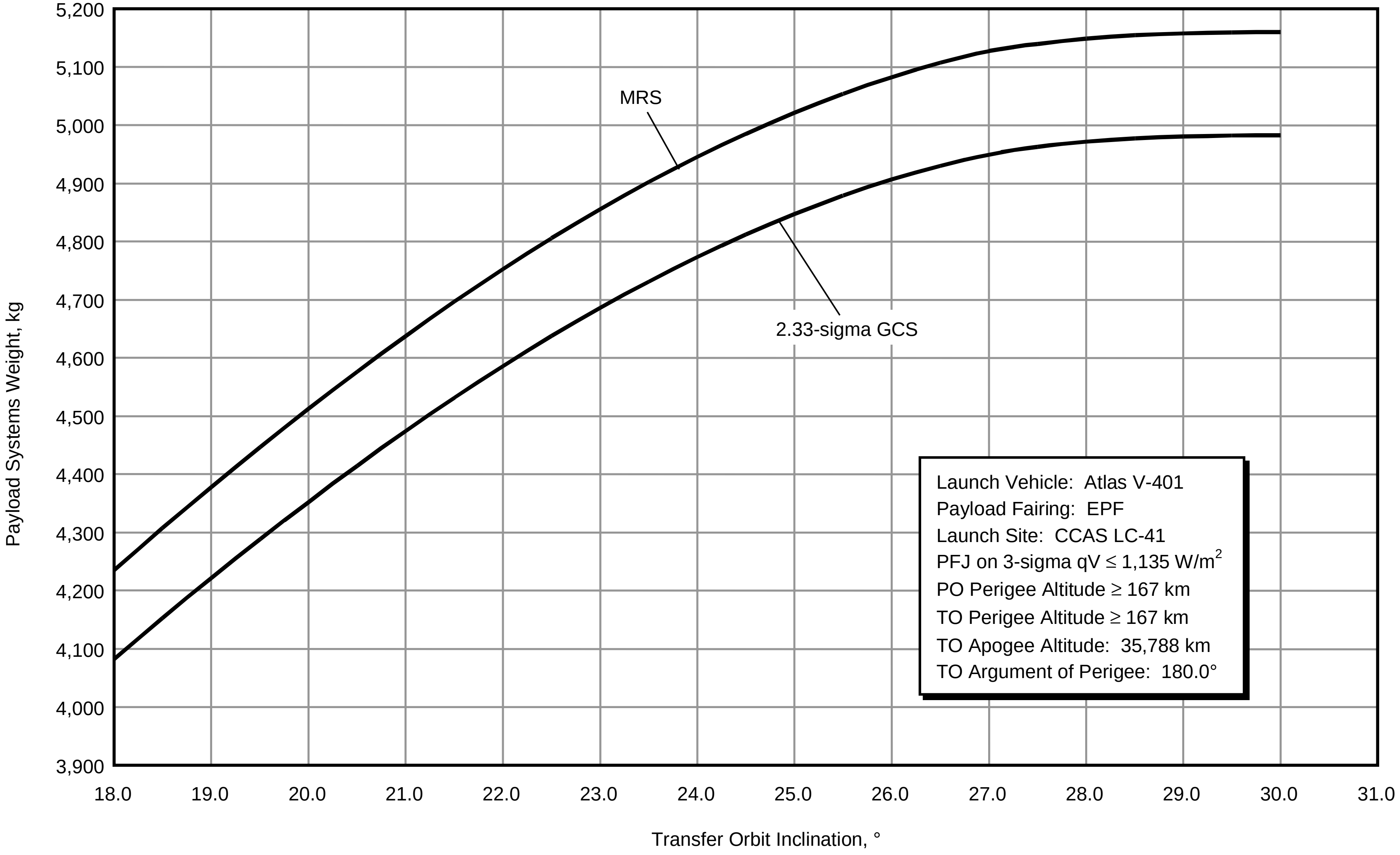


Figure 2.12-4a Atlas V 401 CCAS Reduced Inclination Elliptical Orbit Performance (Metric)

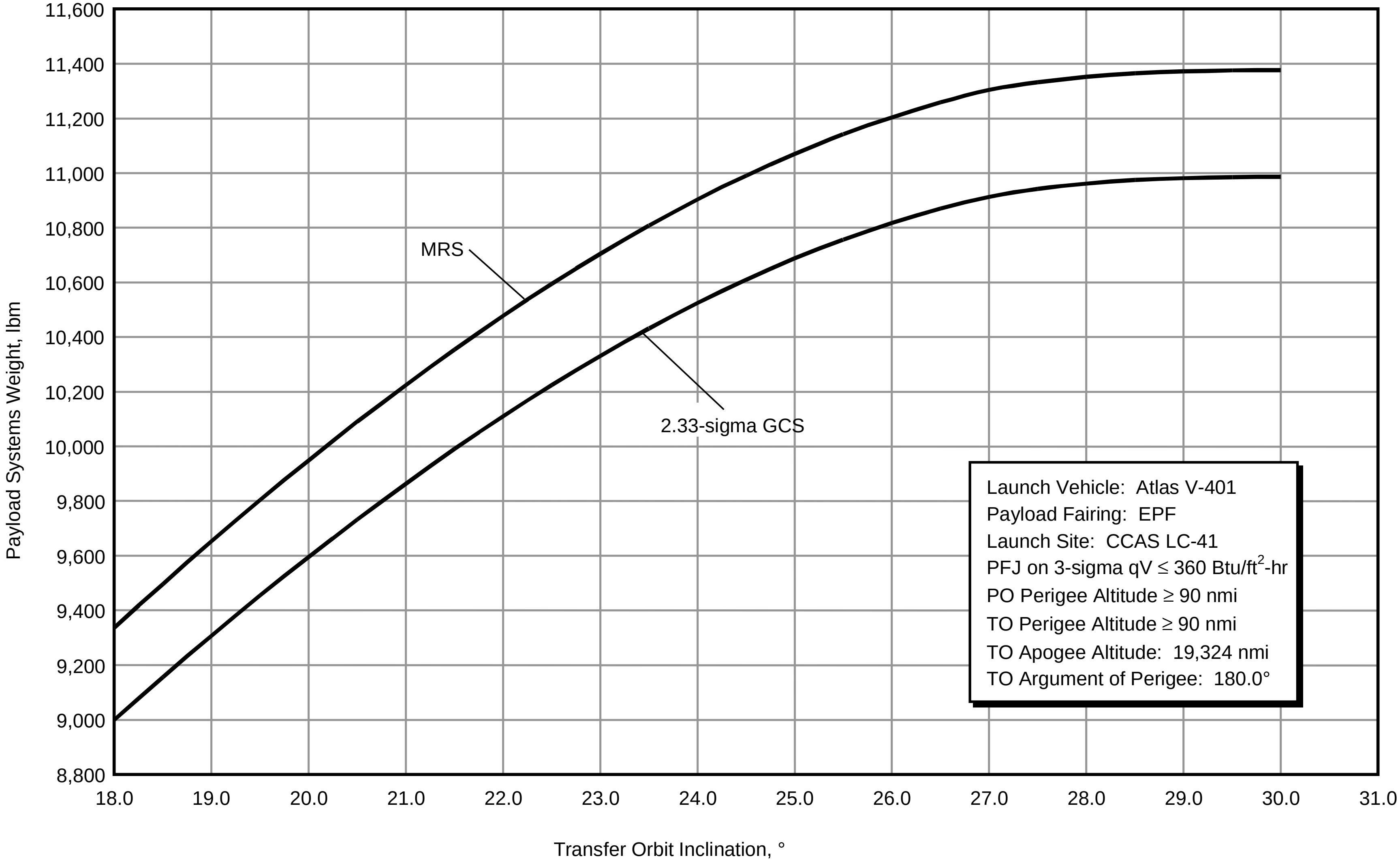


Figure 2.12-4b Atlas V 401 CCAS Reduced Inclination Elliptical Orbit Performance (English)

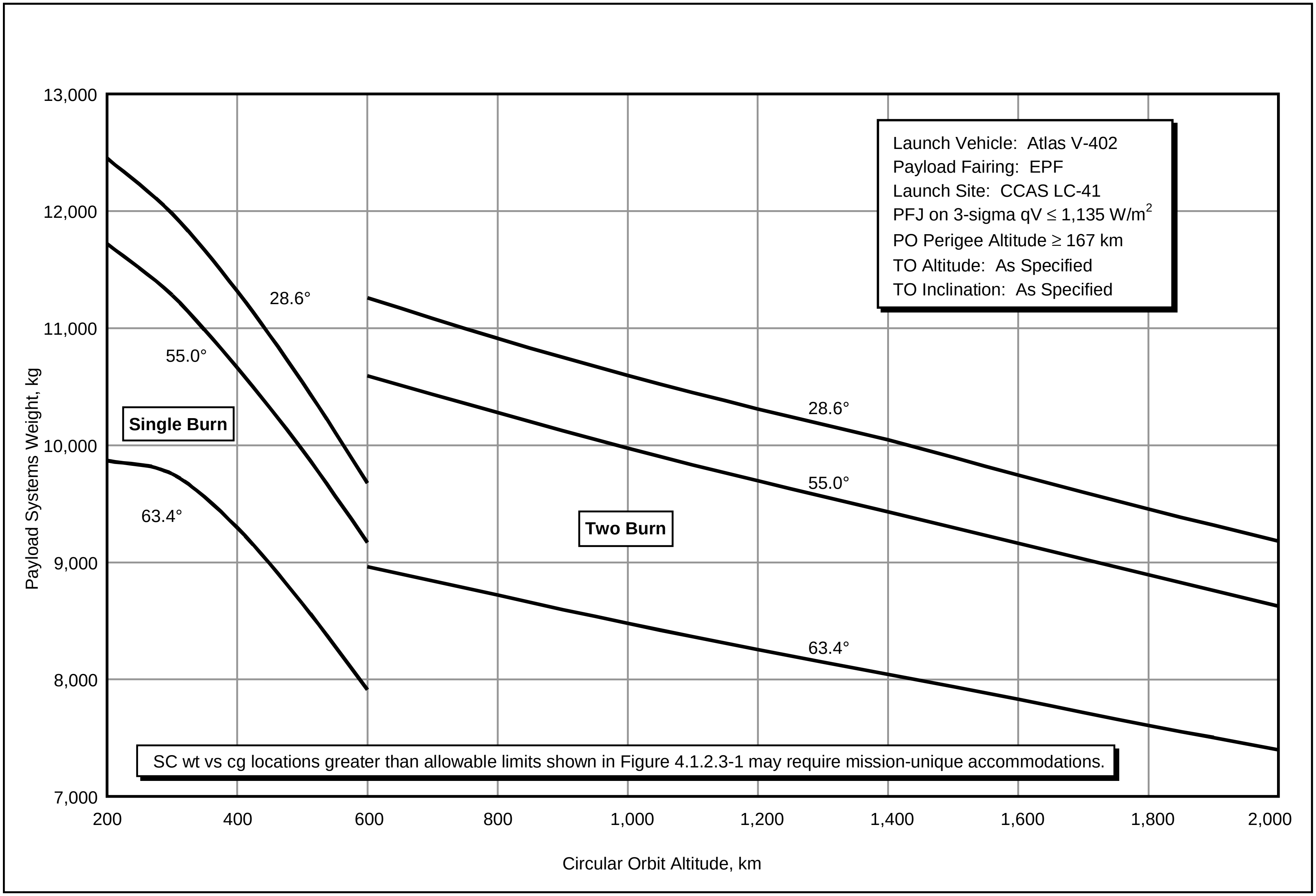


Figure 2.12-7a Atlas V 402 CCAS Low-Earth Orbit Performance (2.33-sigma GCS-Metric)

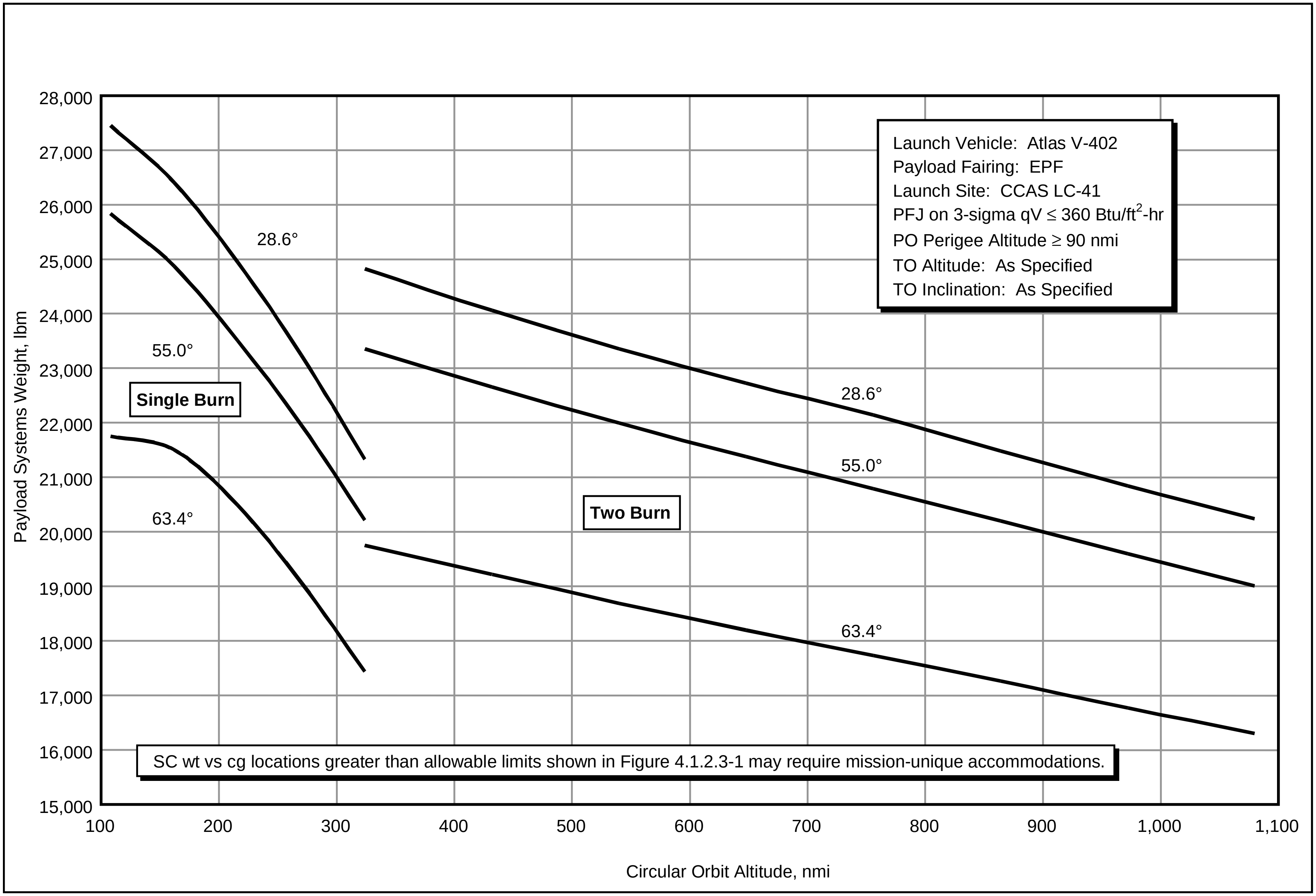


Figure 2.12-7b Atlas V 402 CCAS Low-Earth Orbit Performance (2.33-sigma GCS-English)

Table 2.12-1 Atlas V 401 Elliptical Transfer Orbit Performance—PSW vs Apogee Altitude

Apogee Altitude		Payload Systems Weight, kg (lb)			
		Atlas V 401			
km	(nmi)	MRS		2.33 sigma GCS	
4,630	(2,500)	8,206	(18,090)	7,946	(17,519)
5,556	(3,000)	7,928	(17,479)	7,677	(16,924)
6,482	(3,500)	7,680	(16,932)	7,435	(16,392)
7,408	(4,000)	7,456	(16,438)	7,217	(15,912)
8,334	(4,500)	7,257	(15,999)	7,023	(15,484)
9,260	(5,000)	7,079	(15,606)	6,850	(15,102)
10,186	(5,500)	6,916	(15,247)	6,691	(14,752)
11,112	(6,000)	6,770	(14,924)	6,549	(14,438)
12,038	(6,500)	6,634	(14,625)	6,417	(14,147)
13,427	(7,250)	6,455	(14,231)	6,243	(13,763)
14,816	(8,000)	6,296	(13,881)	6,088	(13,422)
16,205	(8,750)	6,156	(13,573)	5,952	(13,123)
17,594	(9,500)	6,033	(13,301)	5,833	(12,859)
18,983	(10,250)	5,919	(13,050)	5,722	(12,614)
20,372	(11,000)	5,818	(12,827)	5,623	(12,397)
23,150	(12,500)	5,642	(12,437)	5,451	(12,018)
25,928	(14,000)	5,495	(12,115)	5,309	(11,704)
28,706	(15,500)	5,372	(11,843)	5,189	(11,439)
31,484	(17,000)	5,264	(11,606)	5,084	(11,209)
34,262	(18,500)	5,173	(11,404)	4,995	(11,012)
35,788	(19,324)	5,127	(11,302)	4,950	(10,913)
37,966	(20,500)	5,066	(11,168)	4,891	(10,783)
40,744	(22,000)	4,996	(11,015)	4,823	(10,633)
43,522	(23,500)	4,937	(10,884)	4,766	(10,507)
46,300	(25,000)	4,882	(10,762)	4,712	(10,388)
49,078	(26,500)	4,832	(10,653)	4,663	(10,281)
51,856	(28,000)	4,787	(10,555)	4,620	(10,186)
54,634	(29,500)	4,744	(10,458)	4,578	(10,092)
57,412	(31,000)	4,708	(10,379)	4,542	(10,014)
62,968	(34,000)	4,643	(10,236)	4,480	(9,876)
68,524	(37,000)	4,586	(10,111)	4,424	(9,754)
74,080	(40,000)	4,537	(10,003)	4,377	(9,649)
79,636	(43,000)	4,496	(9,911)	4,336	(9,559)
87,044	(47,000)	4,447	(9,803)	4,288	(9,454)
92,600	(50,000)	4,414	(9,730)	4,256	(9,383)
98,156	(53,000)	4,386	(9,669)	4,229	(9,324)
109,268	(59,000)	4,337	(9,562)	4,182	(9,219)
120,380	(65,000)	4,297	(9,474)	4,143	(9,134)
131,492	(71,000)	4,262	(9,395)	4,108	(9,057)
142,604	(77,000)	4,234	(9,334)	4,081	(8,997)
153,716	(83,000)	4,208	(9,276)	4,056	(8,941)

Note:
- EPF Jettison at 3-sigma qv ≤1,135 W/m2 (360 Btu/ft^2-hr)
- Parking Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Orbit Inclination = 27.0°
- Argument of Perigee = 180°

Table 2.12-2 Atlas V 401 Performance to Reduced Inclination Transfer Orbit—PSW vs Orbit Inclination

Inclination, °	Payload Systems Weight, kg (lb)			
	Atlas V 401			
	MRS		2.33-sigma GCS	
18.0	4,235	(9,336)	4,082	(9,000)
18.5	4,308	(9,497)	4,153	(9,156)
19.0	4,378	(9,652)	4,222	(9,307)
19.5	4,447	(9,803)	4,288	(9,454)
20.0	4,513	(9,950)	4,353	(9,596)
20.5	4,577	(10,090)	4,415	(9,733)
21.0	4,638	(10,226)	4,475	(9,865)
21.5	4,697	(10,355)	4,532	(9,991)
22.0	4,753	(10,478)	4,586	(10,111)
22.5	4,806	(10,595)	4,638	(10,224)
23.0	4,856	(10,705)	4,686	(10,331)
23.5	4,902	(10,808)	4,732	(10,432)
24.0	4,946	(10,904)	4,774	(10,525)
24.5	4,986	(10,991)	4,813	(10,610)
25.0	5,022	(11,071)	4,848	(10,687)
25.5	5,054	(11,143)	4,879	(10,757)
26.0	5,083	(11,205)	4,907	(10,818)
26.5	5,107	(11,259)	4,930	(10,870)
27.0	5,127	(11,304)	4,950	(10,913)
27.5	5,140	(11,332)	4,963	(10,942)
28.0	5,149	(11,351)	4,972	(10,961)
28.5	5,155	(11,365)	4,978	(10,974)
29.0	5,158	(11,371)	4,981	(10,981)
29.5	5,160	(11,375)	4,982	(10,984)
30.0	5,160	(11,376)	4,983	(10,985)

Note:
- EPF Jettison at 3-sigma qV ≤ 1,135 W/m^2 (360 Btu/ft^2-hr)
- Parking Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Apogee Altitude = 35,788 km (19,324 mn)
- Argument of Perigee = 180°

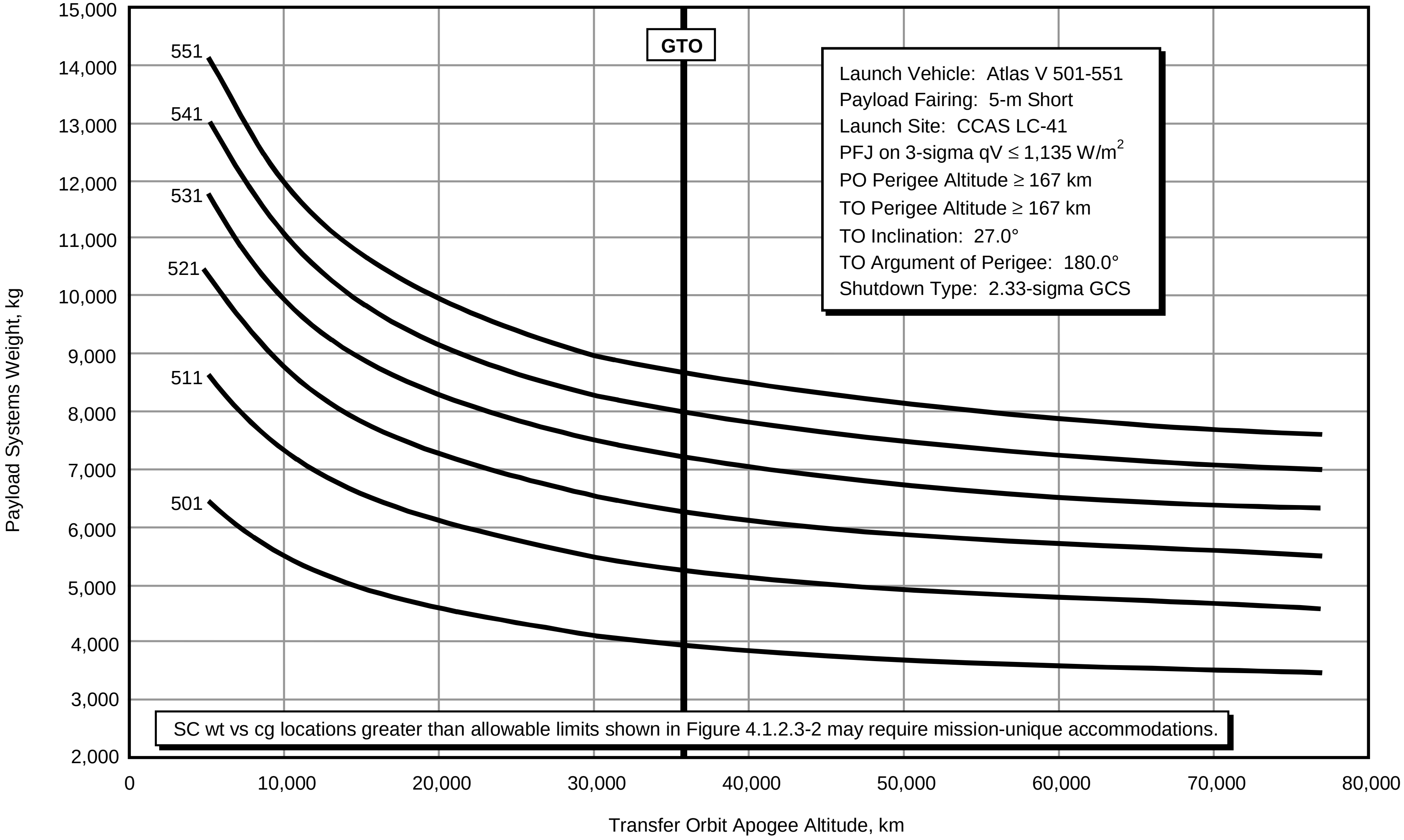


Figure 2.13-2a Atlas V 501-551 CCAS Performance to Elliptical Transfer Orbit (GCS-Metric)

