Pegasus®

Pegasus® User's Guide

August 2000
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Pegasus®

ORBITAL SCIENCES CORPORATION

August 2000

Pegasus® Users Guide

Release 5.0

This Pegasus User's Guide is intended to familiarize potential space launch vehicle users with the Pegasus launch system, its capabilities and its associated services. The launch services described herein are available for commercial procurement directly from Orbital Sciences Corporation.

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Copies of this Pegasus User's Guide may be obtained from our website at http://www.orbital.com. Hardcopy documents and electronic (CD format) are also available upon request.

TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION PAGE

TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION PAGE

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF FIGURES

LIST OF FIGURES
(CONTINUED)

A	Amperes
AACS	Airborne Air Conditioning System
ac	Alternating Current
A/C	Air Conditioning
AFB	Air Force Base
AIT	Assembly and Integration Trailer
amps	Amperes
ARAR	Accident Risk Asessment Report
ARO	After Receipt of Order
ASE	Airborne Support Equipment
ATP	Authority to Proceed
AWG	American Wire Gauge
C	Centigrade
C/CAM	Collision/Contamination Avoidance Maneuver
CCB	Configuration Control Board
CDR	Critical Design Review
CFR	Code of Federal Regulations
c.g.	Center of Gravity
c.m.	Center of Mass
cm	Centimeter
dB	Decibels
dc	Direct Current
deg	Degrees
DFRF	Dryden Flight Research Facility
DoD	Department of Defense
DoT	Department of Transportation
DPDT	Double Pole, Double Throw
EGSE	Electrical Ground Support Equipment
EICD	Electrical Interface Control Document
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
ER	Eastern Range (USAF)
F	Fahrenheit
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
fps	Feet Per Second
FRR	Flight Readiness Review
ft	Feet
FTS	Flight Termination System
g	Gravity
GCL	Guidance and Control Lab
GN_2	Gaseous Nitrogen
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System (NAVSTAR)
Grms	Gravity Root Mean Squared
GSE	Ground Support Equipment
h	Height
HAPS	Hydrazine Auxiliary Propulsion System
HEPA	High Efficiency Particulate Air
HF	High Frequency
HVAC	Heating, Ventilating, and Air Conditioning
H/W	Hardware
Hz	Hertz
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronic Engineers
ILC	Initial Launch Capability
IMU	Inertial Measurement Unit
in	Inch

INS	Inertial Navigation System
ISO	International Standardization Organization
kbps	Kilobits per Second
kg	Kilograms
km	Kilometers
KMR	Kwajalein Missile Range
kPa	Kilo Pascal
L-	Time Prior to Launch
L+	Time After Launch
lbf	Pound(s) of Force
lbm	Pound(s) of Mass
LOWG	Launch Operations Working Group
LPO	Launch Panel Operator
LRR	Launch Readiness Review
LSC	Linear Shaped Charge
m	Meters
M	Mach
mA	Milliamps
MDL	Mission Data Load
MHz	MegaHertz
MICD	Mechanical Interface Control Document
MIL-STD	Military Standard
MIWG	Mission Integration Working Group
mm	Millimeter
MRR	Mission Readiness Review
ms	Millisecond
MSD	Mission Specification Document
MSPSP	Missile System Prelaunch Safety Package
MUX	Multiplexer
m/s	Meters Per Second
N_2	Nitrogen
N	Newtons
N/A	Not Applicable
NRTSim	Non Real Time Simulation
nm	Nautical Miles
NTE	Not To Exceed
OASPL	Overall Sound Pressure Level
OCA	Orbital Carrier Aircraft
OD	Operations Directive
OR	Operations Requirements Document
Orbital	Orbital Sciences Corporation
PDR	Preliminary Design Review
PDU	Pyrotechnic Driver Unit
P/L	Payload
PLF	Payload Fairing
POST	Program to Optimize Simulated Trajectories
PPWR	P Power
PRD	Program Requirements Document
psf	Pounds Per Square Foot
psi	Pounds Per Square Inch
PSP	Program Support Plan
PSSTU	Pegasus Separation System Test Unit
PTRN	P Turn
PTS	Power Transfer Switch
PWP	Pegasus Work Package
QA	Quality Assurance
RCS	Reaction Control System
RF	Radio Frequency

rpm	Revolutions Per Minute
RTB	Return to Base
RSS	Root Summed Squared
S&A	Safe & Arm
scfm	Standard Cubic Feet Per Minute
sec	Second(s)
SIXDOF	Six Degree-of-Freedom
S/N	Serial Number
S/W	Software
SWC	Soft Walled Cleanroom
TLM	Telemetry
T.O.	Take-Off
TT&C	Telemetry, Tracking & Commanding
TVC	Thrust Vector Control
UDS	Universal Documentation System
UFS	Ultimate Factory of Safety
USAF	United States Air Force
V	Volts
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VDC	Volts Direct Current
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio
WFF	Wallops Flight Facility
WR	Western Range (USAF)
XL	Extended Length (Pegasus)
YFS	Yield Factor of Safety

Section 1.0—Introduction

On August 10, 1989 Orbital Sciences Corporation (Orbital) rolled out the first commercially developed space launch vehicle for providing satellites to low earth orbit (see **Figure 1-1**). Over the past ten years, the "winged rocket" known as Pegasus has proven to be the most successful in its class, placing 70 satellites in orbit with 29 launches.

This Pegasus User's Guide is intended to familiarize mission planners with the capabilities and services provided with a Pegasus launch.

The Pegasus XL was developed as an increased performance design evolution from the original Pegasus vehicle to support NASA and the USAF performance requirements and is now the baseline configuration for all commercial Pegasus launches.

Pegasus is a mature and flight proven small launch system that has achieved consistent accuracy and dependable performance. The Pegasus launch system has achieved a high degree of reliability through its significant flight experience.

Pegasus offers a variety of capabilities that are uniquely suited to small spacecraft. These capabilities and features provide the small spacecraft customer with greater mission utility in the form of:

- A range of custom payload interfaces and services to accommodate unique small spacecraft missions;
- Payload support services at the Pegasus Vehicle Assembly Building at Vandenberg AFB;
- Horizontal payload integration;
- Shared payload launch accommodations for more cost effective access to space as Dual Launches;
- Portable air-launch capability from worldwide locations to satisfy unique mission requirements; and
- Fast, cost-effective and reliable access to space.

Figure 1-1. *Pegasus Rollout.*

The mobile nature of Pegasus allows Orbital to integrate the spacecraft to the Pegasus XL in our integration facility, the Vehicle Assembly Building (VAB), located at Vandenberg Air Force Base (VAFB), CA and ferry the launch-ready system to a variety of launch ranges. Pegasus has launched from a number of launch locations worldwide (see **Figure 1-2**).

The unique mobile capability of the Pegasus launch system provides flexibility and versatility to the payload customer. The Pegasus launch vehicle can accommodate integration of the spacecraft at a customer desired location as well as optimize desired orbit requirements based on the initial launch location. In 1997, after final build up of the rocket at the VAB, Pegasus was mated to the Orbital Carrier Aircraft (OCA) and ferried to Madrid, Spain to integrate Spain's MINISAT-01 satellite. Following integration of the satellite, Pegasus was then ferried to the island of Gran Canaria for launch. The successful launch of Spain's MINISAT-01 satellite proved out Pegasus' ability to accommodate the payload provider's processing and launch requirements at locations better suited to the customer rather than the launch vehicle. This unprecedented launch vehicle approach is an example of Pegasus's way of providing customer oriented launch service.

In the interest of continued process improvement and customer satisfaction, the Pegasus Program successfully completed a one year effort of ISO