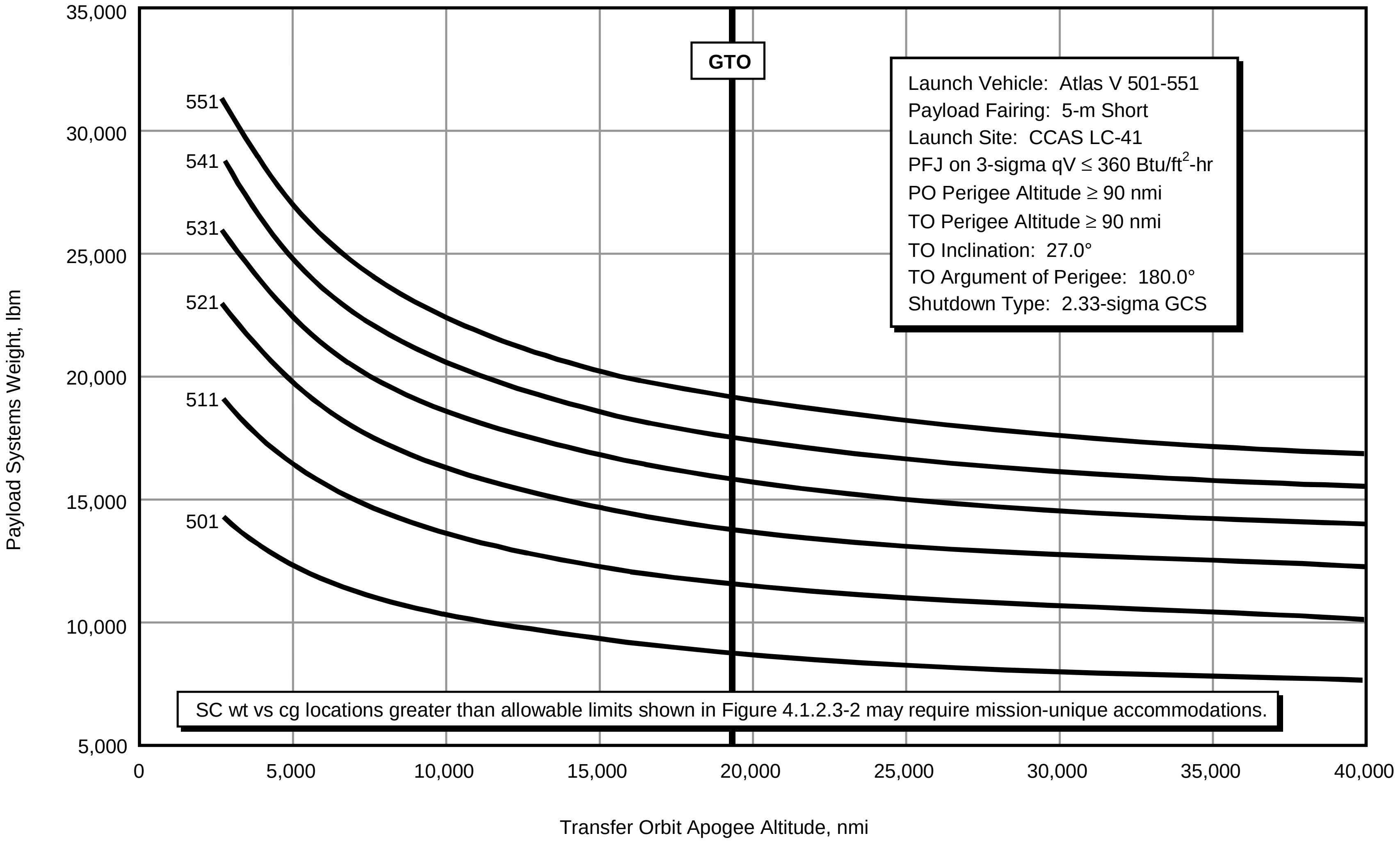


Figure 2.13-2b Atlas V 501-551 CCAS Performance to Elliptical Transfer Orbit (GCS-English)

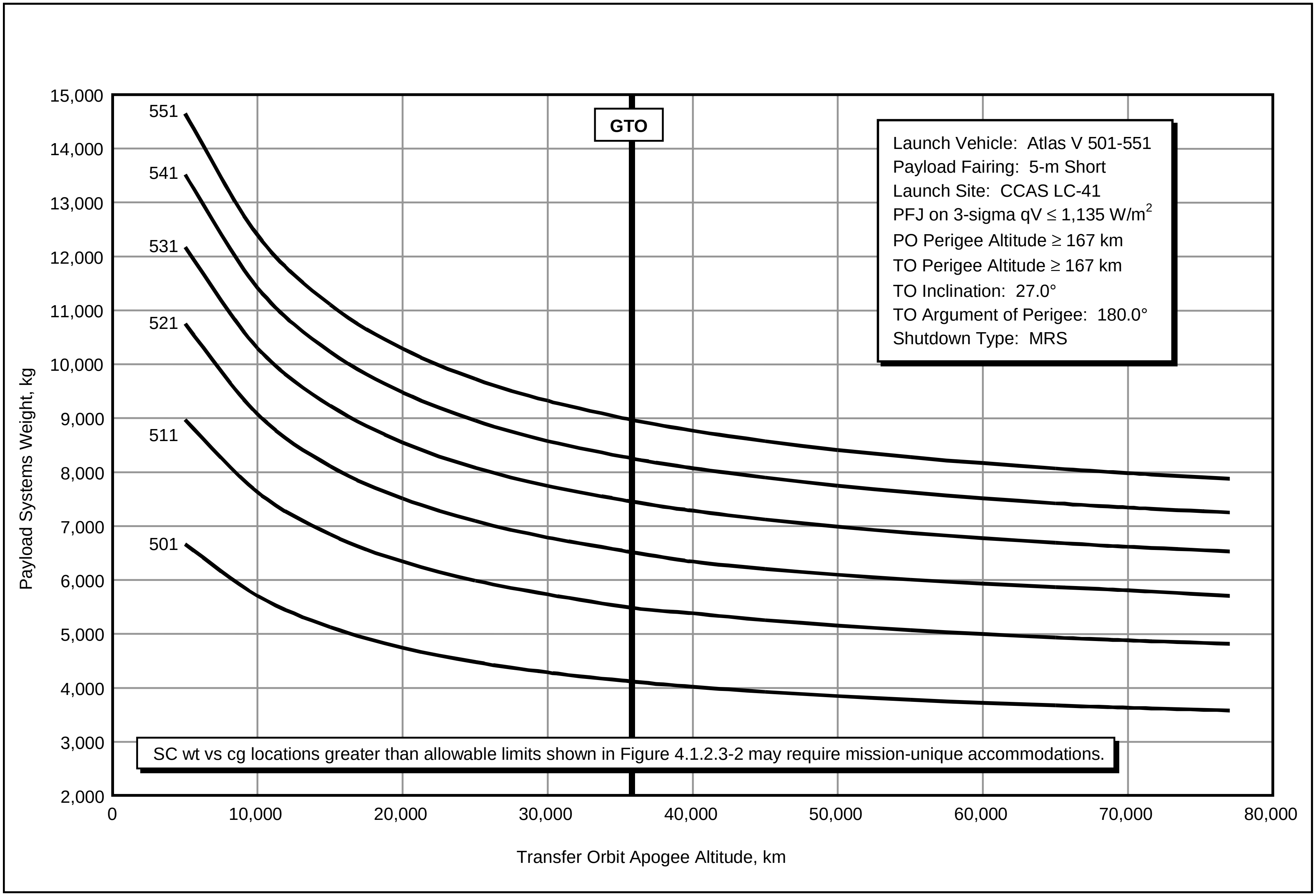
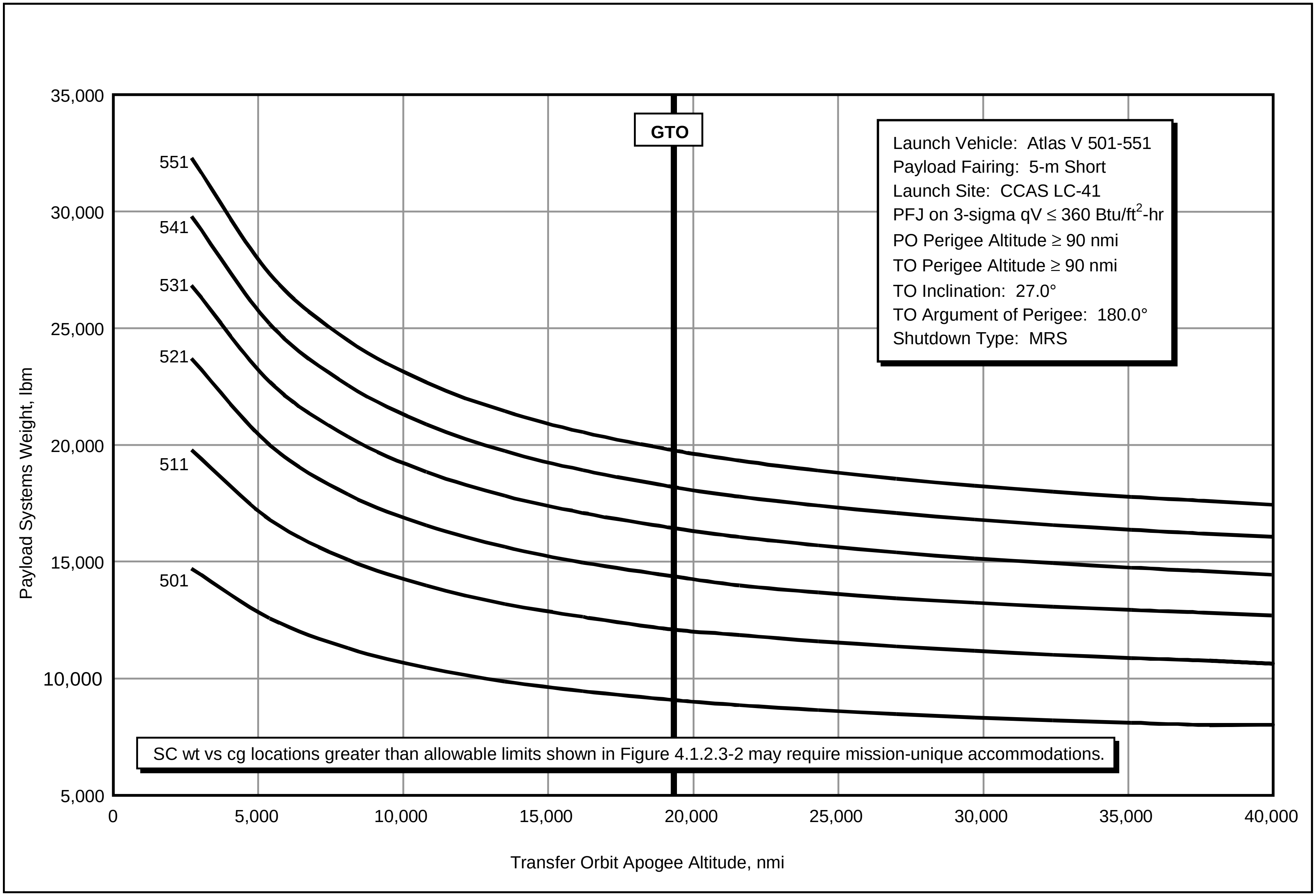


Figure 2.13-3a Atlas V 501-551 CCAS Performance to Elliptical Transfer Orbit (MRS-Metric)



Launch Vehicle: Atlas V 501-551
Payload Fairing: 5-m Short
Launch Site: CCAS LC-41
PFJ on 3-sigma qV ≤ 360 Btu/ft^2-hr
PO Perigee Altitude ≥ 90 nmi
TO Perigee Altitude ≥ 90 nmi
TO Inclination: 27.0°
TO Argument of Perigee: 180.0°
Shutdown Type: MRS

SC wt vs cg locations greater than allowable limits shown in Figure 4.1.2.3-2 may require mission-unique accommodations.

Figure 2.13-3b Atlas V 501-551 CCAS Performance to Elliptical Transfer Orbit (MRS-English)

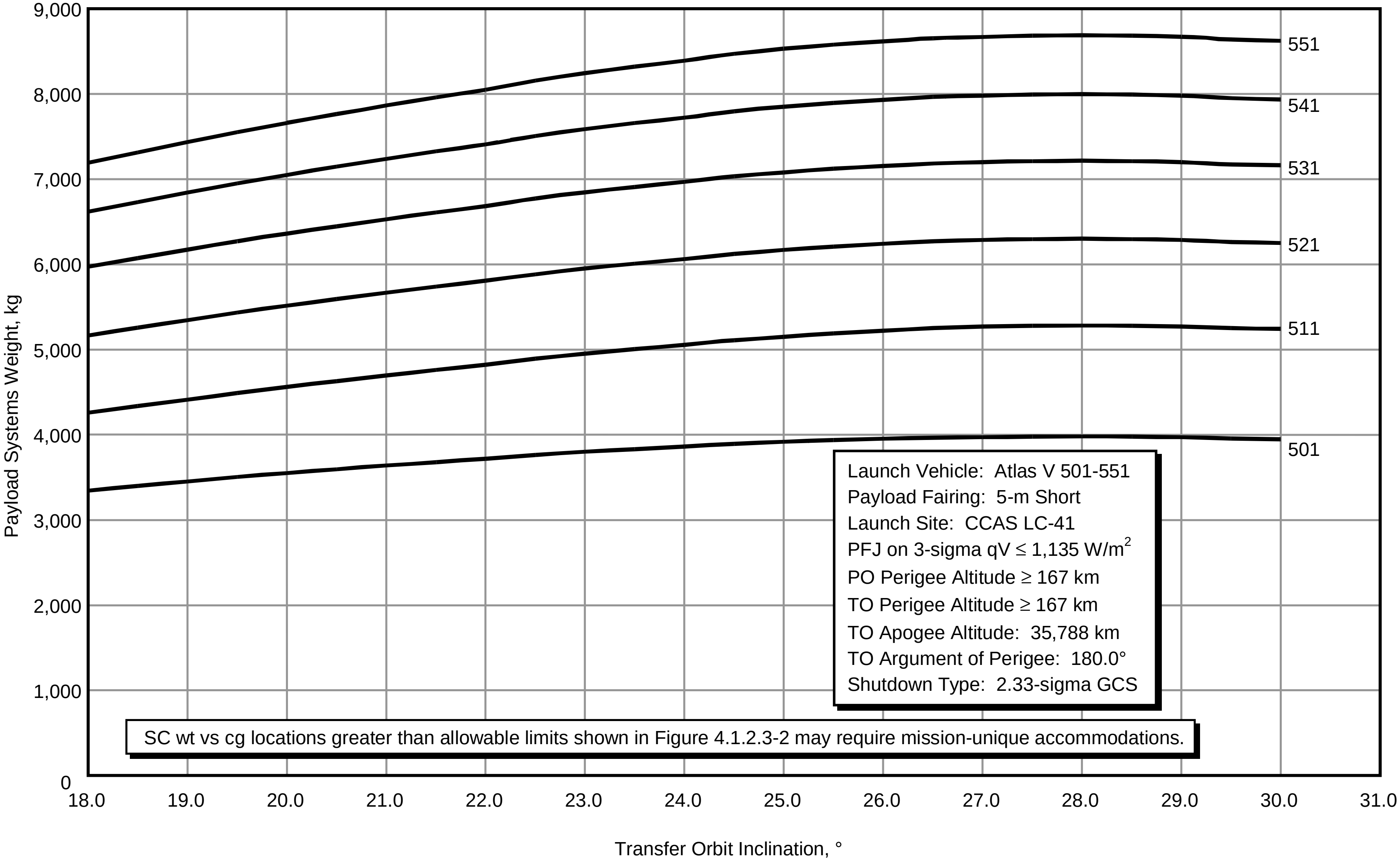


Figure 2.13-4a Atlas V 501-551 CCAS Reduced Inclination Elliptical Orbit Performance (GCS-Metric)

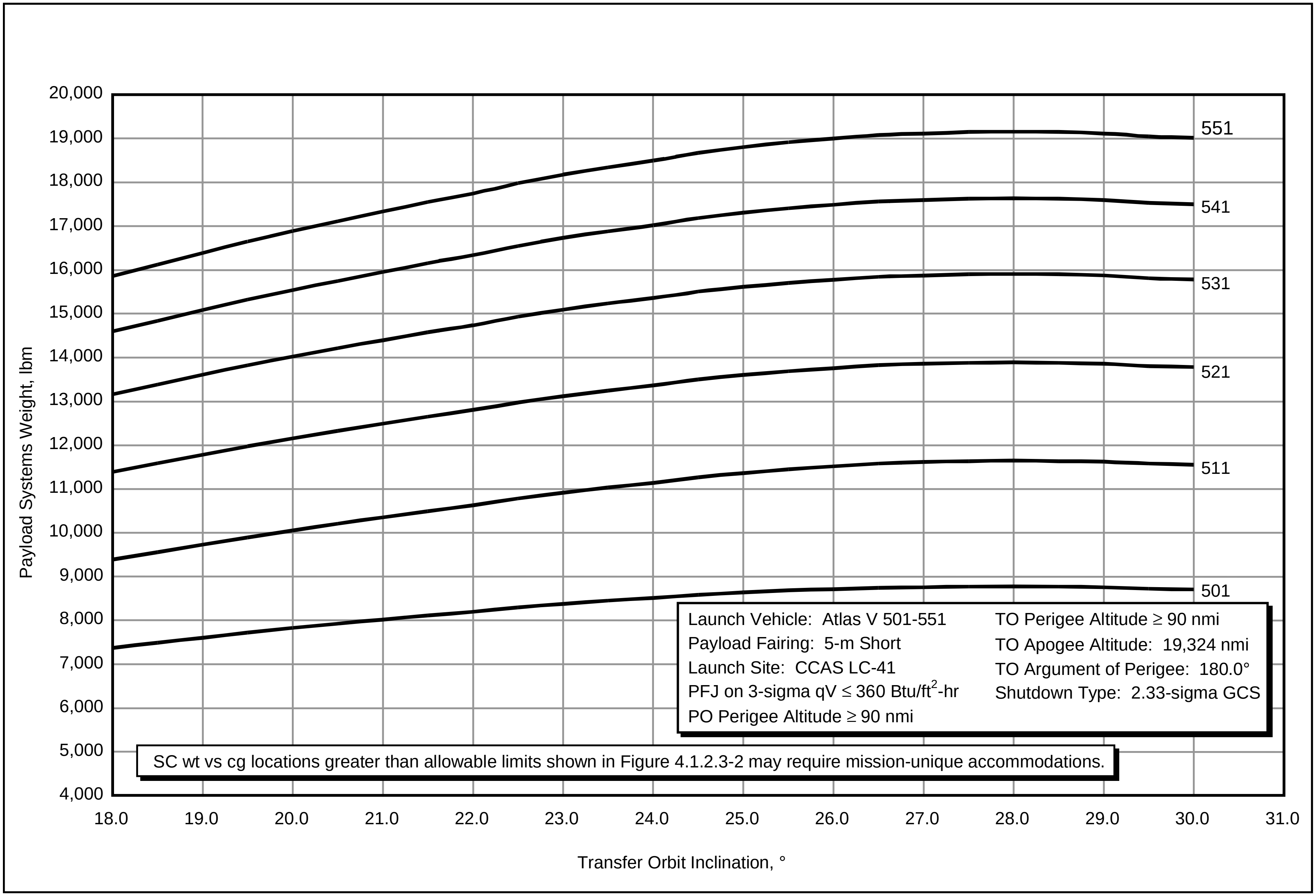


Figure 2.13-4b Atlas V 501-551 CCAS Reduced Inclination Elliptical Orbit Performance (GCS-English)