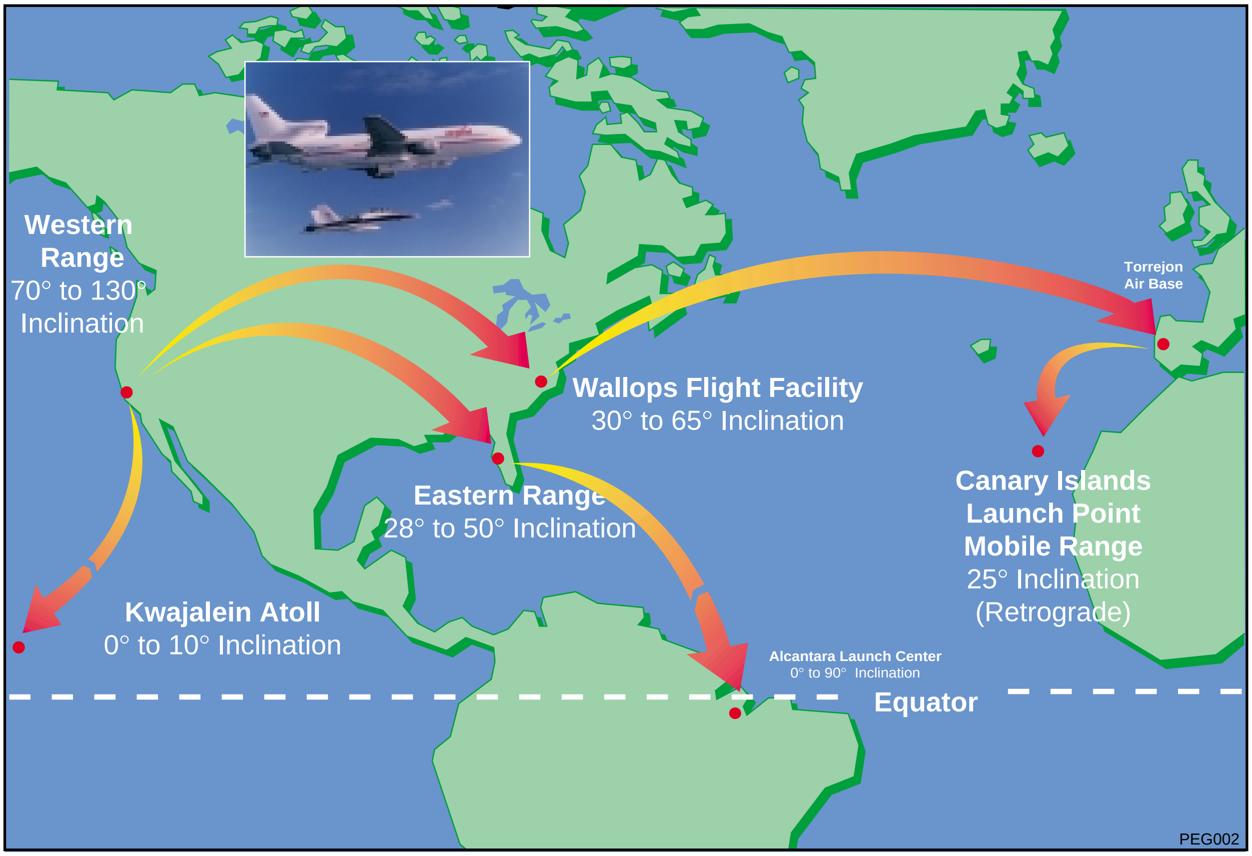


Figure 1-2. *Pegasus Launch Locations.*

9001 certification. In July 1998, Orbital's Launch Systems Group was awarded this internationally recognized industry benchmark for operating a quality management system producing a quality product and service. In the true spirit of ISO 9001, this level of quality is not only achieved, but must be maintained. To this end, the Launch Systems Group has successfully passed each semi-annual audit since the award in 1998.

Pegasus is a customer oriented and responsive launch vehicle system. From Pegasus' commercial heritage comes the desire to continually address the payload customer market to best accommodate its needs. The Pegasus launch vehicle system has continually matured and evolved over its ten year history. This ability and desire to react to the customer has produced the single most successful launch vehicle in its class. To ensure our goal of complete customer satisfaction, a team of managers and engineers is assigned to each mission from "contract award to post-flight report". This dedicated team is committed to providing the payload customer 100% satisfaction of mission requirements.

Each Pegasus mission is assigned a mission team led by a Mission Manager and a Mission Engineer. The mission team is responsible for mission planning and scheduling, launch vehicle production coordination, payload integration services, systems engineering, mission-peculiar design and analysis, payload interface definition, range coordination, launch site processing and operations. The mission team is responsible for ensuring all mission requirements have been satisfied.