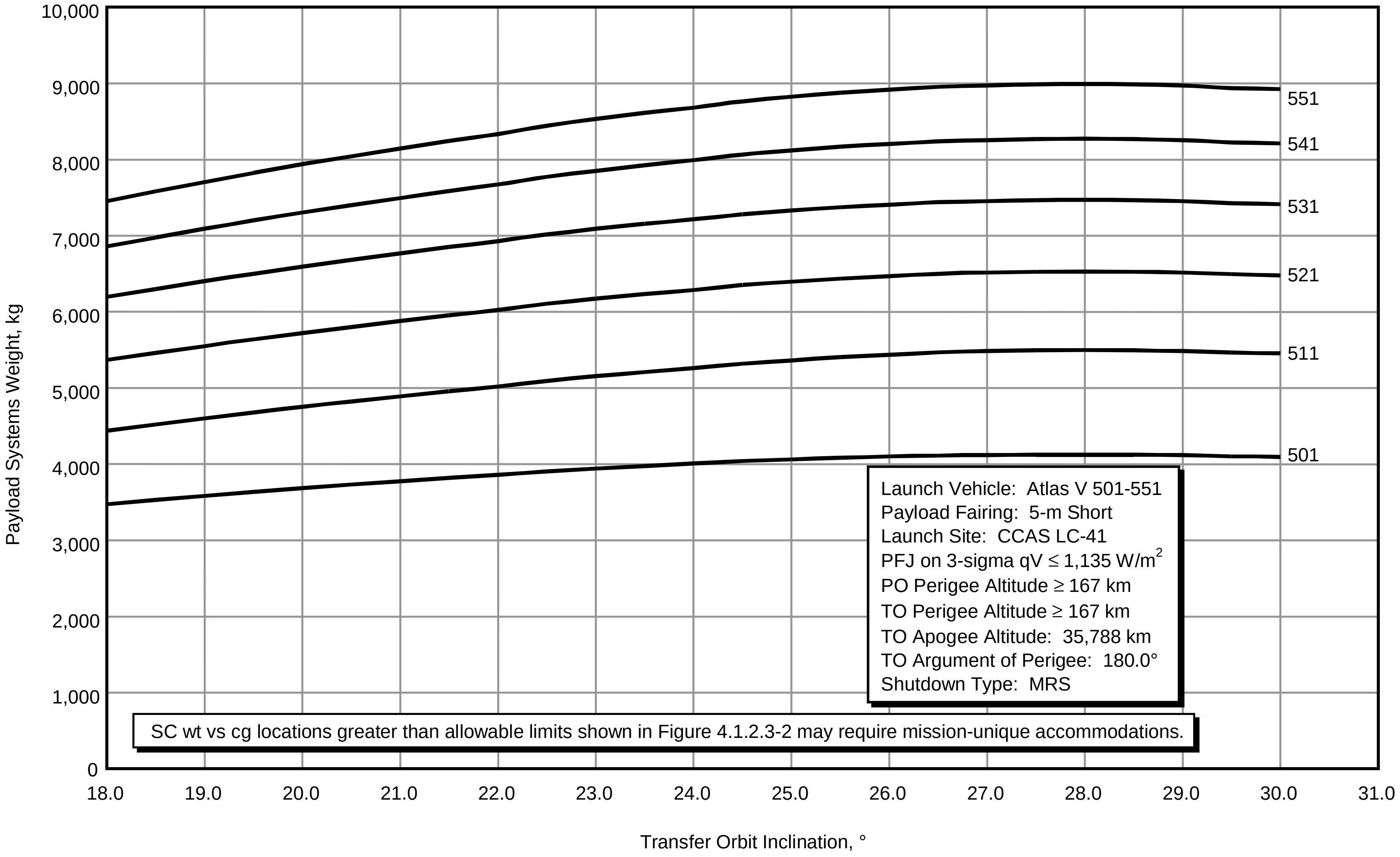
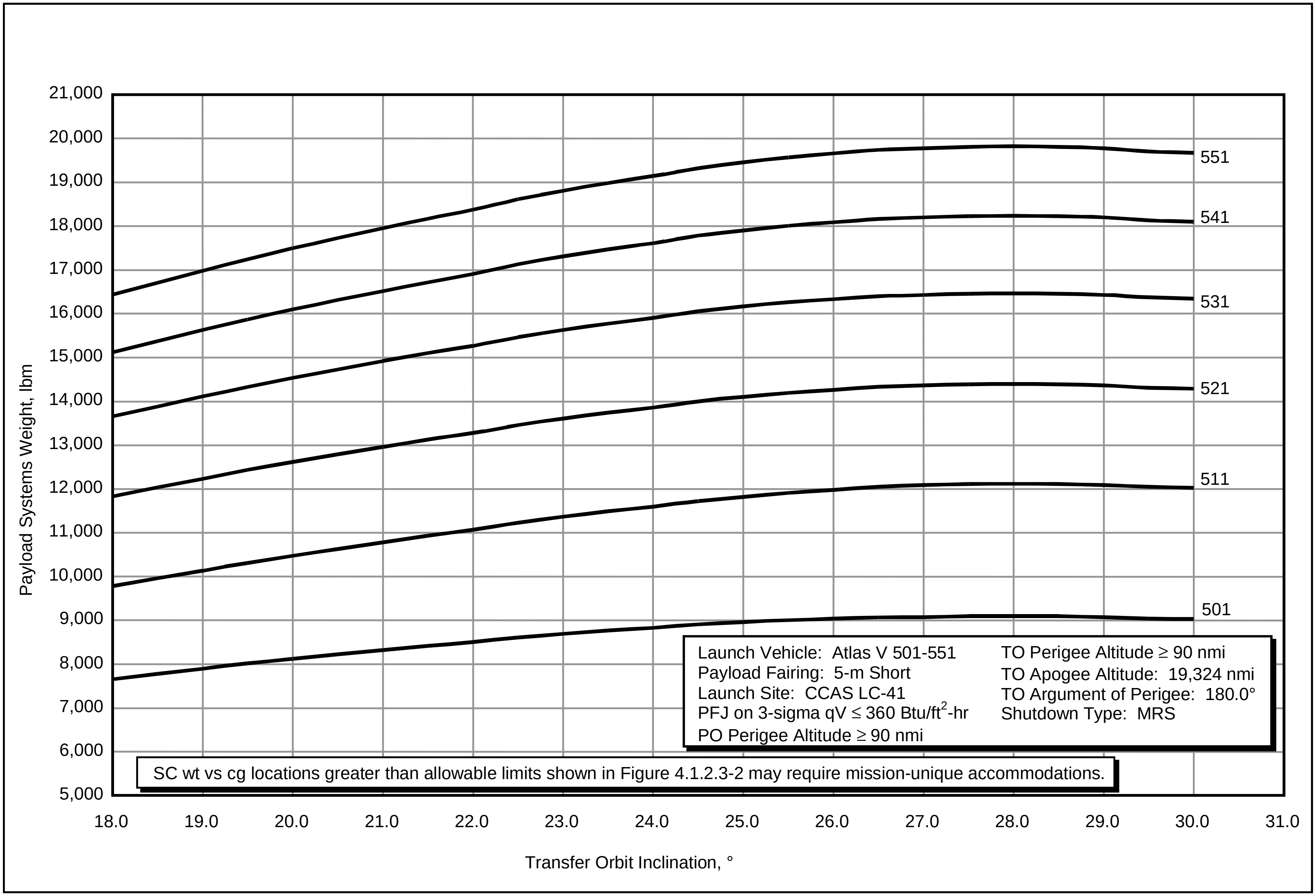


Figure 2.13-5a Atlas V 501-551 CCAS Reduced Inclination Elliptical Orbit Performance (MRS-Metric)



Launch Vehicle: Atlas V 501-551
Payload Fairing: 5-m Short
Launch Site: CCAS LC-41
PFJ on 3-sigma qV ≤ 360 Btu/ft^2-hr
PO Perigee Altitude ≥ 90 nmi
TO Perigee Altitude ≥ 90 nmi
TO Apogee Altitude: 19,324 nmi
TO Argument of Perigee: 180.0°
Shutdown Type: MRS

SC wt vs cg locations greater than allowable limits shown in Figure 4.1.2.3-2 may require mission-unique accommodations.

Figure 2.13-5b Atlas V 501-551 CCAS Reduced Inclination Elliptical Orbit Performance (MRS-English)

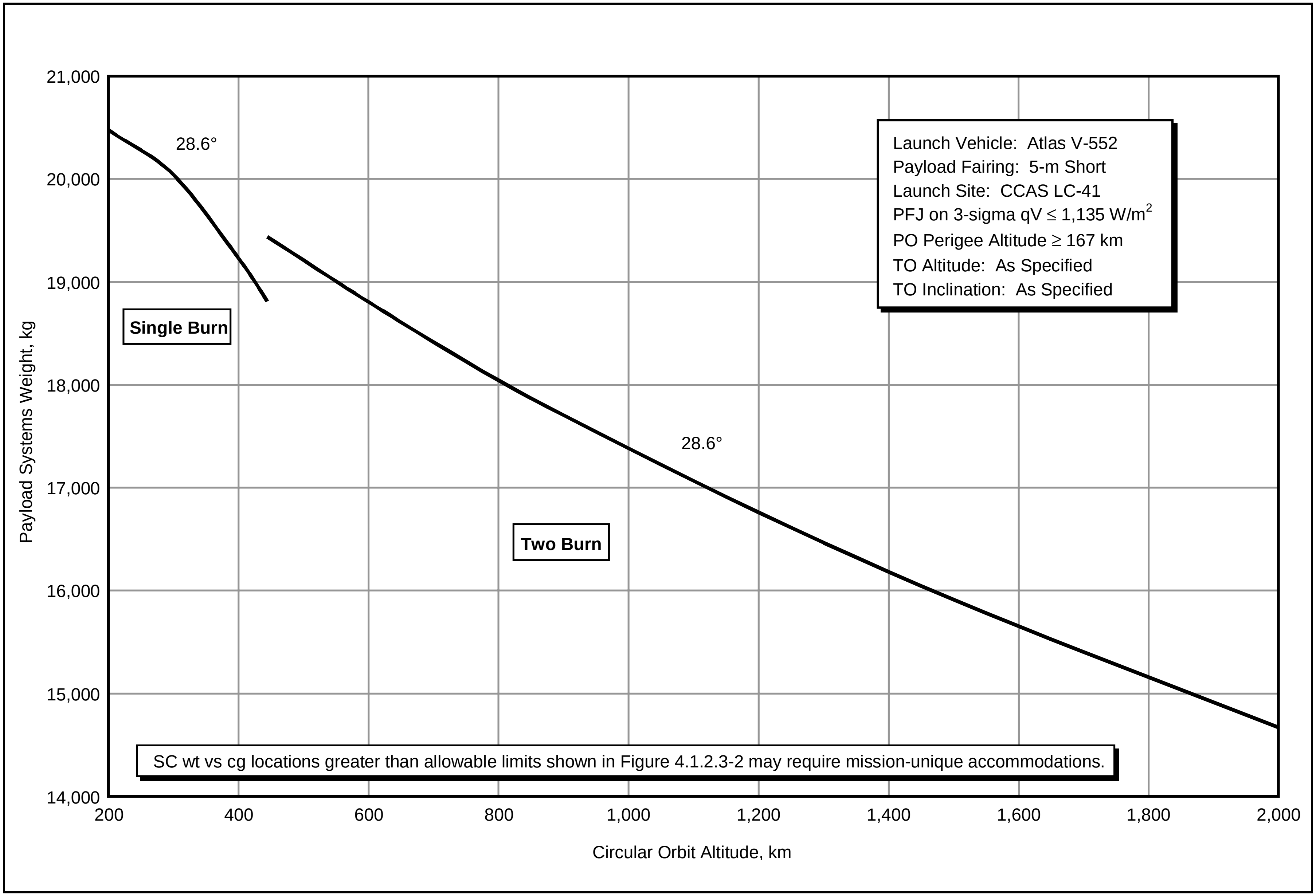


Figure 2.13-7a Atlas V 552 CCAS Low-Earth Orbit Performance (2.33-sigma GCS-Metric)

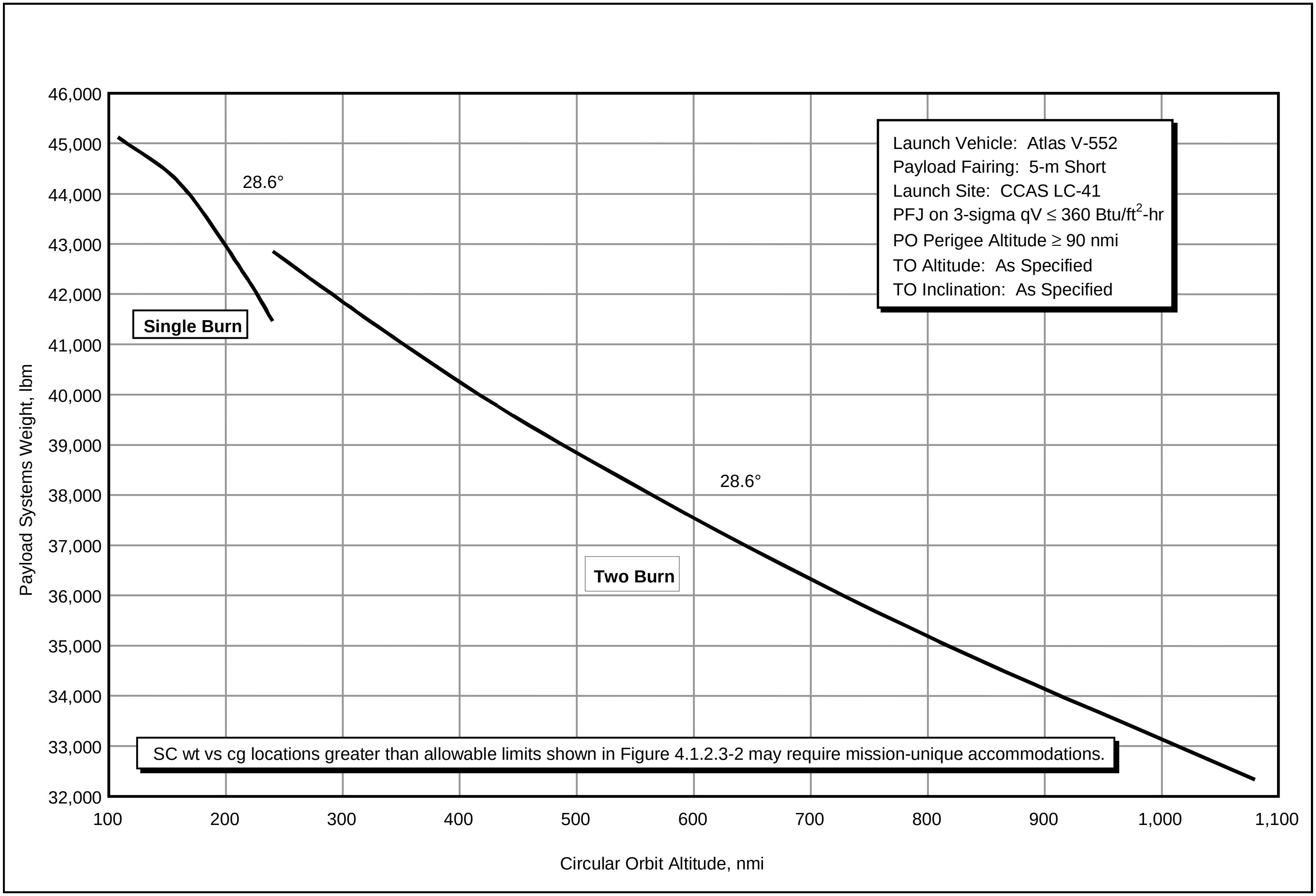


Figure 2.13-7b Atlas V 552 CCAS Low-Earth Orbit Performance (2.33-sigma GCS-English)

Table 2.13-1 Atlas V 500 Series Elliptical Transfer Orbit Performance—PSW vs Apogee Altitude

		Payload Systems Weight, kg (lb)											
Apogee Altitude		**Atlas V 501**				**Atlas V 511**				**Atlas V 521**			
km	**(nmi)**	**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**	
5,000	(2,700)	6,669	(14,703)	6,448	(14,216)	8,975	(19,786)	8,649	(19,067)	10,753	(23,706)	10,398	(22,924)
10,000	(5,400)	5,705	(12,578)	5,512	(12,152)	7,627	(16,815)	7,335	(16,172)	9,076	(20,009)	8,770	(19,334)
15,000	(8,099)	5,128	(11,305)	4,951	(10,915)	6,843	(15,086)	6,571	(14,486)	8,110	(17,879)	7,832	(17,266)
20,000	(10,799)	4,747	(10,466)	4,582	(10,101)	6,340	(13,976)	6,075	(13,392)	7,511	(16,559)	7,250	(15,984)
25,000	(13,499)	4,480	(9,877)	4,322	(9,528)	5,985	(13,196)	5,750	(12,677)	7,093	(15,638)	6,844	(15,089)
30,000	(16,199)	4,288	(9,452)	4,135	(9,116)	5,732	(12,637)	5,489	(12,101)	6,789	(14,967)	6,549	(14,439)
35,788	(19,324)	4,118	(9,078)	3,970	(8,752)	5,484	(12,091)	5,270	(11,618)	6,517	(14,367)	6,285	(13,856)
40,000	(21,598)	4,020	(8,862)	3,874	(8,542)	5,379	(11,858)	5,146	(11,345)	6,342	(13,982)	6,115	(13,482)
45,000	(24,298)	3,925	(8,652)	3,782	(8,339)	5,257	(11,589)	5,029	(11,087)	6,204	(13,677)	5,981	(13,185)
50,000	(26,998)	3,846	(8,478)	3,705	(8,169)	5,157	(11,370)	4,928	(10,864)	6,095	(13,437)	5,875	(12,952)
55,000	(29,698)	3,779	(8,332)	3,641	(8,027)	5,072	(11,181)	4,844	(10,679)	6,006	(13,241)	5,789	(12,762)
60,000	(32,397)	3,723	(8,208)	3,586	(7,906)	4,996	(11,015)	4,775	(10,528)	5,931	(13,076)	5,716	(12,602)
65,000	(35,097)	3,674	(8,100)	3,539	(7,802)	4,934	(10,878)	4,714	(10,393)	5,865	(12,931)	5,652	(12,461)
70,000	(37,797)	3,632	(8,007)	3,498	(7,711)	4,882	(10,763)	4,663	(10,280)	5,807	(12,801)	5,595	(12,335)
77,000	(41,577)	3,581	(7,894)	3,448	(7,602)	4,815	(10,615)	4,599	(10,140)	5,704	(12,576)	5,496	(12,116)
Apogee Altitude		**Atlas V 531**				**Atlas V 541**				**Atlas V 551**			
km	**(nmi)**	**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**	
5,000	(2,700)	12,175	(26,841)	11,782	(25,976)	13,517	(29,799)	13,087	(28,853)	14,651	(32,299)	14,180	(31,262)
10,000	(5,400)	10,302	(22,712)	9,964	(21,968)	11,423	(25,184)	11,055	(24,373)	12,397	(27,330)	11,993	(26,441)
15,000	(8,099)	9,232	(20,354)	8,926	(19,679)	10,231	(22,556)	9,898	(21,822)	11,106	(24,484)	10,741	(23,680)
20,000	(10,799)	8,553	(18,855)	8,266	(18,224)	9,478	(20,894)	9,167	(20,209)	10,289	(22,684)	9,949	(21,934)
25,000	(13,499)	8,086	(17,826)	7,813	(17,225)	8,958	(19,748)	8,662	(19,096)	9,730	(21,450)	9,406	(20,736)
30,000	(16,199)	7,751	(17,087)	7,488	(16,508)	8,582	(18,919)	8,297	(18,292)	9,323	(20,553)	9,011	(19,866)
35,788	(19,324)	7,454	(16,433)	7,200	(15,873)	8,255	(18,200)	7,980	(17,593)	8,971	(19,778)	8,670	(19,114)
40,000	(21,598)	7,285	(16,061)	7,036	(15,512)	8,070	(17,791)	7,800	(17,196)	8,770	(19,334)	8,474	(18,683)
45,000	(24,298)	7,120	(15,697)	6,876	(15,158)	7,897	(17,410)	7,632	(16,827)	8,574	(18,901)	8,284	(18,264)
50,000	(26,998)	6,985	(15,398)	6,744	(14,869)	7,747	(17,078)	7,486	(16,504)	8,414	(18,549)	8,129	(17,922)
55,000	(29,698)	6,871	(15,147)	6,634	(14,625)	7,622	(16,803)	7,365	(16,237)	8,279	(18,251)	7,998	(17,633)
60,000	(32,397)	6,773	(14,933)	6,539	(14,417)	7,515	(16,568)	7,262	(16,009)	8,164	(17,999)	7,887	(17,389)
65,000	(35,097)	6,690	(14,749)	6,459	(14,239)	7,423	(16,365)	7,172	(15,812)	8,066	(17,782)	7,792	(17,178)
70,000	(37,797)	6,617	(14,589)	6,388	(14,083)	7,343	(16,189)	7,095	(15,641)	7,981	(17,595)	7,709	(16,996)
77,000	(41,577)	6,531	(14,398)	6,304	(13,898)	7,249	(15,980)	7,003	(15,439)	7,878	(17,368)	7,609	(16,776)

Note:
- 5-m Short PLF Jettison at 3-sigma qV ≤ 1,135 W/m^2 (360 Btu/ft^2-hr)
- Parking Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Orbit Inclination = 27.0°
- Argument of Perigee = 180°

Table 2.13-2a Atlas V 501, 511, 521 Performance to Reduced Inclination Transfer Orbit—PSW vs Orbit Inclination

	Payload Systems Weight, kg (lb)											
	Atlas V 501				**Atlas V 511**				**Atlas V 521**			
Inclination, °	**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**	
18.0	3,475	(7,660)	3,344	(7,372)	4,437	(9,783)	4,257	(9,384)	5,367	(11,832)	5,167	(11,392)
18.5	3,530	(7,782)	3,398	(7,491)	4,518	(9,961)	4,335	(9,557)	5,459	(12,036)	5,257	(11,590)
19.0	3,584	(7,901)	3,450	(7,606)	4,598	(10,136)	4,412	(9,727)	5,550	(12,236)	5,345	(11,785)
19.5	3,637	(8,018)	3,502	(7,721)	4,677	(10,311)	4,489	(9,896)	5,640	(12,434)	5,433	(11,977)
20.0	3,686	(8,126)	3,550	(7,826)	4,751	(10,474)	4,560	(10,053)	5,723	(12,618)	5,514	(12,156)
20.5	3,732	(8,228)	3,595	(7,925)	4,821	(10,630)	4,629	(10,204)	5,803	(12,793)	5,591	(12,327)
21.0	3,776	(8,326)	3,638	(8,020)	4,890	(10,781)	4,695	(10,350)	5,880	(12,962)	5,666	(12,491)
21.5	3,819	(8,420)	3,680	(8,112)	4,957	(10,929)	4,760	(10,494)	5,954	(13,127)	5,739	(12,652)
22.0	3,859	(8,507)	3,718	(8,197)	5,020	(11,067)	4,821	(10,628)	6,024	(13,280)	5,806	(12,801)
22.5	3,905	(8,610)	3,763	(8,297)	5,092	(11,227)	4,891	(10,783)	6,105	(13,459)	5,885	(12,974)
23.0	3,944	(8,694)	3,801	(8,379)	5,154	(11,363)	4,951	(10,915)	6,173	(13,609)	5,951	(13,120)
23.5	3,977	(8,767)	3,833	(8,449)	5,210	(11,485)	5,004	(11,033)	6,233	(13,741)	6,010	(13,249)
24.0	4,006	(8,832)	3,861	(8,513)	5,260	(11,597)	5,054	(11,141)	6,288	(13,862)	6,063	(13,366)
24.5	4,040	(8,907)	3,895	(8,586)	5,318	(11,724)	5,109	(11,264)	6,350	(13,999)	6,124	(13,500)
25.0	4,064	(8,961)	3,918	(8,638)	5,363	(11,822)	5,152	(11,359)	6,397	(14,103)	6,169	(13,601)
25.5	4,085	(9,006)	3,938	(8,682)	5,402	(11,910)	5,191	(11,444)	6,438	(14,193)	6,209	(13,689)
26.0	4,100	(9,038)	3,953	(8,714)	5,435	(11,981)	5,222	(11,513)	6,470	(14,264)	6,240	(13,758)
26.5	4,113	(9,068)	3,966	(8,743)	5,466	(12,050)	5,252	(11,579)	6,500	(14,331)	6,270	(13,823)
27.0	4,118	(9,078)	3,970	(8,752)	5,485	(12,092)	5,270	(11,618)	6,517	(14,367)	6,285	(13,856)
27.5	4,124	(9,092)	3,977	(8,767)	5,493	(12,111)	5,279	(11,638)	6,527	(14,390)	6,296	(13,880)
28.0	4,127	(9,098)	3,979	(8,773)	5,497	(12,119)	5,283	(11,646)	6,531	(14,399)	6,300	(13,889)
28.5	4,124	(9,092)	3,977	(8,767)	5,493	(12,111)	5,279	(11,638)	6,527	(14,390)	6,296	(13,880)
29.0	4,118	(9,078)	3,970	(8,753)	5,485	(12,091)	5,271	(11,620)	6,517	(14,367)	6,286	(13,858)
29.5	4,102	(9,044)	3,956	(8,720)	5,464	(12,047)	5,251	(11,576)	6,492	(14,313)	6,262	(13,806)
30.0	4,095	(9,029)	3,949	(8,706)	5,455	(12,026)	5,242	(11,556)	6,481	(14,289)	6,252	(13,782)

Note:

- 5-m Short PLF Jettison at 3-sigma qV ≤ 1,135 W/m^2 (360 Btu/ft^2-hr)
- Parking Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Apogee Altitude = 35,788 km (19,324 nmi)
- Argument of Perigee = 180°

Table 2.13-2b Atlas V 531, 541, 551 Performance to Reduced Inclination Transfer Orbit—PSW vs Orbit Inclination

	Payload Systems Weight, kg (lb)											
	Atlas V 531				**Atlas V 541**				**Atlas V 521**			
Inclination, °	**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**		**MRS**		**2.33-sigma GCS**	
18.0	6,196	(13,659)	5,974	(13,171)	6,862	(15,128)	6,621	(14,598)	7,457	(16,440)	7,194	(15,860)
18.5	6,299	(13,888)	6,075	(13,393)	6,977	(15,381)	6,733	(14,844)	7,582	(16,715)	7,315	(16,128)
19.0	6,401	(14,111)	6,174	(13,611)	7,089	(15,629)	6,843	(15,086)	7,704	(16,984)	7,434	(16,390)
19.5	6,501	(14,333)	6,272	(13,827)	7,200	(15,874)	6,951	(15,325)	7,825	(17,250)	7,552	(16,650)
20.0	6,594	(14,537)	6,362	(14,026)	7,303	(16,101)	7,052	(15,546)	7,936	(17,496)	7,661	(16,890)
20.5	6,682	(14,732)	6,448	(14,216)	7,401	(16,316)	7,147	(15,756)	8,042	(17,730)	7,765	(17,118)
21.0	6,767	(14,919)	6,531	(14,398)	7,495	(16,523)	7,239	(15,958)	8,145	(17,956)	7,864	(17,338)
21.5	6,850	(15,101)	6,612	(14,576)	7,586	(16,725)	7,328	(16,155)	8,244	(18,175)	7,961	(17,552)
22.0	6,926	(15,269)	6,686	(14,740)	7,671	(16,911)	7,410	(16,337)	8,336	(18,378)	8,051	(17,750)
22.5	7,016	(15,467)	6,773	(14,932)	7,770	(17,130)	7,507	(16,550)	8,444	(18,615)	8,156	(17,981)
23.0	7,090	(15,631)	6,846	(15,093)	7,853	(17,312)	7,588	(16,728)	8,533	(18,813)	8,244	(18,174)
23.5	7,155	(15,775)	6,910	(15,233)	7,925	(17,471)	7,658	(16,884)	8,612	(18,986)	8,320	(18,343)
24.0	7,214	(15,905)	6,967	(15,360)	7,990	(17,615)	7,722	(17,024)	8,683	(19,142)	8,390	(18,496)
24.5	7,282	(16,054)	7,033	(15,506)	8,065	(17,781)	7,795	(17,186)	8,764	(19,322)	8,469	(18,672)
25.0	7,332	(16,165)	7,082	(15,613)	8,121	(17,903)	7,849	(17,305)	8,825	(19,455)	8,528	(18,801)
25.5	7,375	(16,260)	7,124	(15,706)	8,169	(18,008)	7,896	(17,408)	8,877	(19,570)	8,579	(18,913)
26.0	7,408	(16,332)	7,156	(15,777)	8,205	(18,089)	7,932	(17,487)	8,916	(19,657)	8,618	(18,998)
26.5	7,439	(16,400)	7,187	(15,844)	8,239	(18,164)	7,965	(17,560)	8,953	(19,739)	8,654	(19,079)
27.0	7,454	(16,433)	7,200	(15,873)	8,255	(18,200)	7,980	(17,593)	8,971	(19,778)	8,670	(19,114)
27.5	7,466	(16,459)	7,213	(15,901)	8,268	(18,229)	7,994	(17,624)	8,985	(19,809)	8,685	(19,148)
28.0	7,470	(16,470)	7,217	(15,911)	8,274	(18,240)	7,999	(17,635)	8,991	(19,822)	8,691	(19,160)
28.5	7,466	(16,459)	7,213	(15,901)	8,268	(18,229)	7,994	(17,624)	8,985	(19,809)	8,685	(19,148)
29.0	7,454	(16,432)	7,201	(15,875)	8,255	(18,199)	7,981	(17,595)	8,971	(19,777)	8,671	(19,117)
29.5	7,426	(16,372)	7,174	(15,816)	8,225	(18,132)	7,951	(17,530)	8,938	(19,704)	8,639	(19,045)
30.0	7,413	(16,344)	7,162	(15,789)	8,211	(18,101)	7,938	(17,500)	8,922	(19,671)	8,624	(19,012)

Note:
- 5-m Short PLF Jettison at 3-sigma qV ≤ 1,135 W/m^2 (360 Btu/ft^2-hr)
- Parking Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Perigee Altitude ≥ 167 km (90 nmi)
- Transfer Orbit Apogee Altitude = 35,788 km (19,324 nmi)
- Argument of Perigee = 180°

3.0 ATLAS V ENVIRONMENTS

This section describes the environments to which the spacecraft is exposed, both during ground processing and in flight. Detailed spacecraft environmental data are provided for Launch Complex 41 (LC-41) at Cape Canaveral Air Station (CCAS), and Space Launch Complex 3W (SLC-3W) at Vandenberg Air Force Base (VAFB).

Atlas V Prelaunch Environments are described in Section 3.1; Atlas V Launch and Flight Environments in Section 3.2, and Spacecraft Compatibility Test Requirements in Section 3.3.

3.1 ATLAS V PRELAUNCH ENVIRONMENTS

3.1.1 Atlas V Thermal

The spacecraft thermal environment is controlled during prelaunch activity, maintained during ground transport, and controlled after mate to the launch vehicle.

During ground transport from the payload processing facility (PPF) to the vehicle integration facility (VIF) at CCAS, the temperature within the payload fairing (PLF) remains between 4 and 30°C (40-86°F), with positive pressure provided by a gaseous nitrogen (GN_2) purge. If required, an air conditioning unit can maintain air temperatures between 10 and 25°C (50-77°F). In both cases, the relative humidity remains at or below 50%. At VAFB, the transporter maintains the temperature between 10 and 27°C (50-80°F), with conditioned air and a GN_2 backup system.

During hoisting operations the encapsulated spacecraft is purged with dry GN_2 and relative humidity is maintained at or below 50%. If required, a high-flow-rate conditioned air system can be used during hoist operations at the VIF.

After spacecraft mate to Atlas V, gas conditioning is provided to the PLF at the required temperature, humidity, and flow rate. Air with a maximum dewpoint of 4.4°C (40°F) is used until approximately 5 hours before launch, after which GN_2 with a maximum dewpoint of -37°C (-35°F) is used. Table 3.1.1-1 summarizes prelaunch gas conditioning temperature capabilities for the nominal configuration without a thermal shield in the PLF.

Gas to the payload compartment is supplied through a ground/airborne disconnect on the PLF and is controlled by prime and backup environmental control units. These units provide air or GN_2 conditioned to the following parameters:

1) Cleanliness: Class 5,000 per FED-STD-209,
2) Inlet Temperature: Setpoint from 10-29°C (50-85°F),

Table 3.1.1-1 Gas Conditioning Capabilities (A/C and GN_2)

			Temperature Range Inside Payload Fairing**			
			Atlas V 400		Atlas V 500	
Location	Inlet Temperature Capability*	Inlet Flowrate Capability, kg/min (lb/min)	LPF, °C(°F)	EPF, °C(°F)	5-m Short, °C(°F)	5-m Medium, °C(°F)
Post-LV Mate Through Move to Launch Configuration	10-29°C (50-85°F)	Atlas V 400 22.8-72.6 (50-160) Atlas V 500 22.8-136.2 (50-300)	TBS	TBS	TBS	TBS
Post-Move to Launch Configuration	10-29°C (50-85°F)	Atlas V 400 22.8-72.6 (50-160) Atlas V 500 22.8-136.2 (50-300)	TBS	TBS	TBS	TBS

Notes: * Inlet Temperature is Adjustable (Within System Capability) According to Spacecraft Requirements
** Temperature Ranges Are Based on Worst-Case Minimum & Maximum External Heating Environments
Ranges Shown Assume a 72.6 kg/min (160 lb/min) for EPF/LPF ECS Flow Rate & 136.2 kg/min (300 lb/min) for 5-m Short/Medium ECS Flow Rate

3) Inlet Temperature Control: ±3°C (±5°F),
4) Filtration: 99.97% HEPA not dioctyl phthalate (DOP) tested,
5) Flow Rates
    a) Atlas V 400: 0.38–1.21 kg/s ±0.038 kg/s (50–l60 lb/min ±5 lb/min),
    b) Atlas V 500: 0.38–2.27 kg/s ±0.095 kg/s (50–300 lb/min ±12.5 lb/min),
6) Dewpoint (Maximum): 4.4°C (40°F) air, -37.2°C (-35°F) GN_2.

Internal ducting defectors in the PLF (refer to the *Atlas Launch System Mission Planner's Guide [Rev. 7],* Fig. 3.1.1-1) direct the gas upward to prevent direct impingement on the spacecraft. The conditioning gas is vented to the atmosphere through one-way flapper doors below the spacecraft. The PLF air distribution system will provide a maximum air flow velocity in all directions of no more than 9.75 mps (32 fps) for the Atlas V 400 and 10.67 mps (35 fps) for the Atlas V 500. There will be localized areas of higher flow velocity at, near, or associated with the air conditioning outlet. Maximum air flow velocities correspond to maximum inlet mass flow rates. Reduced flow velocities are achievable using lower inlet mass flow rates.

The conditioned air is typically delivered near the top of the PLF. When required, the flow can be divided so that up to 40% of the gas flow is directed to the base of the payload compartment for use in battery cooling or other operations.

Mission-specific arrangements for dedicated grade B or C GN_2 purges with a maximum dewpoint of -37.2°C (-35°F) of specific satellite components can be provided for up to 14.2 standard cubic meters/hour (500 standard cubic feet/hour).

3.1.2 Atlas V Radiation and Electromagnetics

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

3.1.2.1 Launch Vehicle-Generated Radio Environment—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

3.1.2.2 Launch Vehicle-Generated Electromagnetic Environment—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

3.1.2.3 Launch Range Electromagnetic Environment—The EM environment resulting from emitters controlled by the launch range is based on information in TOR-95 (5663)-1. An EMC analysis will be performed to ensure EMC of the spacecraft/launch vehicle interface with the range environment.

Table 3.1.2.3-1 documents EM emitters in the vicinity of CCAS. Field intensities at LC-41 are provided. Data can be provided for other locations upon request.

Table 3.1.2.3-2 in the *Atlas Launch System Mission Planner's Guide (Rev. 7)* lists EM emitters in the vicinity of VAFB. These data are based on an EM site survey conducted at SLC-3 in June 1997.

Launch trajectory and uncontrolled emitters in the area (i.e., nearby cruise ships or Navy vessels) may cause RF environments to exceed the levels shown in these tables.

3.1.2.4 Spacecraft-Generated Environment Limitation—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

3.1.3 Atlas V Contamination and Cleanliness

Launch vehicle hardware that comes into contact with the spacecraft environment is designed and manufactured according to strict contamination control requirements and guidelines. This hardware is defined as contamination-critical and, on Atlas V 400, includes the Centaur common equipment module, adapters, and the interior surface of the PLF. For the Atlas V 500 configuration, contamination-critical hardware includes that described for Atlas V 400 including the interior surfaces of the payload module of the 5-m PLF plus the centaur forward load reactor (CFLR) deck (Ref Sections 3.2.4 and 4.1.2.2), and more of the Centaur stub adapter surfaces. Ground operations at the launch site have been designed to

Table 3.1.2.3-1 Worst-Case RF Environment for CCAS from Controlled Emitters Only

LC-41				
Emitter Name	**Frequency, MHz**	**Theoretical Intensity, v/m**	**Duty Cycle**	**Mitigation**
Radar 0.14	5690	76.9	0.0016	Procedure Mask
Radar 1.16	5690	56.4	0.00064	Procedure Mask
Radar 1.39	5690 & 5800	60.9	0.005	Procedure Mask
Radar 19.14	5690	114.1	0.0016	Procedure Mask
Radar 19.17	5690	59.0	0.0008	Procedure Mask
Radar 28.14	5690	16.6	0.0016	Topography
Radar 1.8	9410	2.0	0.0012	Procedure Mask
Radar FPS-66	1265 & 1345	8.0	0.0022	None
Radar GPN-20	2750 & 2840	4.0	0.0008	None
WSR-74C	5625	10.6	0.0064	None
WSR-88D	2879	11.3	0.006	None
GPS Gnd Station	1784	2.1	CW	Ops Min 3°
NASA STDN	2025 & 2120	6.6	CW	None
TVCF	1761 & 1842	1.9	CW	Ops Min 5°

Note:

- Source Taken from Aerospace Report TOR-95(5663)-1, “Radio Frequency Environment, Eastern Range,” 5/95
- Avg. v/m = Pk, v/m* sqrt (Duty Cycle)
- CW = Continuous Wave
- Shaded Blocks Indicate Emitters Without Specific Mechanical or Software Mitigation; Measures
- Inflight Levels for Tracking Radar (0.14. 1.16, 1.39, 19.14, & 19.17) Are Typically 20 v/m

ensure a clean environment for the spacecraft. A comprehensive Contamination Control Plan has been written to identify these requirements and procedures. Some guidelines and practices used in the plan can be found in the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

3.1.3.1 Contamination Control Before Launch-Site Delivery

Design and Assembly—Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

Materials Selection—Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

3.1.3.2 Contamination Control Before Spacecraft Encapsulation

Cleanliness Levels—Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

PLF Cleaning Techniques—Refer to the *Atlas Launch System Mission Planner’s Guide (Rev. 7).*

Cleanliness Verification—Contamination-critical hardware surfaces are visually inspected to verify Visibly Clean Level 2 criteria described above. Contamination-critical surfaces are also verified to have less than 1 mg/ft^2 of nonvolatile residue (NVR).

Additional verification techniques shown below can be provided on a mission-unique basis:

1) Particulate Obscuration—Tape lift sampling;
2) Nonvolatile Residue (NVR)—Solvent wipe sampling;
3) Particulate Obscuration—Ultraviolet light inspection;
4) Particulate and Molecular Fallout—Witness plates.

3.1.3.3 Contamination Control After Encapsulation

Contamination Diaphragm—Contamination barriers are provided to assist in protecting the spacecraft from possible contamination during Centaur operations performed after spacecraft mating. For Atlas V 400s, after the two halves of the PLF are joined, the encapsulation is completed by closing the aft opening with a ground support equipment (GSE) reinforced plastic film diaphragm. The doughnut-shaped diaphragm stretches from the payload adapter to the aft end of the PLF cylinder and creates a protected environment for the spacecraft through mating to the Centaur. For Atlas V 500s, the conical interstage adapter is temporarily sealed during ground operations to isolate the spacecraft compartment from the Centaur engine compartment.

PLF Purge—After encapsulation, the PLF environment is continuously purged with filtered nitrogen or air filtered with high-efficiency particulate air (HEPA) filters to ensure the cleanliness of the environment and preclude ingestion of windborne contamination during transport to the launch vehicle, hoist, mate, and postmate operations.

Clean Work Area—The Atlas V includes provisions for PLF access that maintain the spacecraft environment within the PLF to Class 100,000 standards. This access is used for encapsulated spacecraft mate and subsequent incursions inside the payload fairing through the access doors. Access to the encapsulated spacecraft is performed from workstands. Personnel garmenting, activities, and work procedures are controlled to maintain the environment surrounding the PLF to Class 100,000 standards.

3.1.3.4 Payload Fairing Helium Environment During Prelaunch Operations—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

3.2 ATLAS V LAUNCH AND FLIGHT ENVIRONMENTS

This section describes general environmental conditions that may be encountered by a spacecraft during launch and flight with the Atlas V. All flight environments defined in this section are maximum expected levels and do not include margins typically associated with qualification tests.

3.2.1 Spacecraft Design Loads

3.2.1.1 Design Load Factors—Design load factors (DLF) (Table 3.2.1.1-1) are used for preliminary design of the primary structure and/or evaluation of Atlas V suitability for an existing spacecraft. Load factors are intended for application at the spacecraft's center of gravity to evaluate primary structure. The response of a spacecraft to launch vehicle transients will depend on its mass properties, stiffness, and amount of axial-to-lateral coupling. Load factors given are intended to provide a conservative design envelope for a typical spacecraft as follows:

1) 907-kg (2,000-lbm) to 9,072-kg (20,000-lbm) weight class with first lateral modes above 8 Hz and first axial mode above 15 Hz (Atlas V 400 only),
2) 4,536-kg (10,000-lbm) to 19,051-kg (42,000-lbm) weight class with first lateral modes above 2.5 Hz and first axial mode above 15 Hz (Atlas V 500 only).

Load factors for the 500 series represent the lightest typical payload on the more severe configuration, the 55X. Heavier payloads and fewer SRMs generally result in lower load factors.

Table 3.2.1.1-1 Spacecraft Limit Load Factors for Atlas V 400 and Atlas V 500

Load Condition	**Direction**	**Atlas V 400 Steady State, g**	**Atlas V 400 Dynamic, g**
Launch	Axial Lateral	1.2 —	±0.5 ±0.8
Flight Winds	Axial Lateral	2.2 ±0.4	±0.5 ±1.6
BECO	Axial Lateral	5.5 —	±0.5 ±1.0
MECO			
(Max Axial)	Axial Lateral	4.8-0.0* —	±0.5 ±0.2
(Max Lateral)	Axial Lateral	0.0 —	±2.0 ±0.6
Load Condition	**Direction**	**Atlas V 500 Steady State, g**	**Atlas V 500 Dynamic, g**
Launch	Axial Lateral	1.6 —	±2.0 ±2.0
Flight Winds	Axial Lateral	2.4 ±0.4	±0.5 ±1.6
Strap-On SRM Separation	Axial Lateral	3.0 —	±0.5 ±0.5
BECO	Axial Lateral	5.5 —	±0.5 ±1.0
MECO			
(Max Axial)	Axial Lateral	4.8-0.0* —	±0.5 ±0.2
(Max Lateral)	Axial Lateral	0.0 —	±2.0 ±0.6

- Sign Convention:
- Longitudinal Axis: + (Positive) = Compression
- - (Negative) = Tension
- Pitch Axis: ± May Act in Either Direction
- Yaw Axis: ± May Act in Either Direction
- Lateral & Longitudinal Loading May Act Simultaneously During Any Flight Event
- Loading Is Induced Through the cg of the Spacecraft

Note: * Decaying to Zero

Load factors for preliminary design in Table 3.2.1.1-1 include a dynamic uncertainty factor (DUF) of 1.25. This factor is typically applied to preliminary coupled loads analysis responses to conservatively account for design changes or modal corrections before the final design load cycle. Although interface bending moments, shears, and axial forces calculated from preliminary design loads cycle (PDLC) analyses are generally enveloped by DLFs, Lockheed Martin does not guarantee that this will be the case for all spacecraft and DUF combinations. Consult Lockheed Martin if questions exist concerning this issue.

Transient load analyses during integration will provide the actual loads on the space vehicle for both primary and secondary structure.

Table 3.2.1.1-1 load factors are separated into a quasi-steady-state and oscillatory dynamic. Total load factors in a direction are obtained by adding the steady-state and dynamic portion of the load factors. Lateral load factors are total and can be in any azimuth normal to the flight (longitudinal) axis.

3.2.1.2 Coupled Loads Analysis—Atlas V coupled loads analyses (CLA) are performed to provide the spacecraft customer with accelerations, loads, and deflections for drawing release, test planning, and verification of minimum margins of safety; and to verify that Atlas V loads remain within allowables. Liftoff, airloads (at several Mach numbers), booster engine cutoff (BECO), Centaur main engine start (MES), and Centaur main engine cutoff (MECO) events may be analyzed. Not all events are analyzed in each loads cycle. Some events may not be analyzed dynamically if class analyses or flight experience show them to be benign.

The PDLC is typically performed with a spacecraft dynamic model representing the preliminary sizing of hardware before drawing release or qualification testing. The determination of coupled responses early in the design and integration schedule allows optimization of spacecraft structure for Atlas V environments and reduces the risk of costly redesign after hardware manufacture. The incorporation of a DUF to account for the preliminary nature of the dynamic characterization of the spacecraft is recommended. A DUF appropriate for preliminary models is typically in the 1.25–1.50 range, depending on the maturity of the spacecraft dynamic model.

The flight verification loads cycle (VLC) requires a test-verified dynamic model of the spacecraft, as specified by the interface control document (ICD), for determination of maximum expected flight loads. These responses are provided to the spacecraft customer for calculation of spacecraft minimum margins of safety for submittal to Lockheed Martin, as required by the ICD verification matrix.