Section 2.0—Pegasus XL Vehicle Description

2.1 Pegasus XL Vehicle Description

As discussed in Section 1.0, Pegasus continues to evolve in response to customer requirements. The initial configuration of Pegasus (referred to as the Standard Pegasus) was modified to provide increased performance and vehicle enhancements. The last of the Pegasus Standard launch vehicles is expected to be launched by the end of 2000, therefore, this Pegasus User's Guide is dedicated to the discussion of the Pegasus XL configuration, capabilities, and associated services.

Pegasus XL is a winged, three-stage, solid rocket booster which weighs approximately 23,130 kg (51,000 lbm) and measures 16.9 m (55.4 ft) in length and 1.27 m (50 in) in diameter and has a wing span of 6.7 m (22 ft). **Figure 2-1** shows the Pegasus on the Assembly Integration Trailer (AIT). Pegasus is lifted by the Orbital Carrier Aircraft (OCA) to a level flight condition of about 11,900 m (39,000 ft) and Mach 0.80. Five seconds after release from the OCA stage 1 motor ignition occurs. The vehicle's autonomous guidance and flight control system provide the guidance necessary to insert payloads into a wide range of orbits.

Figure 2-2 shows an expanded view of the Pegasus XL configuration. The Pegasus Vehicle design combines state-of-the-art, flight-proven technologies, and conservative design margins to achieve performance and reliability at reduced cost. The vehicle incorporates eight major elements:

Figure 2-1. *Pegasus XL on the Assembly and Integration Trailer (AIT).*

- Three solid rocket motors;
- A payload fairing;
- An avionics assembly;
- A lifting wing;
- Aft skirt assembly including three movable control fins; and
- A payload interface system.

Pegasus also has an option for a liquid propellant fourth stage, HAPS (see Section 10). **Figure 2-3** illustrates Pegasus XL's principle dimensions.

2.1.1 Solid Rocket Motors

The three solid rocket motors were designed and optimized specifically for Pegasus and include features that emphasize reliability, manufacturability, and affordability. The design was developed using previously flight-proven and qualified materials and components. Common design features, materials, and production techniques are applied to all three motors to maximize cost efficiency and reliability. These motors are fully flight-qualified. Typical motor characteristics are shown in **Figure 2-4.**

2.1.2 Payload Fairing

The Pegasus payload fairing consists of two composite shell halves, a nose cap integral to a shell half, and a separation system. Each shell half is composed of a cylinder and ogive sections. The two halves are held together with two titanium straps along the cylinder and a retention bolt in the nose. A cork and Room Temperature Vulcanizing (RTV) Thermal Protection System (TPS) provides protection to the graphite composite fairing structure. The amount of TPS applied has been determined to optimize fairing performance and payload environmental protection.

The two straps are tensioned using bolts, which are severed during fairing separation with pyrotechnic bolt cutters, while the retention bolt