Verification of minimum factors of safety (structural capability versus predicted load) are typically accomplished with a combination of static and sinusoidal base acceleration testing of the spacecraft. In this method, primary structure capability is validated by static testing, while the more complex dynamic responses from the sinusoidal base acceleration test verify that the primary and secondary structure can withstand the dynamic loads environment. For heavy payloads that exceed shaker testing capabilities, a modal survey test to validate the spacecraft dynamic model, along with a static test to verify structural capability, are performed. Following these tests, a comparison of analytical loads to allowables from test is accomplished. Fidelity of CLA is typically 0–50 Hz, and notching of the base input in this frequency band is recommended. Notching philosophy is the subject of early integration meetings.

3.2.2 Acoustics

The spacecraft is exposed to an acoustic environment throughout the boost phase of flight until the vehicle is out of the atmosphere. Two portions of flight have significantly higher acoustic levels than the others. The highest acoustic level occurs for approximately 10 seconds during liftoff, when the acoustic energy of the engine exhaust is being reflected by the launch pad. The other significant level occurs for approximately 20 seconds during the transonic portion of flight and is caused by the interaction of shock waves with a highly turbulent boundary layer. The acoustic level inside the PLF will vary slightly with different spacecraft. This is because the acoustic absorption of each spacecraft depends on its size, shape, and surface material properties. Acoustic sound pressure levels for the Atlas V 400 configuration with both the LPF and EPF are provided in Figure 3.2.2-1; levels for the Atlas V 500 are provided in Figure 3.2.2-2. The acoustic environment shown is for the standard PLF with acoustic attenuation systems as described in Section 4.1.1.3. As a mission-unique service, additional acoustic protection can be provided with resulting reduction of payload envelope. Conversely, a payload that is not sensitive to acoustics may wish to fly without the standard acoustic protection package. The levels presented are for typical spacecraft of square cross-section with 50–60% fill of the fairing by cross-sectional area. An acoustic analysis is required for spacecraft with other fill factors to bound the acoustic environment. The spacecraft should be capable of functioning properly after a 1-minute exposure to this level. For the LPF/EPF with acoustic panels, special consideration should be given to components located within 76 cm (30 in.) of PLF vents.

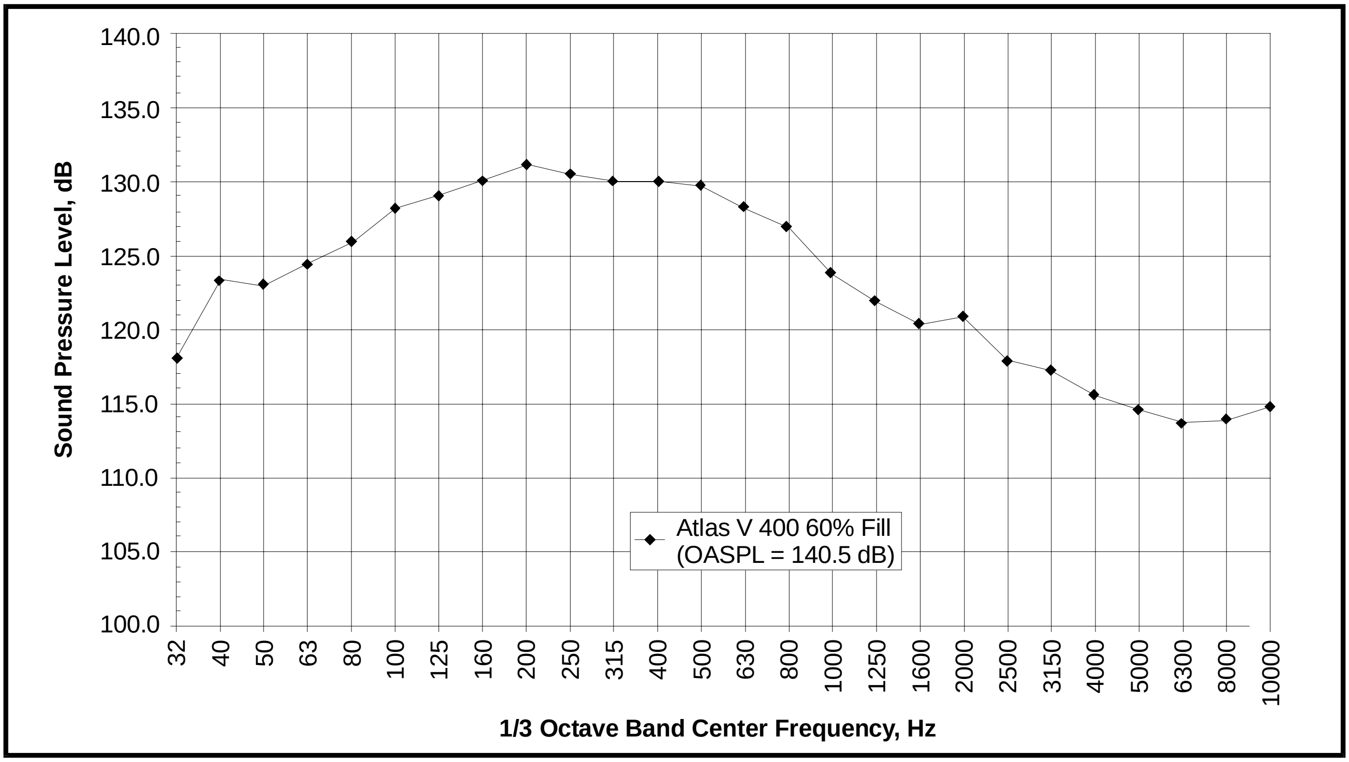


Figure 3.2.2-1 Acoustic Levels for Atlas V 400 with LPF and EPF (with Acoustic Blankets)

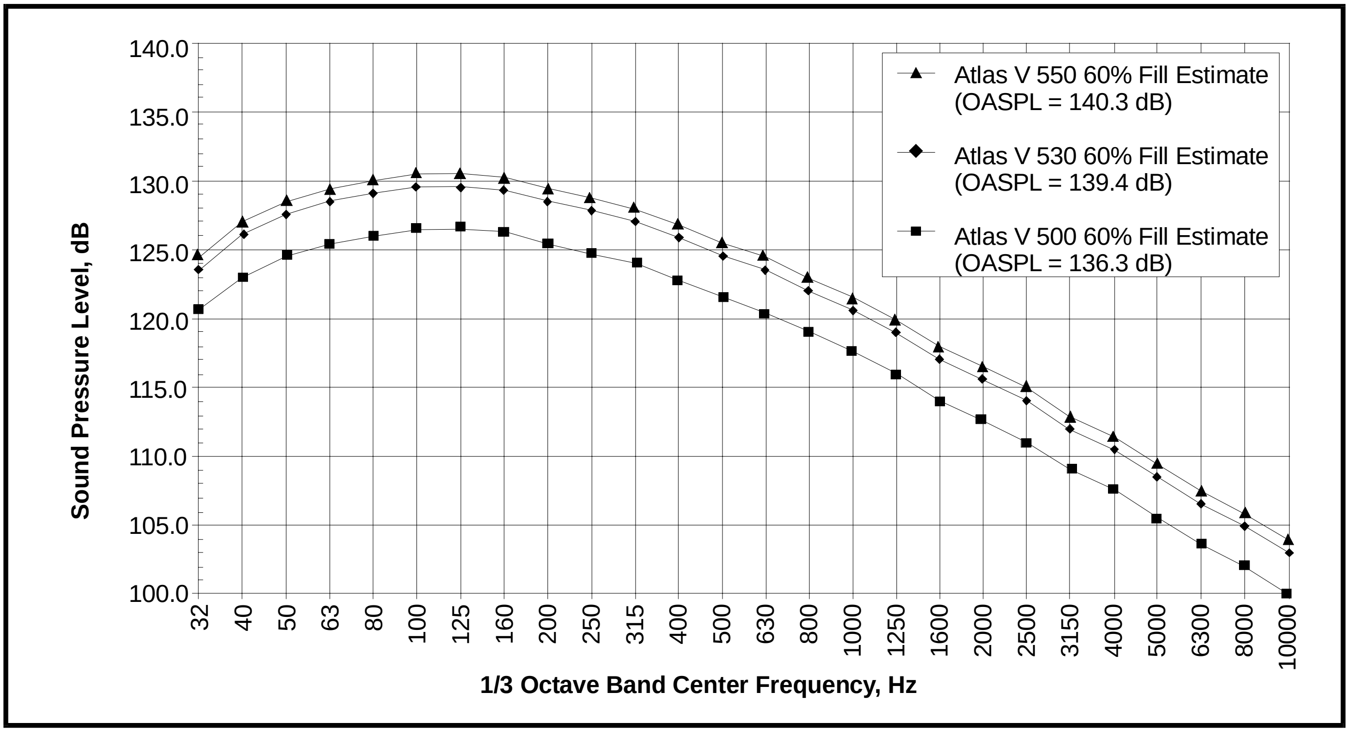


Figure 3.2.2-2 Estimated Acoustic Levels for Atlas V 5-m Short PLF (180-in. Diameter Payload Volume with Enhanced FAP)

3.2.3 Vibration

Estimated sine vibration levels for Atlas V 400 are similar to existing Atlas vehicles (Ref the *Atlas Launch System Mission Planner's Guide [Rev. 7])*. Atlas V 500 levels are TBS.

3.2.4 Shock

Three pyrotechnic shock events occur during flight on the Atlas V 400 family of vehicles that potentially affect the spacecraft: (1) payload fairing jettison (PFJ), (2) Centaur separation from the Common Core Booster™ (CCB), and (3) spacecraft separation. For mission-unique Atlas V 500 applications, separation of the Centaur forward load reactor (CFLR) from the forward end of the Centaur provides a fourth pyrotechnic shock event affecting the spacecraft. The CFLR provides a structural connection between the top of the Centaur and the 5-m PLF, resulting in greater PLF stiffness and reduced loss of clearance within the payload compartment. Because the system for Centaur separation from the CCB is located far from the spacecraft, the shock is highly attenuated by the time it reaches the spacecraft and does not produce a significant shock at the spacecraft interface. This is also true for the 5-m PLF PFJ and for separation of the Atlas V 500 strap-on boosters from the center CCB. Separation devices for the Atlas V 400 PFJ are located closer to the spacecraft; thus, the shock at the spacecraft interface is noticeable. The spacecraft separation device located at the top of the payload adapter is typically closest to the spacecraft/Centaur interface and generally produces the highest shock.

Figure 3.2.4-1 shows the maximum expected shock levels at the standard interface plane (SIP) (Ref Sect. 4.1.2 for SIP locations) resulting from launch vehicle events for the Atlas V 400 configurations. Figure 3.2.4-2 shows the maximum expected shock levels at the SIP resulting from launch vehicle events for the Atlas V 500 configurations. These figures represent the maximum expected environment based on a 95% probability with a 50% confidence, and a resonant amplification factor, Q = 10. The maximum allowable shock level at the equipment module interface from the spacecraft separation event is shown in Figure 3.2.4-3 of the *Atlas Launch System Mission Planner's Guide (Rev. 7)*. This shock limit capability is planned to be updated by mid-2002 (Ref Sect. 8.3.1 in this Addendum.)

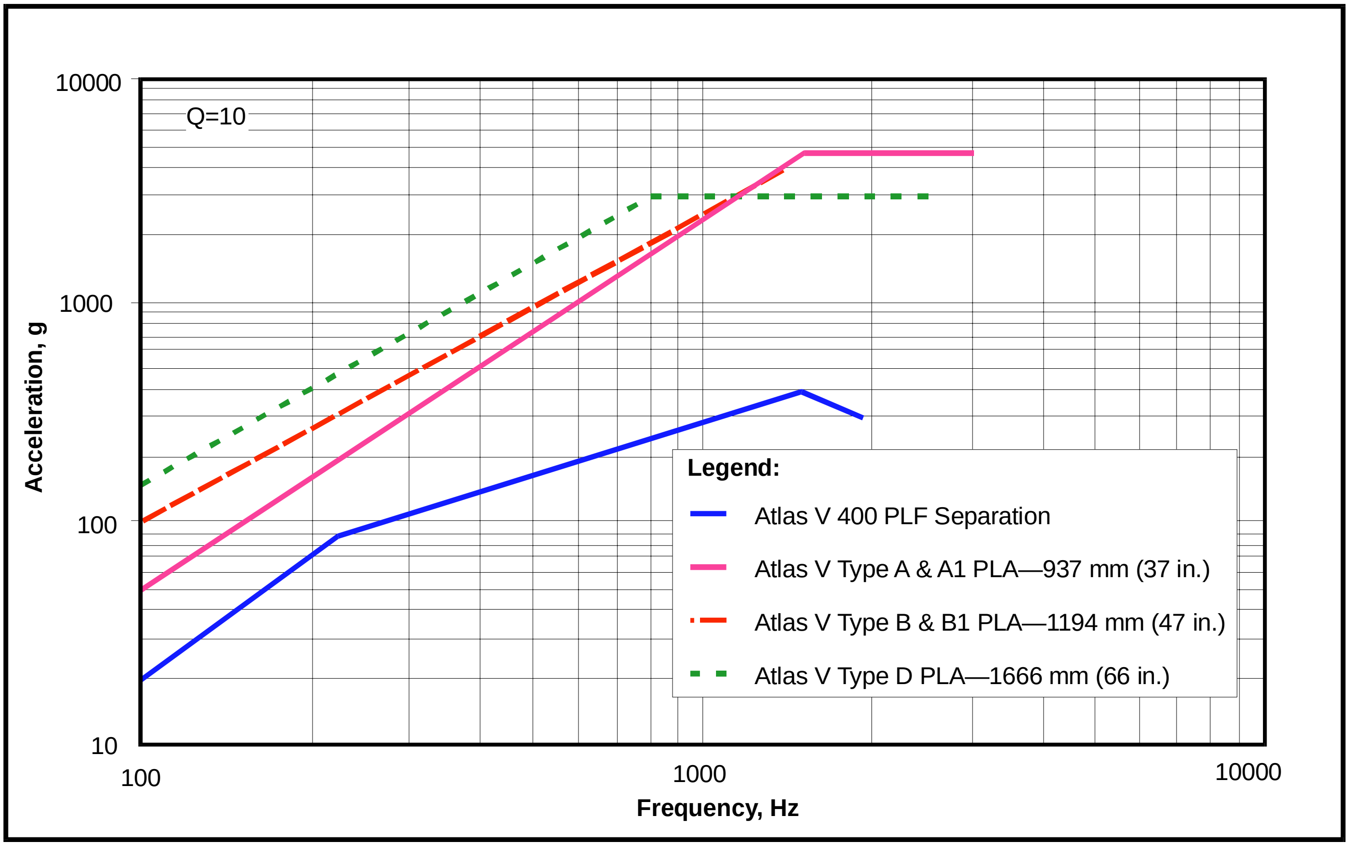


Figure 3.2.4-1 Maximum Expected Atlas V 400 Shock Levels at the SIP Due to Launch Vehicle Events

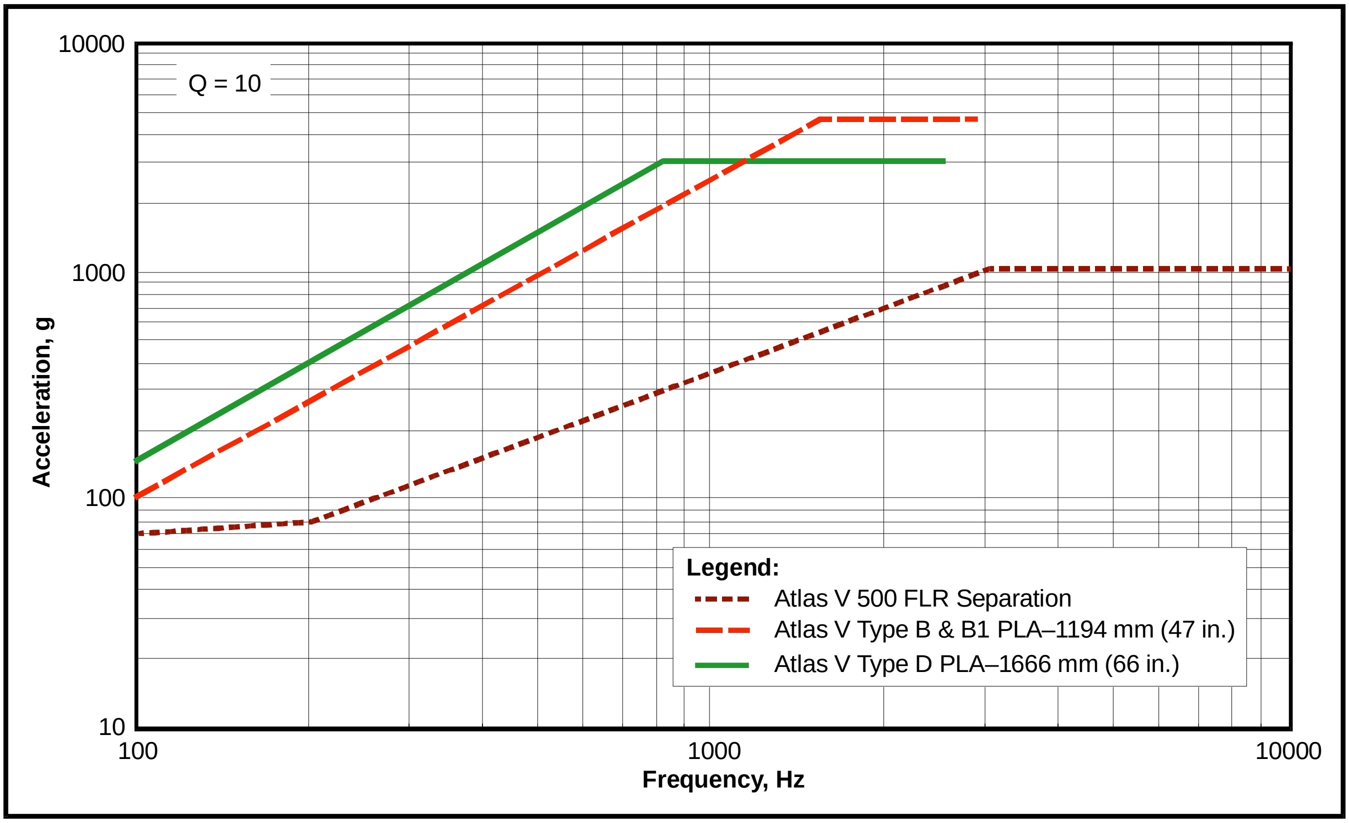


Figure 3.2.4-2 Maximum Expected Atlas V 500 Shock Levels at the SIP Due to Launch Vehicle Events

3.2.5 Thermal

Within Fairing—The PLF protects the spacecraft during ascent to a nominal altitude of approximately 122,000 m (400,000 ft). Aerodynamic heating on the fairing results in a time-dependent radiant heating environment around the spacecraft before fairing jettison. The fairings use cork on the external surface to minimize fairing skin temperatures. The spacecraft thermal environment is further attenuated by the acoustic suppression system that is baselined for the PLF cylinder and the lower portion of the respective nose cones. Inner surfaces of the Atlas V 400 PLF cone and cylinder have a low-emittance finish ($\varepsilon < 0.1$). The inner surfaces of the composite 5-m PLF cone and cylinder have an emittance of 0.9. The peak heat flux radiated by the inner surfaces of the cone and cylinder of the Atlas V 400 PLF is less than 400 W/m^2 (125 Btu/hr-ft^2), and peak temperatures remain below 212°C (414°F) at the warmest location. The peak heat flux radiated by the inner surfaces of the cone and cylinder of the 5-m PLF is less than 914 W/m^2 (290 Btu/hr-ft^2), and peak temperatures remain below 93°C (200°F) at the warmest location.

After Fairing Jettison—Fairing jettison typically occurs when the 3-sigma maximum free molecular heat flux decreases to 1,135 W/m^2 (360 Btu/hr-ft^2). Jettison timing can be adjusted to meet specific mission requirements. Typical free molecular heating (FMH) profiles are highly dependent on the trajectory flown. Peak FMH levels can be reduced by raising the parking orbit perigee altitude. However, raising perigee altitude will have a minor negative effect on delivered launch vehicle performance.

The spacecraft thermal environment following fairing jettison includes free molecular heating, solar heating, Earth albedo heating, and Earth thermal heating, plus radiation to the upper stage and to deep space. In addition, the spacecraft is conductively coupled to the forward end of the Centaur upper stage through the payload adapter. Solar, albedo, and Earth thermal heating can be controlled as required by the spacecraft by specification of launch times, vehicle orientation (including rolls), and mission design.

The Centaur nominally provides a benign thermal influence to the spacecraft, with radiation environments ranging from -45°C to 52°C (-50°F to 125°F) and interface temperatures ranging from 4°C to 49°C (40°F to 120°F) at the forward end of the payload adapter. Neither the upper-stage main engine plumes nor reaction control system (RCS) engine plumes provide any significant heating to the spacecraft. Main engine plumes are non-luminous because of the high purity of the LH_2 and LO_2 reactants.

3.2.6 Static Pressure (PLF Venting)

The payload compartment is vented during the ascent phase through one-way vent doors. Payload compartment pressure rates are a function of the fairing design and trajectory.

The LPF/EPF and 5-m PLF are designed to have a depressurization rate of no more that 6.2 kPa/s (0.9 psi/s). For the Atlas 400 series, the pressure decay rate will always be less than 2.1 kPa/s (0.3 psi/s), except for a maximum of about 5 seconds around transonic flight when the decay rate does not exceed 6.2 kPa/s (0.9 psi/s). For the Atlas 500 series, the pressure decay rate will always be less than 2.8 kPa/s (0.4 psi/s), except for a maximum of about 3 seconds around transonic flight when the decay rate does not exceed 6.2 kPa/s (0.9 psi/s). Typical depressurization rates are less than these values. Figure 3.2.6-1 illustrates typical depressurization rates for the LPF/EPF.

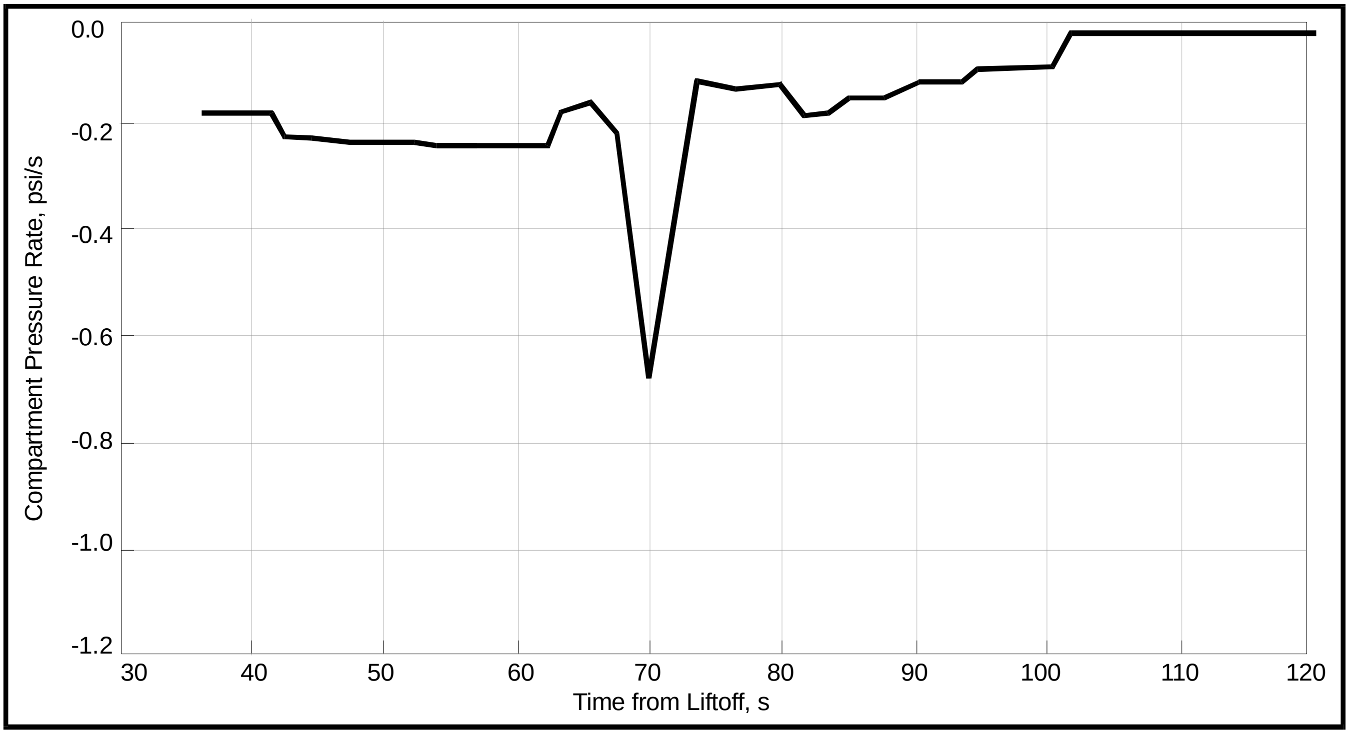


Figure 3.2.6-1 Typical Payload Compartment Pressure Decay Rate for the LPF/EPF

3.2.7 Atlas V Contamination Control

Depositions on spacecraft surfaces from all launch system sources are limited to 150-Å molecular and 1.0% particle obscuration. These deposition limits are verified by vehicle class analyses. Launch system ground contamination sources were addressed in Paragraphs 3.1.3.2 and 3.1.3.3. Launch system ascent contamination sources include:

1) Molecular outgassing,
2) NVR redistribution,
3) Particle redistribution,
4) PLF separation,
5) Booster separation,
6) Centaur reaction control system.

Mission-unique verification analysis will be performed to verify spacecraft deposition requirements beyond those stated above and to verify the above requirements for mission or vehicle designs not anticipated by the system specification. Mission-unique contamination analysis incorporates thermal, trajectory, and configuration data. These analyses will draw heavily on the appropriate class analysis.

3.2.7.1 Atlas V Booster Separation—The booster is separated from Centaur with a linear-shaped charge located just aft of the Centaur aft tank ring. After separation, eight retrorockets located in the booster intertank compartment are fired to ensure the expended booster moves away from Centaur. These eight retrorockets use solid propellants and exhaust products consisting of small solid particles and very low density gases.

The linear-shaped charge and retrorocket exhaust products pose no contamination threat to the Atlas V 400 spacecraft because the payload fairing is jettisoned after the booster separation event. For the Atlas V 500, the payload fairing has been jettisoned before booster separation; however, the boattail remains and shields the spacecraft from particles in the linear-shaped charge and retrorocket exhaust. Retrorocket exhaust gases that expand around the boattail and impinge on the spacecraft are rarefied and only a small fraction are condensable because spacecraft surfaces are still relatively warm from prelaunch payload compartment gas conditioning. Moderate molecular depositions can be expected on aft facing surfaces.

3.2.7.2 Upper Stage Reaction Control System (RCS)—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

3.2.7.3 Upper-Stage Main Engine Blowdown—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

3.2.7.4 Separation Event—Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

3.2.7.5 Atlas V Molecular Outgassing and NVR Redistribution—Spacecraft molecular depositions resulting from outgassing of launch vehicle materials are limited in the design phase by selecting only materials for the payload compartment that meet strict outgassing requirements. Redistribution of NVR from launch vehicle hardware surfaces is limited because all launch vehicle sources exposed within the payload compartment will be verified to have less than 1.0 mg/ft^2 NVR before encapsulation of the satellite.

Moderate depositions to the satellite may be expected from these sources.

3.2.7.6 Atlas V Particle Redistribution—During ascent, particles may be released from launch vehicle surfaces due to the vibro-acoustic environment, and migrate to spacecraft surfaces. Depositions on the spacecraft will be small because the exposed launch vehicle hardware surfaces within the payload compartment will be cleaned and verified to Visibly Clean Level 2 criteria before encapsulation. The PLF is also vibrated as part of the cleaning process. Additional launch vehicle hardware cleanliness levels may be specified to meet mission-unique requirements.

3.2.7.7 Atlas V PLF Separation—LPF/EPF halves are separated by self-contained explosive bolts. The separation force is provided by redundant spring actuators. Satellite particulate contamination from this event has been shown by a combination of tests and analyses to be negligible.

5-m PLF halves are separated by a vertical separation system that is fully contained in expandable bellows. Sheared rivets are also contained. Satellite contamination from this system is expected to be negligible based on the results of analyses and tests.

3.2.8 Radiation and EMC

The description of environments in Sections 3.1.2.1–3.1.2.4 encompasses worst-case flight environments.

3.3 SPACECRAFT COMPATIBILITY TEST REQUIREMENTS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7)*.

4.0 SPACECRAFT INTERFACES

4.1 SPACECRAFT-TO-LAUNCH VEHICLE INTERFACES

The primary interfaces between the Atlas V launch vehicle and spacecraft consist of a payload support system in which the payload is supported on top of the launch vehicle, and a payload fairing that encloses and protects the spacecraft during ground operations and launch vehicle ascent. The Atlas program offers a range of standard payload support systems that adapt the spacecraft to the Atlas V standard interface plane (SIP) and payload fairings, depending upon the vehicle configuration chosen by the launch service customer. These standard components can be modified as necessary to provide mission-specific support services for the payload.

Sections 4.1.1 and 4.1.2 describe the payload fairings and payload support systems. The payload envelopes and vehicle interface information contained in these sections should be used only as a guideline. Modifications to these envelopes and adapters may be accommodated on a mission-peculiar basis. Ultimate control of interface information for a given mission is governed through a mechanical interface control drawing (MICD) developed and maintained during the mission integration process.

4.1.1 Mechanical Interface—Payload Fairings (PLF)

4.1.1.1 Atlas V PLF Configurations—The payload fairing provides a protective thermal, acoustic, electromagnetic, and environmental enclosure for the payload and launch vehicle components during prelaunch and ascent. The Atlas V user has a choice between the large payload fairing (LPF) or extended-length payload fairing (EPF) for the Atlas V 400 configuration, and either the 5-m Short 20.7-m (68-ft) or 5-m Medium 23.4-m (77-ft) PLF for the Atlas V 500 configurations. The LPF/EPF used on the Atlas V 400 vehicle is identical to the Atlas II/III LPF/EPF and is described in Section 4.1.1.1 of the *Atlas Launch System Mission Planner's Guide (Rev. 7).* The Atlas V 5-m PLF (Fig. 4.1.1.1-1) was developed along with the increased launch vehicle performance to accommodate growing spacecraft needs. This fairing is a bisector fairing with a structure made from sandwich panels with carbon fiber facesheets and a vented aluminum honeycomb core. This fairing and its associated separation system are derived from an existing flight-proven system. The major components of the fairing are the fixed conical boattail that attaches the PLF to the launch vehicle; the base module that encapsulates the Centaur stage; and the cylindrical module that transitions into a constant radius ogive nose section topped by a spherical nose cap which encapsulates the spacecraft.

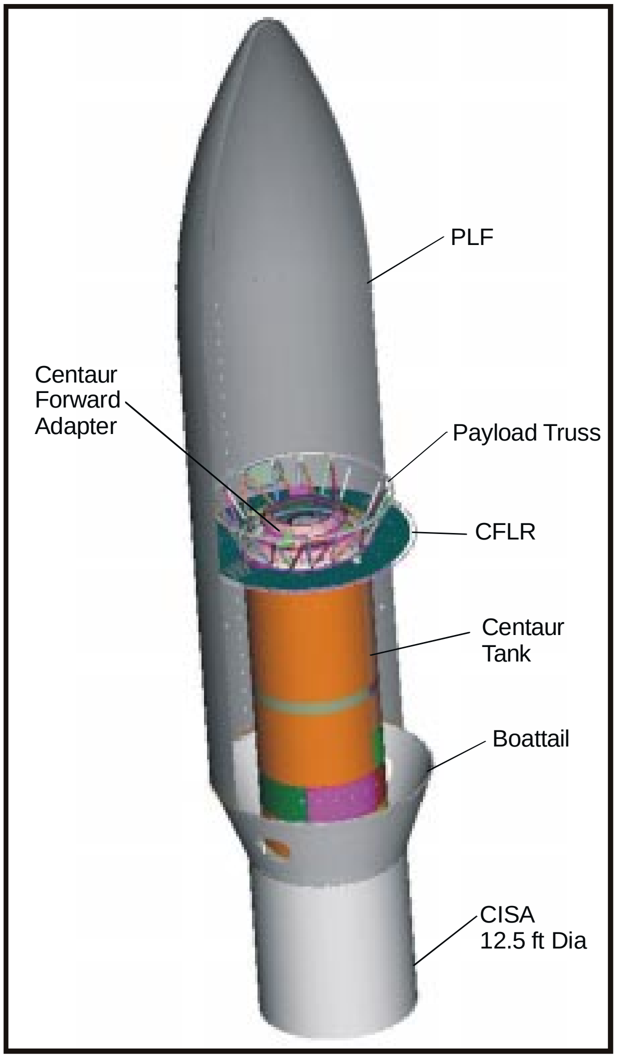


Figure 4.1.1.1-1 Atlas V 500 5-m Payload Fairing (5-m Short Shown)

The PLF cylindrical module and ogive sections provide mounting provisions for various secondary systems. Payload compartment cooling system provisions are contained in the ogive-shaped portion of the fairing. Electrical packages required for the fairing separation system are mounted on the internal surface of the fairing. Fairing acoustic protection (FAP) (Fig. 4.1.1.1-2) is provided as a standard service to attenuate the sound pressure levels to the levels shown previously in Figures 3.2.2.1-1 and 3.2.2.1-2. Provisions for an RF transparent window, reradiating antennas, or an RF probe are provided on an as-needed basis.

The 5-m payload fairings have four large doors in the base module portion of the PLF to provide primary access to the equipment module and the Centaur upper stage. These doors provide an access opening approximately 914-mm (36.3-in.) wide by 610-mm (24-in.) tall and are located one or two per fairing quadrant. They are also available to access the encapsulated spacecraft. Work platforms can be inserted through these doors into the payload compartment to allow access to spacecraft hardware near the aft end of the payload compartment. The Atlas V 500 can provide 600-mm (24-in.) in diameter spacecraft access doors (Fig. 4.1.1.1-3) on the cylindrical portion of the PLF on as-needed basis. These doors can be located in most areas of the fairing cylindrical sections except near split-lines and interface planes. Typical access door locations are shown in Figure 4.1.1.1-4.

Clearance losses for payloads are minimized by the Centaur forward-load reactor (CFLR) system that stabilizes the top of the Centaur, increasing the effective stiffness of the upper section of the PLF, and thereby reducing the relative motion between the PLF and payload.

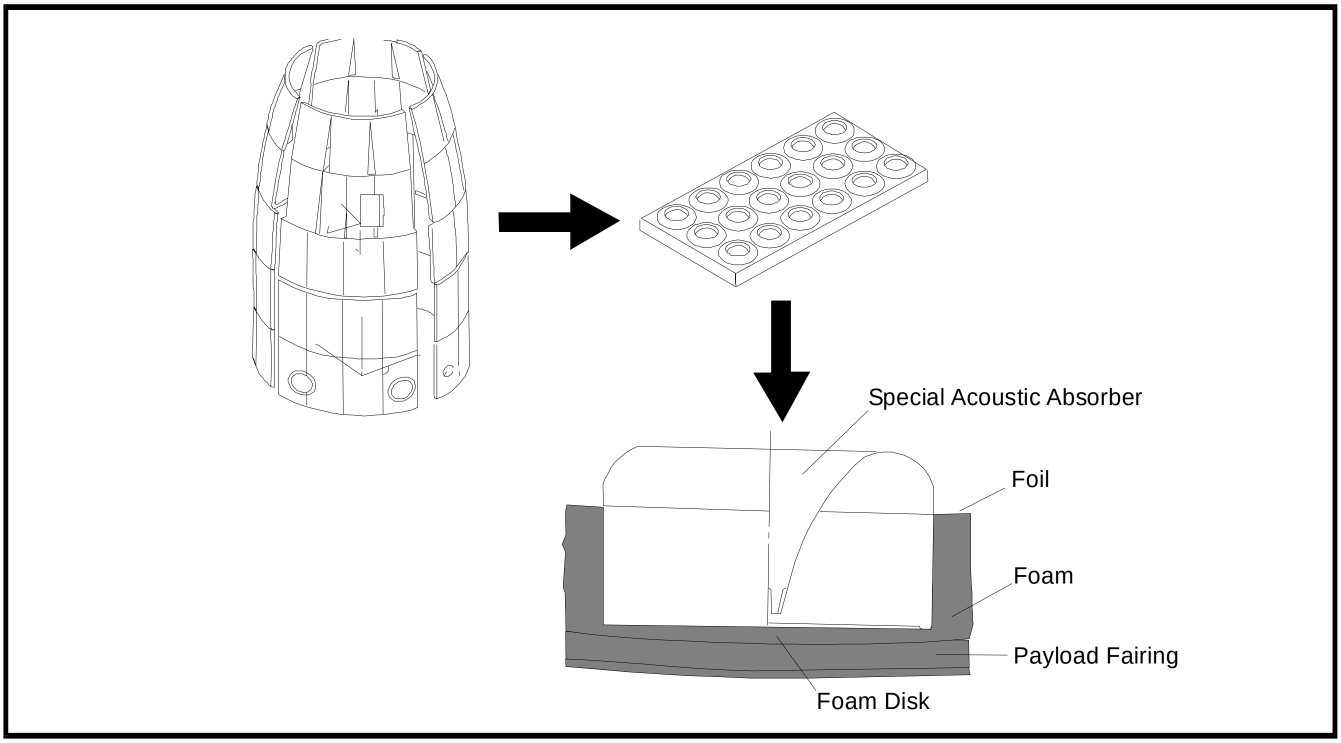


Figure 4.1.1.1-2 5-m Payload Fairing Acoustic Protection

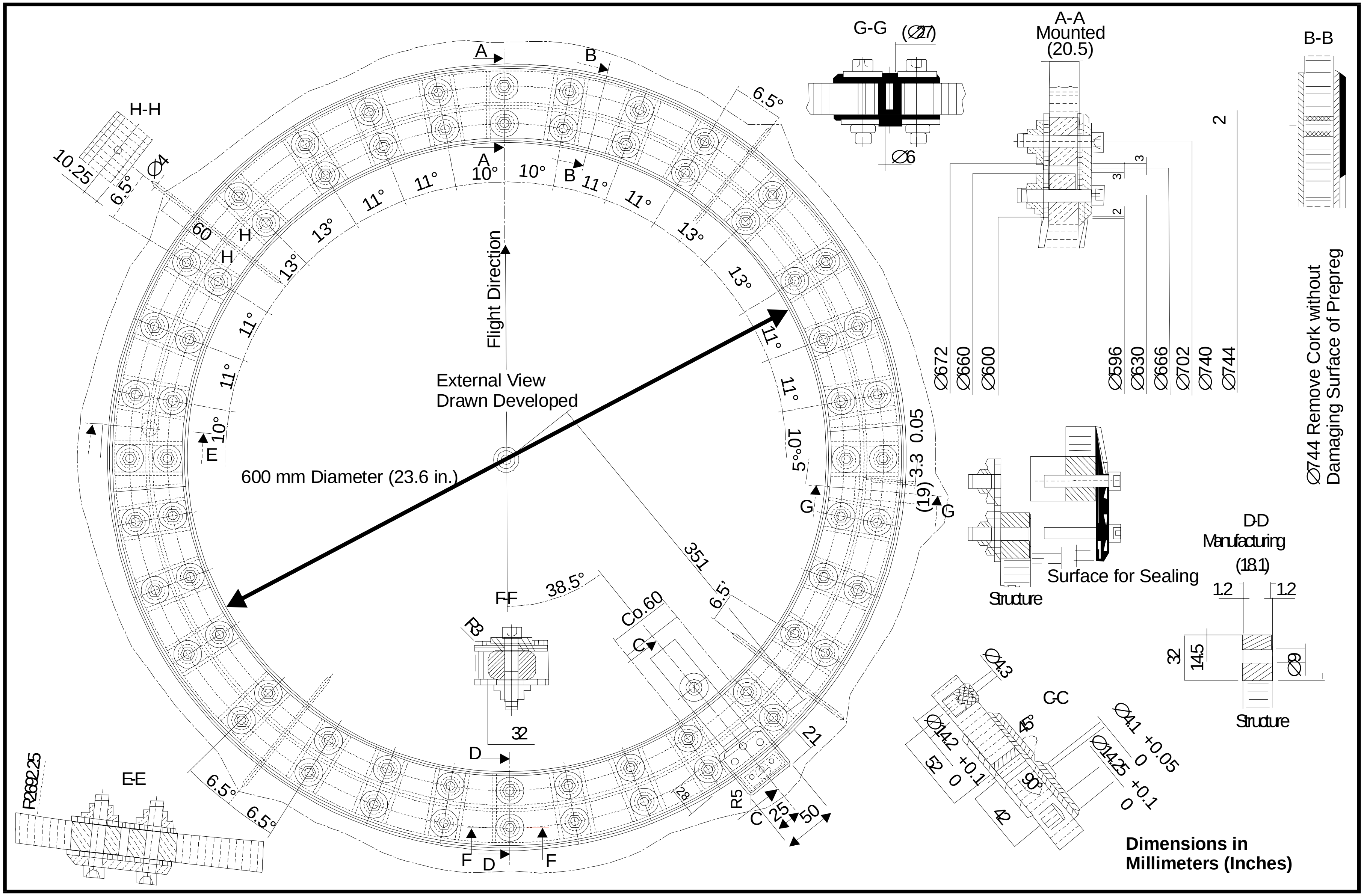
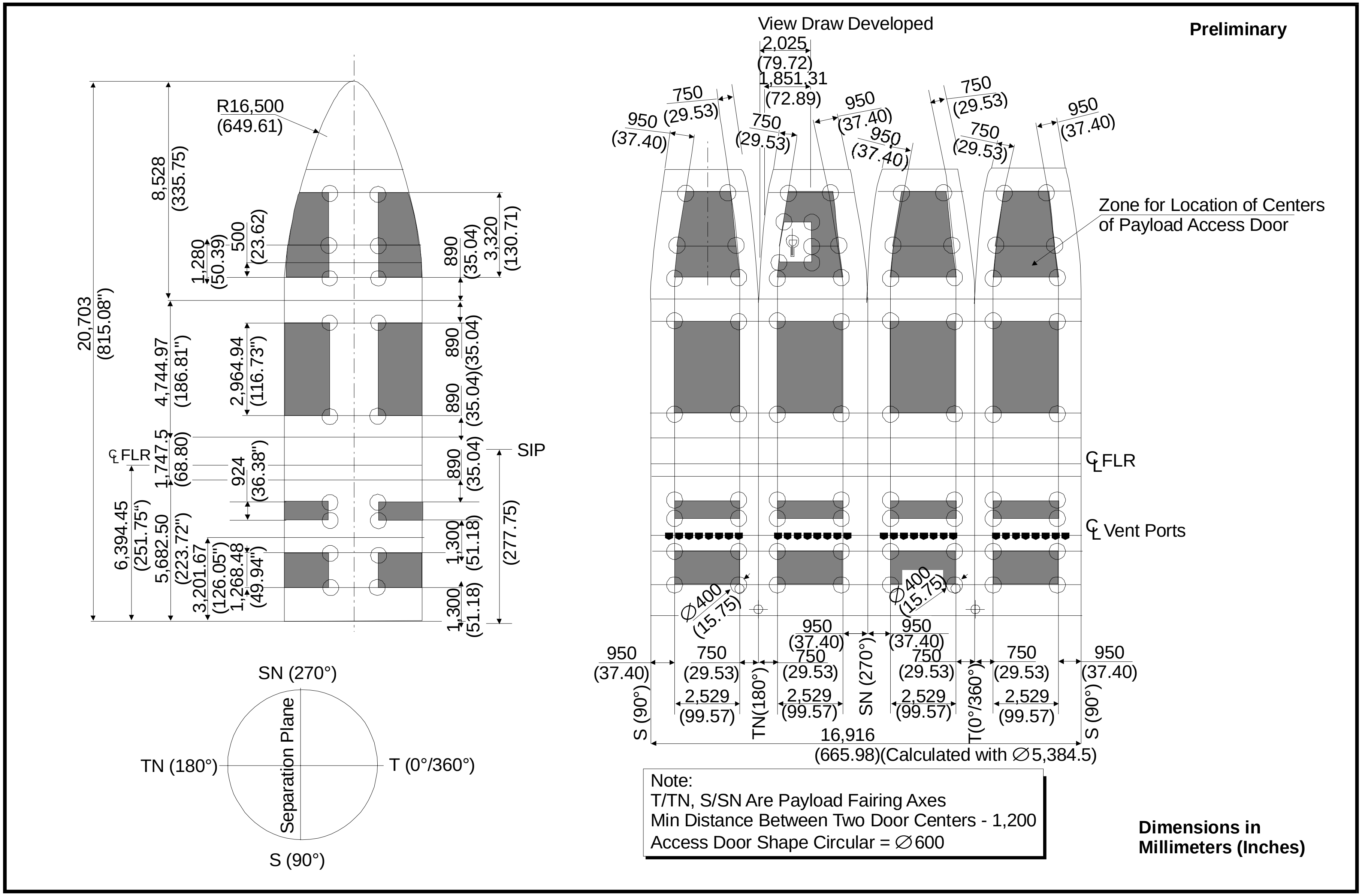


Figure 4.1.1.1-3 Atlas V 500 Standard Access Door Configuration



Preliminary

Note:
T/TN, S/SN Are Payload Fairing Axes
Min Distance Between Two Door Centers - 1,200
Access Door Shape Circular = ∅600

Dimensions in Millimeters (Inches)

Figure 4.1.1.1-4 5-m Short Payload Fairing Payload Access Door Available Location Areas

4.1.1.2 Atlas V Static Payload Envelopes—The static payload envelope for the LPF/EPF used on the Atlas V 400 vehicle is identical to that used on the Atlas II/III LPF/EPF and is described in Section 4.1.1.2 of the *Atlas Launch System Mission Planner's Guide (Rev. 7)*. The useable volume for a spacecraft inside of the Atlas V 500 5-m payload fairing is defined by the static payload envelope. This envelope represents the maximum allowable spacecraft static dimensions (including manufacturing tolerances) relative to the spacecraft/payload adapter interface. These envelopes include allowances for spacecraft and PLF static and dynamic deflections, manufacturing tolerances, out-of-round conditions, and misalignments. They were established to insure that a minimum 1-in. clearance between the spacecraft and payload fairing is maintained.