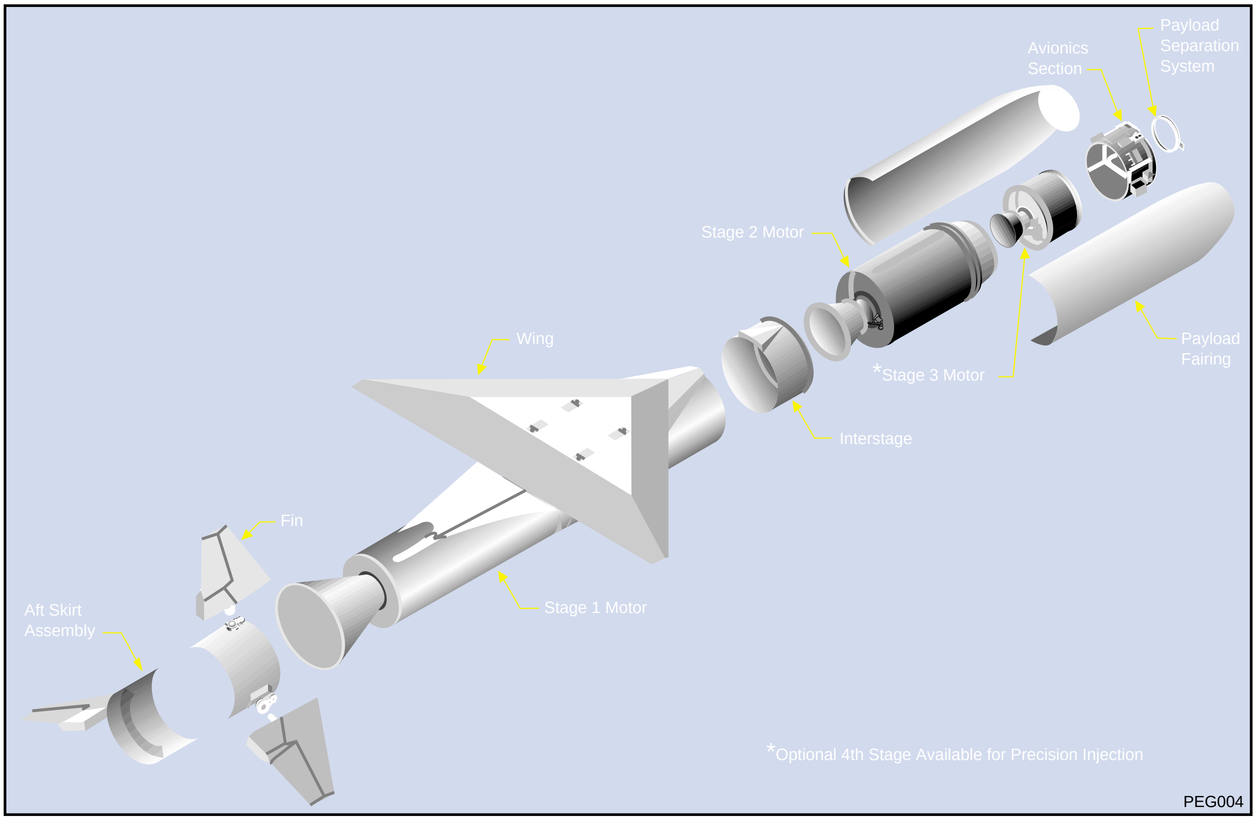


Figure 2-2. *Expanded View of Pegasus XL Configuration.*

in the nose is released with a pyrotechnic separation nut. The base of the fairing is separated with Orbital's low-contamination frangible separation joint. These ordnance events are sequenced for proper separation dynamics. A hot gas generator internal to the fairing is also activated at separation to pressurize two piston-driven pushoff thrusters. These units, in conjunction with cams, force the two fairing halves apart. The halves rotate about fall-away hinges, which guide them away from the satellite and launch vehicle.

The fairing and separation system were fully qualified through a series of structural, functional, and contamination ground vacuum tests and have been successfully flown on all Pegasus XL missions. Section 5 presents a more detailed description of the fairing separation sequence and the satellite dynamic envelope.

2.1.3 Avionics

The Pegasus avionics system is a digital distributed processor design that implements recent developments in hardware, software, communications, and systems design. Mission reliability is achieved by the use of simple designs, high-reliability components, high design margins and extensive testing at the component, subsystem and system level.

The heart of the Pegasus avionics system is a multiprocessor, 32-bit flight computer. The flight computer communicates with the Inertial Measurement Unit (IMU), the launch panel electronics on the carrier aircraft and all vehicle subsystems using standard RS-422 digital serial data links. Most avionics on the vehicle feature integral microprocessors to perform local processing and to handle communications with the flight computer. This RS-422 architecture is central to Pegasus's rapid integration and test, as it allows unit and system-level testing to be accomplished using commercially available ground support equipment with off-the-shelf hardware.