Figure 4.1.1.2-1 shows the usable spacecraft volume provided by the 5-m Short and 5-m Medium payload fairings. The spacecraft volume near the aft end of the static payload envelope is determined by the payload support system and is discussed Section 4.1.2. Clearance layouts and analyses are performed for each spacecraft configuration and, if necessary, critical clearance locations are measured after the spacecraft is encapsulated inside of the fairing to ensure positive clearance during flight. To accomplish

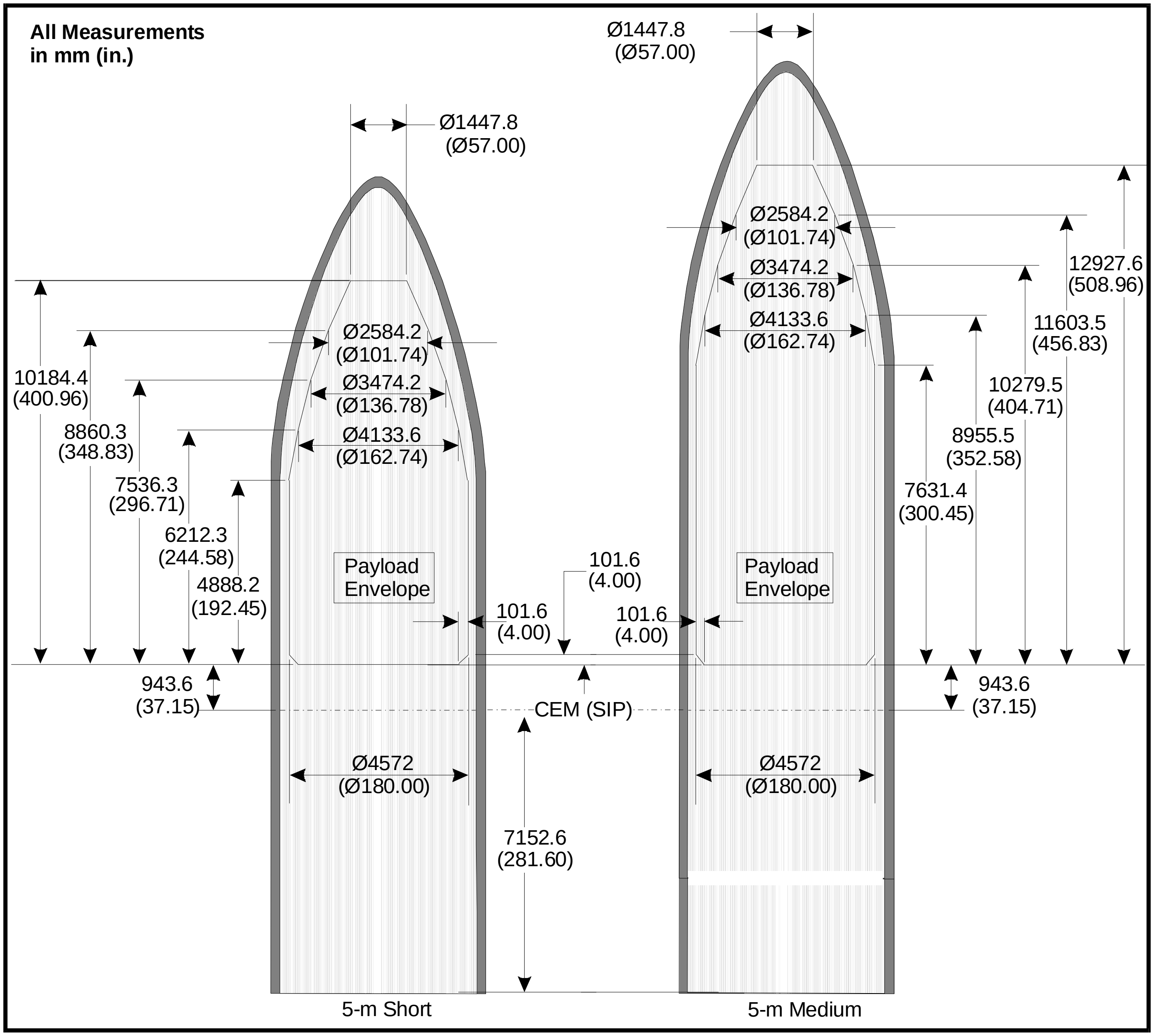


Figure 4.1.1.2-1 Atlas V 500 5-m Payload Envelopes

this, it is important for the spacecraft description to include an accurate physical location (including the maximum manufacturing tolerances) of all points on the spacecraft that are within 50 mm (2 in.) of the allowable envelope. For spacecraft secondary structures (e.g., antennas, thermal shields) in the vicinity of the envelope or for protrusions that may extend outside the envelopes shown, coordination with the Atlas V program is required to define appropriate envelopes.

The Atlas V 500 5-m Medium PLF can be stretched an additional 3-m (10 ft) to a 26.4-m (87-ft) length. Impacts to the launch site are minimal; however, payload processing facilities would need to be assessed. Stretches in length also require evaluation for impacts on flight dynamics and performance. Potential users should contact Lockheed Martin for more information.

4.1.2 Mechanical Interface—Payload Support Systems

The payload support system provides the attachment point for the spacecraft and adapts the spacecraft to the Atlas V standard interface plane (SIP). The SIP for the Atlas V depends upon the support configuration and occurs at either the forward ring of the Centaur common equipment module (CEM) or the top of the launch vehicle-provided payload support truss (Fig. 4.1.2-1).

The payload support system includes the mechanical and electrical interfaces between the launch vehicle and spacecraft. The Atlas V offers a range of payload adapters, bolted interfaces, and trusses that mate the spacecraft to the launch vehicle. All of the Atlas payload adapters and separation systems are designed so that they can be modified to allow the spacecraft to be oriented inside of the payload fairing to best meet mission requirements. In addition, alternate adapter designs can be developed on a mission-peculiar basis.

4.1.2.1 Atlas V Payload Adapter Interfaces—The Atlas V payload adapters are the same configuration as the flight-proven designs used on the Atlas II/III vehicles. The Type B1 and D adapters are being upgraded to accommodate Atlas V weight class spacecraft. These adapters use a launch vehicle-provided Marmon-type clampband payload separation system. The Type B1 adapter has a 1,215-mm (47.0-in.)-diameter forward interface ring and is compatible with the 1194A adapter. The Type D adapter has a 1,666-mm (66.0-in.)-diameter forward interface ring and is compatible with the 1666A adapter. These adapters are described in Section 4.1.2 of the *Atlas Launch System Mission Planner's Guide (Rev. 7).* The only differences that affect the payload interface are minor changes to the cross-sectional geometry of the payload adapter forward rings. These changes do not affect the spacecraft interface requirements, which are identical to those shown in the *Atlas Launch System Mission Planner's Guide (Rev. 7),* Figures 4.1.2.2-3 and

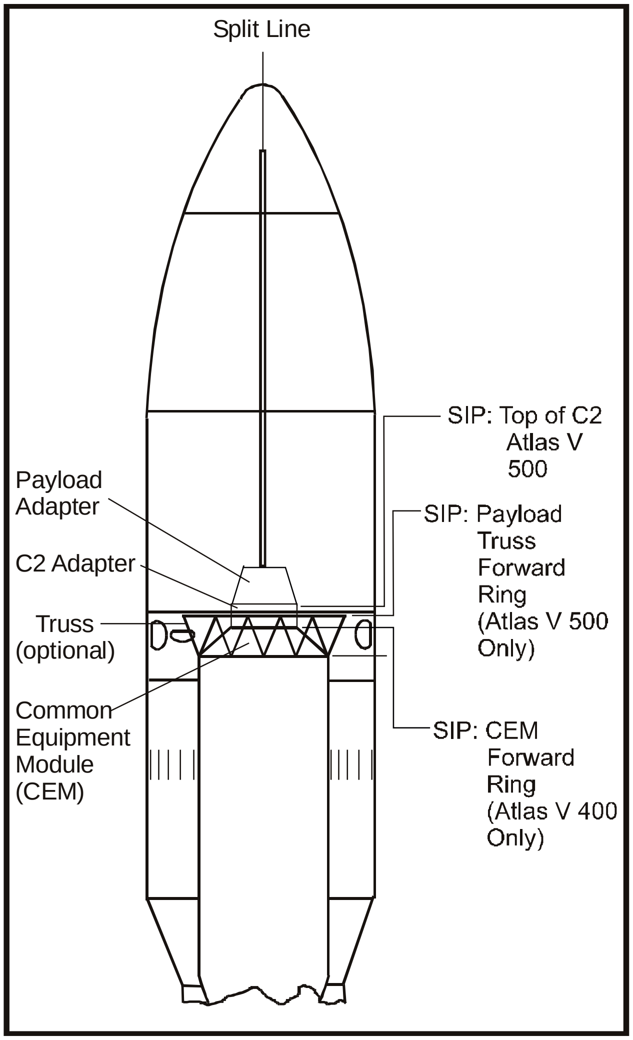


Figure 4.1.2-1 Atlas V Standard Interface Plane (SIP)

4.1.2.2-4 for mechanical interfaces and Figures 4.1.1.2-8 and 4.1.1.2-11 for static payload envelopes. For Atlas V 500, the standard adapters (B1, D, etc.) are installed on top of a type C2 adapter, which is installed on top of the CEM. The C2 adapter, which is similar to the type C1 except that it is 22 inches high, raises the spacecraft in the payload envelope to avoid interference between the aft end of the spacecraft and the new torus required for the 5-m PLF.

For spacecraft that provide their own adapter and separation system, a bolted interface is provided by the equipment module or Type C, C1, and C2 adapters. The spacecraft interfaces and static envelopes for these options are identical to those currently used on the Atlas II/III and are described in Section 4.1.2 of the *Atlas Launch System Mission Planner's Guide (Rev. 7)*. If a customer-provided spacecraft adapter is used, it must provide interfaces for ground handling, encapsulation, and transportation equipment. In particular, there will need to be mechanical provisions and envelope allowances for three torus arm fittings and an encapsulation diaphragm unless a launch vehicle-supplied intermediate (type C, C1, or C2) adapter is used. Lockheed Martin will furnish a matchmate tool for use in positioning and drilling the bolt holes that mate to the equipment module.

The existing Type A, A1, B, and E adapters, described in Section 4.1.2 of the *Atlas Launch System Mission Planner's Guide (Rev. 7),* are also compatible with the Atlas V vehicle within their specified payload structural capabilities.

4.1.2.2 173-in.-Diameter Payload Truss—A 173-in.-diameter payload interface truss is being developed to meet future payload interface requirements. The 914-mm (36-in.) high truss interfaces with the forward stub adapter on the upper stage. The truss is composed of graphite epoxy struts, titanium alloy end fittings, aluminum alloy forward and aft brackets, and an aluminum alloy forward ring (Fig. 4.1.2.2-1). The interface to the spacecraft for this truss is shown in Figure 4.1.2.2-2. When this truss is used, the static payload envelope extends to the top surface of the payload support truss forward ring.

Additionally, a 2,971-mm (117-in.)-diameter bolted interface is being conceptually designed and could be available as a mission-unique option for future heavy payload needs. This mission-unique interface is described in Section 8.4 as a future enhancement.

4.1.2.3 Payload Support System Structural—The allowable spacecraft weights and longitudinal centers of gravity for the Type B1and D adapter/separation systems, equipment module and 173 inch truss for the Atlas V 400 and Atlas V 500 are shown in Figures 4.1.2.3-1 and 4.1.2.3-2 respectively. The Atlas V series lateral accelerations of 1.8g shown in Figure 4.1.2.3-2 are predicated on relatively light spacecraft. Heavier spacecraft typically have lower load factors. The reference point for the allowable spacecraft cg height is dependent upon the payload support system used and occurs at the forward ring of the payload adapters, Centaur equipment module, or payload support truss as appropriate. The Centaur tank capabilities depend on the forward ring of the payload support truss. In order to avoid overstressing the Centaur, spacecraft that exceed the allowable curve for Centaur tank capability may require an upper forward load reactor between the spacecraft or dispenser and the PLF, replacing the CFLR. Spacecraft weight includes all payload systems weight including the payload support system. These spacecraft mass and cg capabilities were determined using generic spacecraft interface ring geometry and a quasi-static lateral load factor as noted on the aforementioned figures. Actual spacecraft design allowables may vary depending on interface ring stiffness and the results of spacecraft mission-peculiar coupled loads analyses. Coordination with the Atlas program is required to define the appropriate structural capabilities for spacecraft designs that exceed these generic allowables.

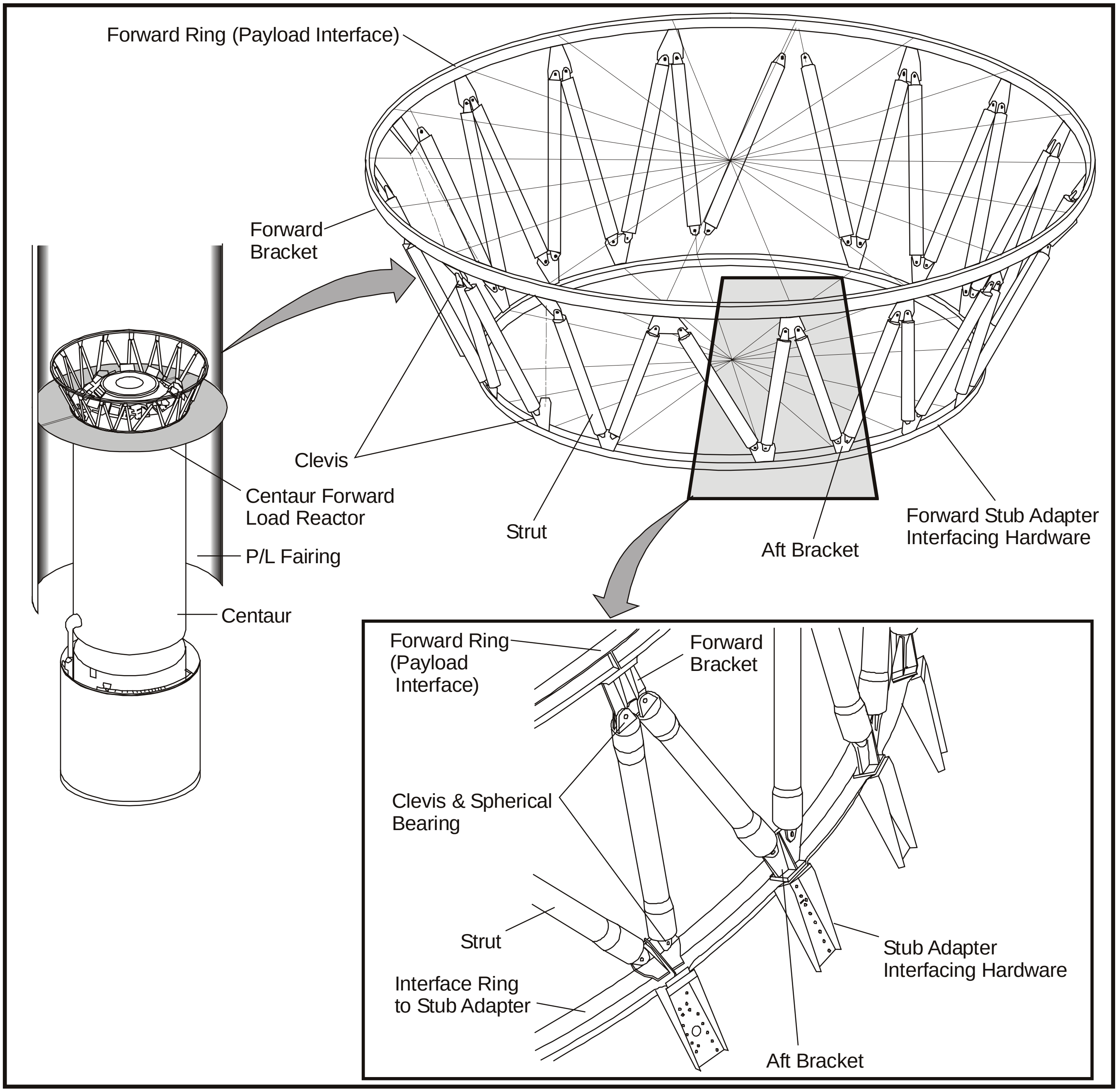


Figure 4.1.2.2-1 Payload Truss Adapter 173-in. Diameter—18 Equally Spaced Hard Points

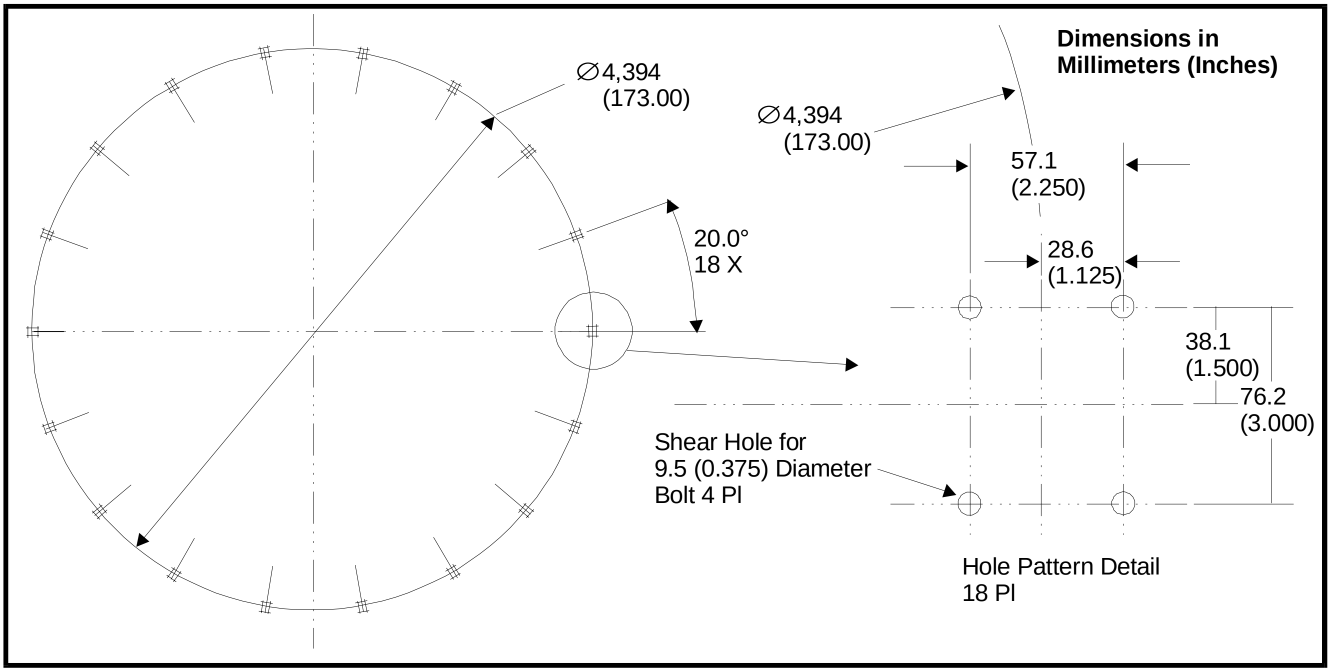


Figure 4.1.2.2-2 Atlas V 500 Standard Mechanical Interface for 173-in. Interface

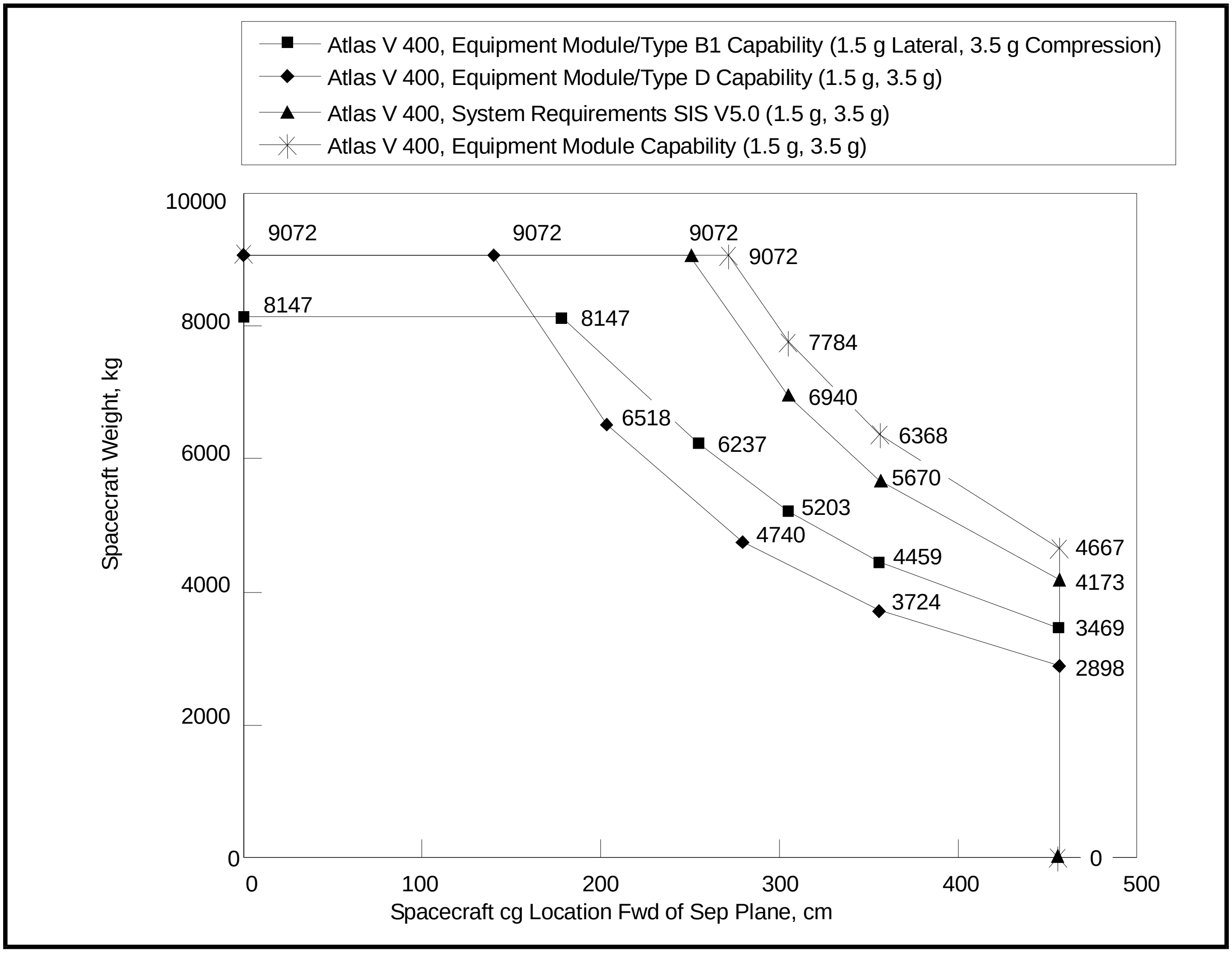


Figure 4.1.2.3-1 Atlas V 400 Allowable cg Location

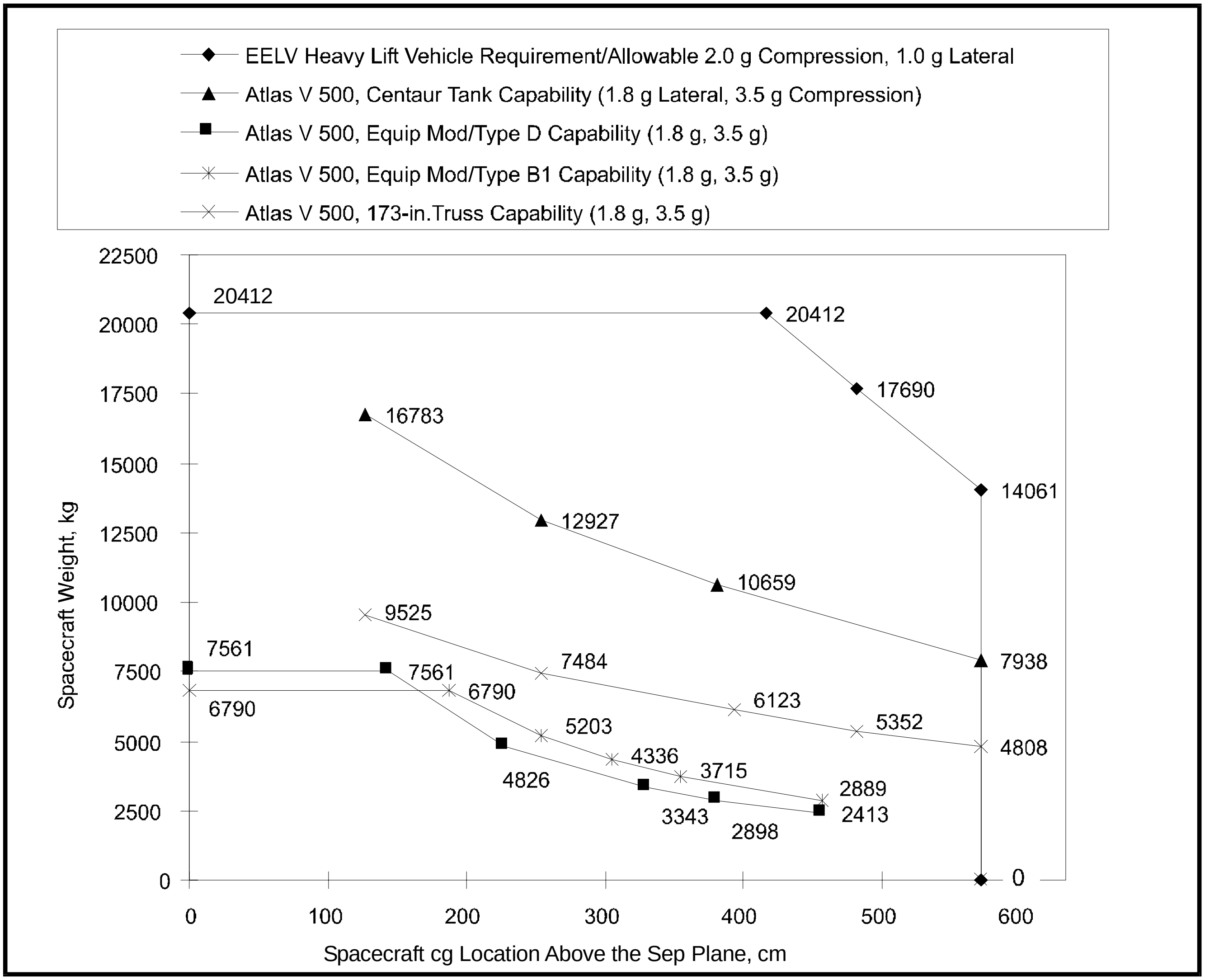


Figure 4.1.2.3-2 Atlas V 500 Allowable cg Location

4.1.3 Electrical Interfaces

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

4.2 SPACECRAFT-TO-GROUND EQUIPMENT INTERFACES

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

4.3 RANGE AND SYSTEM SAFETY INTERFACES

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

5.0 MISSION INTEGRATION

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

6.0 SPACECRAFT AND LAUNCH FACILITIES

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7*) for spacecraft facilities. Launch facilities details are TBD.

7.0 LAUNCH OPERATIONS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7*) for general launch operations information. Detailed information is TBS.

8.0 ATLAS V SYSTEM ENHANCEMENTS

The *Atlas Mission Planners Guide (Rev. 7)* contains many enhancements to the Atlas family of launch vehicles. A number of additional enhancements are planned for the Atlas V launch vehicle configurations to increase the competitiveness of the Atlas V in the launch services market.

8.1 MISSION-UNIQUE ENHANCEMENTS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7.)*

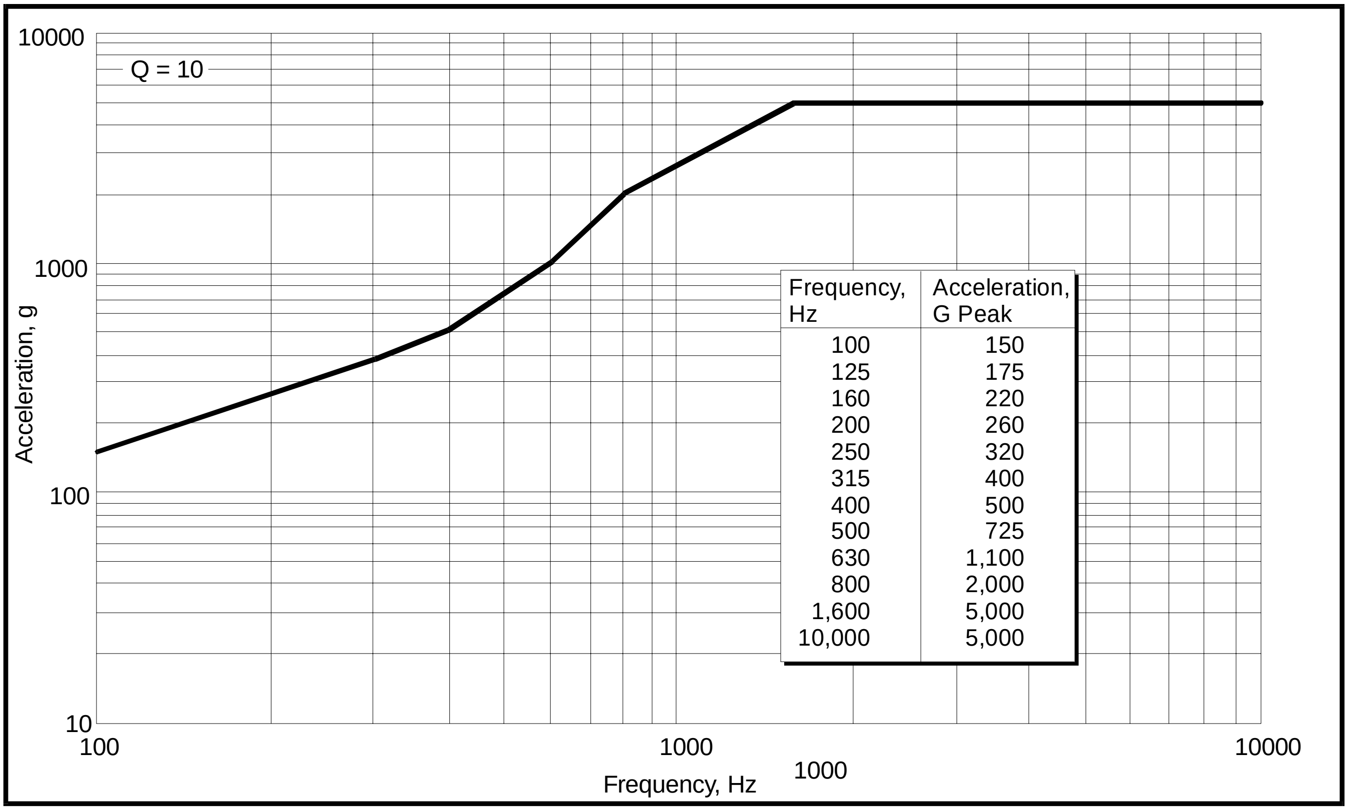
8.2 ATLAS EVOLUTIONARY ENHANCEMENTS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

8.3 ATLAS V SHOCK ENHANCEMENTS

8.3.1 Atlas V 500 Shock Levels

Figure 8.3.1-1 shows maximum allowable spacecraft-produced shock levels at the Centaur common equipment module (CEM). This capability is planned to be available by mid-2002.



Frequency, Hz	Acceleration, G Peak
100	150
125	175
160	220
200	260
250	320
315	400
400	500
500	725
630	1,100
800	2,000
1,600	5,000
10,000	5,000

Figure 8.3.1-1 Maximum Allowable Spacecraft-Produced Shock at Equipment Module Interface

8.4 ATLAS V HEAVY-LIFT ENHANCEMENTS

8.4.1 117-in.-Diameter Payload Truss

A (117-in.)-diameter payload truss has been conceptually developed to meet future heavy lift spacecraft interface requirements. The truss is being designed to carry heavy-lift spacecraft masses and their associated cg locations. The payload interface duplicates the existing Titan IV 2490 skirt interface (Fig. 8.4.1-1). The 914-mm (36-in.)-high truss interfaces with the forward stub adapter on the Centaur upper stage. The truss is composed of graphite epoxy struts, titanium alloy end fittings, aluminum alloy forward and aft brackets, and an aluminum alloy forward ring (Fig. 8.4.1-2). The payload envelope provided in the 5-m PLF using this interface is shown in Figure 8.4.1-3. This interface would be used inside the 5-m PLF on either the Atlas V 500 or Atlas V HLV configurations for evolutionary heavyweight payloads.

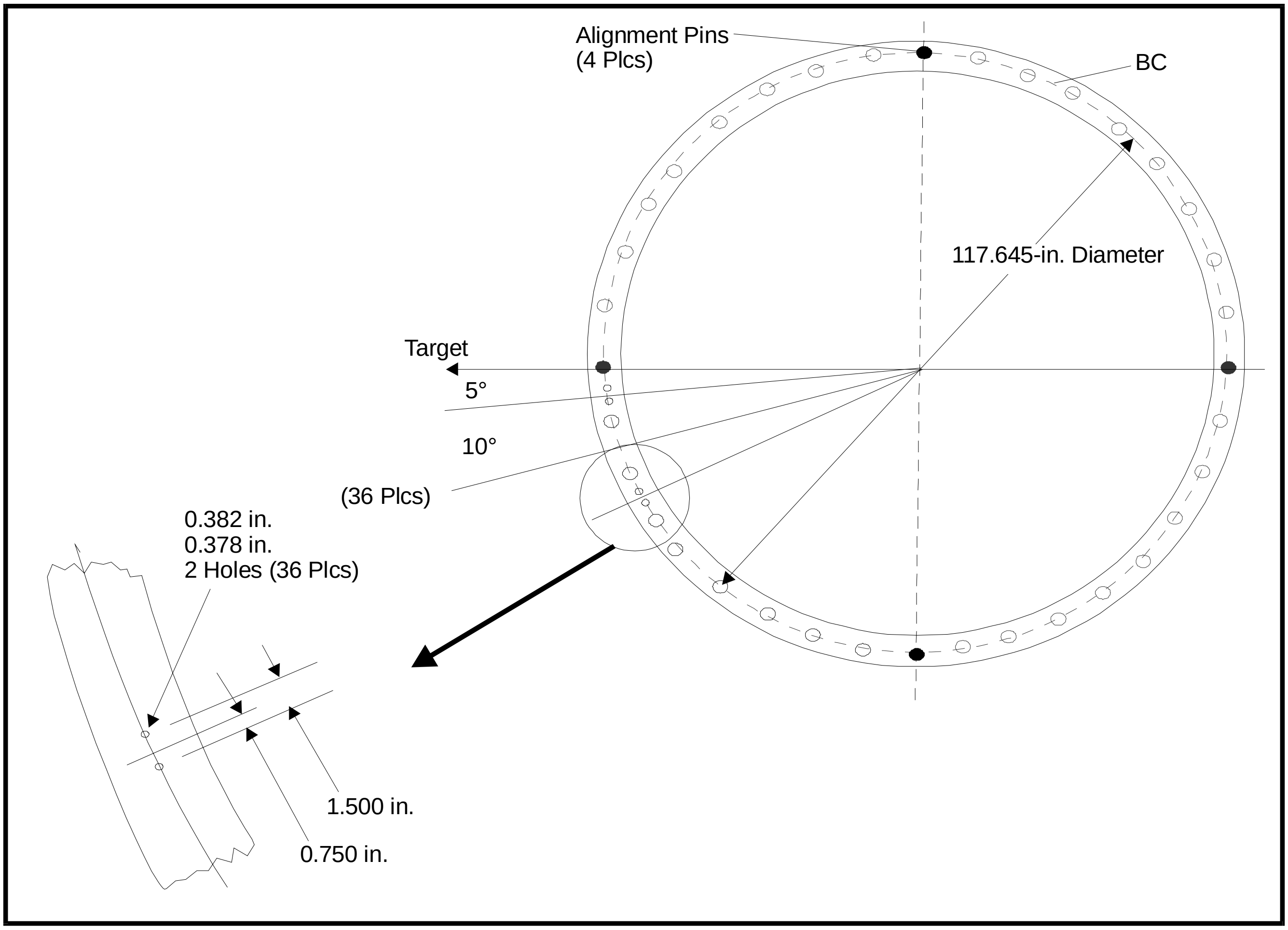


Figure 8.4.1-1 117-in.-Diameter Interface Definition

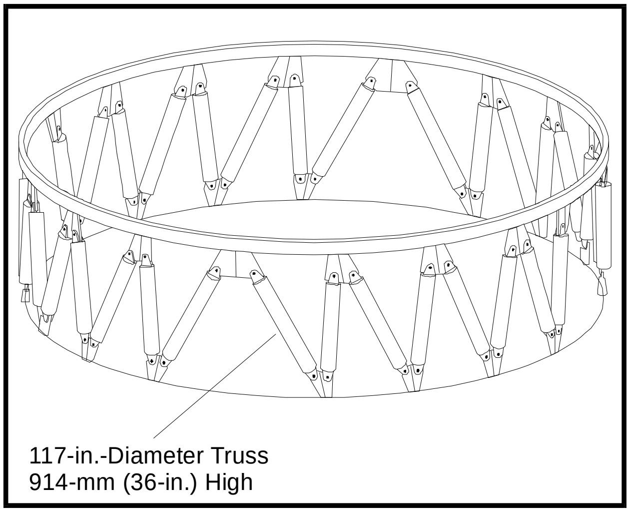


Figure 8.4.1-2 117-in.-Diameter Payload Truss

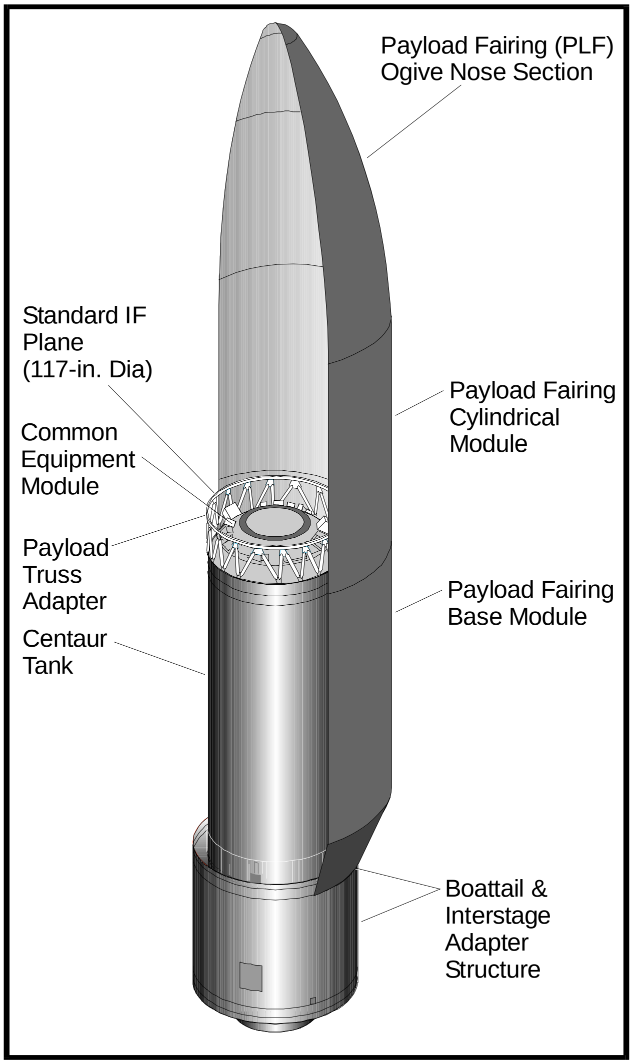


Figure 8.4.1-3 Atlas V 500 and Atlas V HLV Payload Fairing Configurations with the 117-in. Truss Adapter

8.5 ATLAS V 400 SERIES PERFORMANCE ENHANCEMENT

8.5.1 Addition of Solid Rocket Boosters to Atlas V 400 Series Launch Vehicles

The baseline Atlas V 400 launch vehicle configuration includes the provisions to accommodate the addition of up to four solid rocket boosters (SRB). This capability may be made available for future use in response to launch service market requirements. Table 8.5.1-1 provides an example of the relative performance capability to GTO for 4x1 versus 5x1 configurations for one and two SRBs.

Table 8.5.1-1 Atlas V 400 versus 500 Series Performance Summary with Solid Rocket Boosters

Number of SRBs		
	x = 1	x = 2
4x1	6,133 kg	7,155 kg
5x1	5,270 kg	6,285 kg

APPENDIX A—ATLAS HISTORY, VEHICLE DESIGN, AND PRODUCTION

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

APPENDIX B—MISSION SUCCESS AND QUALITY ASSURANCE

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

APPENDIX C—SPACECRAFT DATA REQUIREMENTS

Refer to the *Atlas Launch System Mission Planner's Guide (Rev. 7).*

GLOSSARY

AMPG	Atlas Mission Planner’s Guide
AVMPG	Atlas V Mission Planner’s Guide
BECO	Booster Engine Cutoff
Btu	British Thermal Unit(s)
°C	Degree(s) Celsius
CCAS	Cape Canaveral Air Station
CCB	Common Core Booster™
CEM	Common Equipment Module
CFLR	Centaur Forward Load Reactor
CLA	Coupled Loads Analysis
cm	Centimeter(s)
Ø	Diameter
dB	Decibel(s)
dBm	Decibel(s) Relative to 1 Milliwatt
dBW	Decibel(s) Relative to 1 Watt
dc	Direct Current
DEC	Dual-Engine Centaur
DLF	Design Load Factor
DUF	Dynamic Uncertainty Factor
ε	Emissivity
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EPF	Extended Length Large Payload Fairing
°F	Degree(s) Fahrenheit
FAP	Fairing Acoustic Protection
fps	Feet per Second
ft	Foot; Feet
g	Gravity
GCS	Guidance Commanded Shutdown
GEO	Geosynchronous Earth Orbit
GHe	Gaseous Helium
GN_2	Gaseous Nitrogen
GSE	Ground Support Equipment
GSO	Geostationary Orbit
GTO	Geosynchronous Transfer Orbit
HEPA	High-Efficiency Particulate Air
hp	Horsepower

hr	Hour(s)
Hz	Hertz
ICD	Interface Control Document
IFR	Inflight Retargeting
Isp	Specific Impulse
k	Thousand
kg	Kilogram(s)
klb	Kilopound(s)
km	Kilometer(s)
kN	Kilonewton(s)
kPa	Kilopascal(s)
kV	Kilovolt(s)
kVA	Kilovolt Ampere
lb	Pound(s)
lbf	Pound(s)-Force
LEO	Low-Earth Orbit
LH_2	Liquid Hydrogen
LHe	Liquid Helium
lm	Lumen(s)
LN_2	Liquid Nitrogen
LO_2	Liquid Oxygen
LPF	Large Payload Fairing
µV	Microvolt(s)
m	Meter(s)
M	Million
Max	Maximum
Max Q	Maximum Dynamic Pressure
MECO	Main Engine Cutoff
MES	Main Engine Start
mg	Milligram(s)
MHz	Megahertz
mils	Thousandths of an Inch
min	Minute(s)
mm	Millimeter(s)
mps	Meters per Second
mV	Millivolt(s)
N	Newton(s)
N_2H_4	Hydrazine
nmi	Nautical Mile(s)
ns	Nanosecond(s)

NVR	Nonvolatile Residue
Ω	Ohm(s)
ωρ	Argument of perigee
Pa	Pascal
PDLC	Preliminary Design Loads Cycle
PFJ	Payload Fairing Jettison
PLF	Payload Fairing
PSW	Payload Systems Weight
PSWC	Payload Systems Weight Capability
RCS	Reaction Control System
s	Second(s)
SEC	Single Engine Centaur
Sep	Separation
SEPP	Systems Effectiveness Program Plan
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
VAFB	Vandenberg Air Force Base
VIF	Vehicle Integration Facility
VLC	Verification Loads Cycle