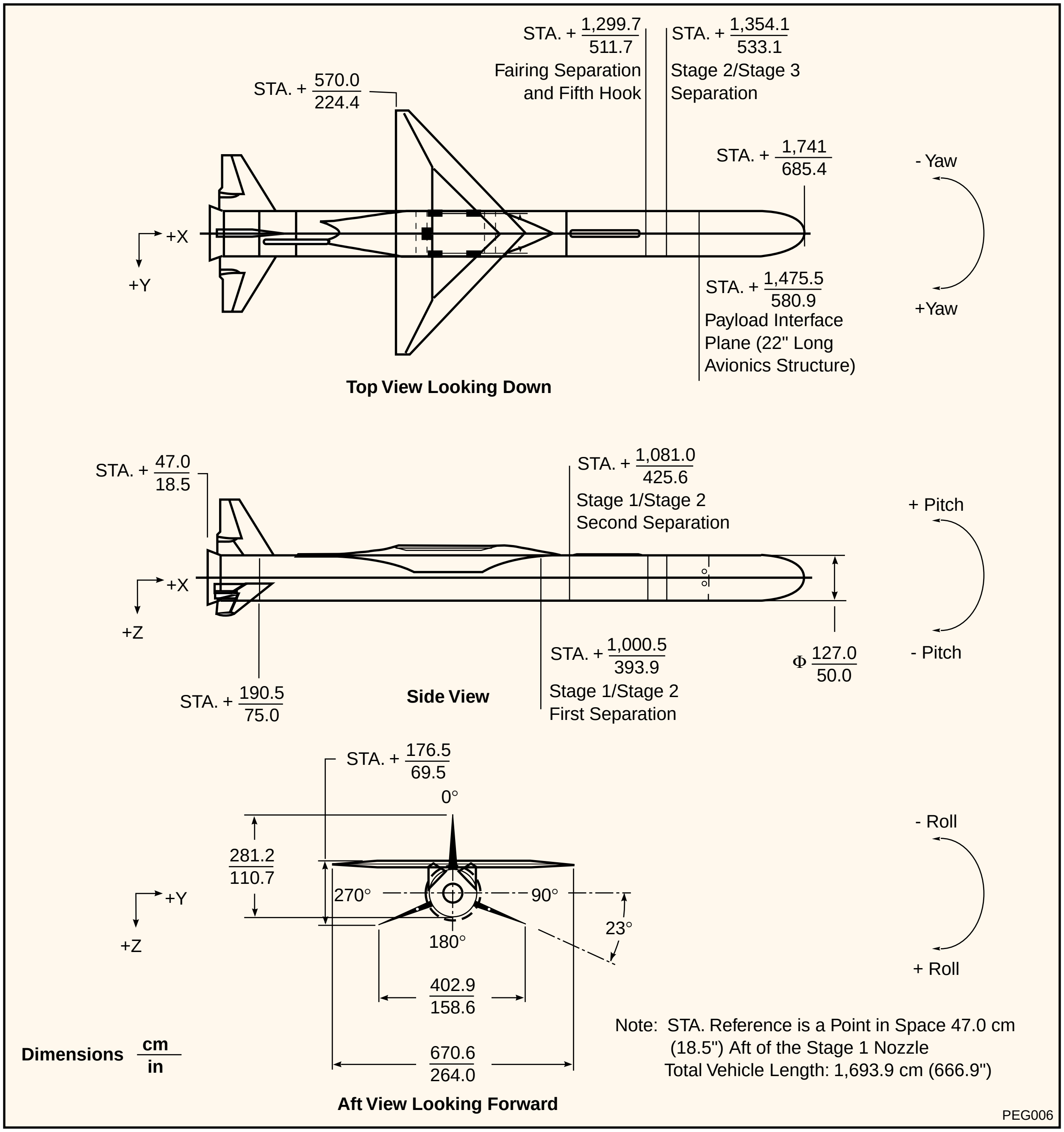


Figure 2-3. *Principal Dimensions of Pegasus XL (Reference Only).*

2.1.4 Flight Termination System

The Pegasus Flight Termination System (FTS) supports ground-initiated command destruct as well as the capability to sense inadvertent stage separation and automatically destruct the rocket. The FTS is redundant, with two independent safe and arm devices, receivers, logic units, and batteries.

2.1.5 Attitude Control Systems

After release from the OCA, the Pegasus attitude control system is fully autonomous. A combination of open-loop steering and closed-loop guidance is employed during the flight. Stage 1 guidance utilizes a pitch profile optimized by ground simulations. Stages 2 and 3 guidance uses an adaptation of an algorithm that was first

Parameter	Units	Stage 1 Motor Orion 50S XL	Stage 2 Motor Orion 50 XL	Stage 3 Motor Orion 38
Overall Length	cm (in)	1,027 (404)	311 (122)	134 (53)
Diameter	cm (in)	128 (50)	128 (50)	97 (38)
Inert Weight (1)	kg (lb)	1,369 (3,019)	416 (918)	126 (278)
Propellant Weight (2)	kg (lb)	15,014 (33,105)	3,925 (8,655)	770 (1,697)
Total Vacuum Impulse (3)	kN-sec (lbf-sec)	43,586 (9,799,080)	11,218 (2,522,070)	2,185 (491,200)
Average Pressure	kPa (psia)	7,515 (1,090)	7,026 (1,019)	4,523 (656)
Burn Time (3) (4)	sec	68.6	69.4	68.5
Maximum Vacuum Thrust (3)	kN (lbf)	726 (163,247)	196 (44,171)	36 (8,062)
Vacuum Specific Impulse Effective (5)	Nsec/kg (lbf-sec/lbm)	2,846 (295)	2,838 (289)	2,817 (287)
TVC Deflection	deg	NA	±3	±3

Notes:
(1) Including Wing Saddle, Truss, and Associated Fasteners
(2) Includes Igniter Propellants
(3) At 21°C (70° F)
(4) To 207 kPa (30 psi)
(5) Delivered (Includes Expended Inerts)

Figure 2-4. *Typical Pegasus XL Motor Characteristics in Metric (English) Units.*

PEG007

developed for the Space Shuttle ascent guidance. Attitude control is closed-loop.

The vehicle attitude is controlled by the Fin Actuator System (FAS) during Stage 1 flight. This consists of electrically actuated fins located at the aft end of Stage 1. For Stage 2 and Stage 3 flight, a combination of electrically activated Thrust Vector Controllers (TVCs) on the Stage 2 and Stage 3 solid motor nozzles and a GN_2 Reaction Control System (RCS) system located on the avionics section, control the vehicle attitude.

Figure 2-5 summarizes the attitude and guidance modes during a typical flight, although the exact sequence is controlled by the Mission Data Load (MDL) software and depends on mission specific requirements.

2.1.6 Telemetry Subsystem

The Pegasus XL telemetry system provides real time health and status data of the vehicle avionics system, as well as key information regarding the position, performance and environment of the Pegasus XL vehicle. This data may be used by Orbital and the range safety personnel to evaluate system performance.

Pegasus contains two separate telemetry systems. The first provides digital data through telemetry multiplexers (MUXs) which gather data from each sensor, digitize it, then relay the information to the flight computer. This Pegasus telemetry stream provides data during ground processing, checkout, captive carry, and during launch. During captive carry, Pegasus telemetry is downlinked to the ground and recorded onboard the OCA. Some payload telemetry data can be interleaved with Pegasus data as a non-standard service. The second system provides analog environments data which are transmitted via a wideband data link and recorded for post-flight evaluation.

2.1.7 Major Structural Subsystems

2.1.7.1 Wing

The Pegasus wing uses a truncated delta platform with a double wedge profile. Wing panels are made of a graphite-faced Nomex-foam sandwich. Channel section graphite spars carry the primary bending loads and half-ribs and reinforcing lay-ups further stabilize the panels and reduce stress concentrations. The wing central box structure has fittings at each corner which provide the structural interface between the Pegasus and the OCA.

Major Phase	Minor Phase	Guidance Mode	Attitude Mode
Fixed Events for All Missions			
Free Drop		None	Inertial Euler Angles
Stage 1 Flight	Ignition and Pull Up	Nominal Trajectory	Inertial Euler Angles
Stage 1 Flight	Maximum Pitch Up	Nominal Trajectory	Vertical Acceleration Limit
Mission Specific Events Tailored to Payload Requirements			
Stage 1 Flight	Pitch Over	Nominal Trajectory	Inertial Euler Angles
Stage 1 Flight	Fins Zeroed	None	Attitude Hold
Stage 1/2 Coast		Begin S2 Powered Explicit GuidanceSolution	Attitude Hold
Stage 2 Flight	S2 Ignition	Closed Loop Powered Explicit Guidance	Commanded Attitude
Stage 2/3 Coast		Begin S3 Powered Explicit GuidanceSolution	Attitude Hold
Stage 2/3 Coast	Maneuver to S3 Ignition Attitude	None	Commanded Attitude
Stage 3	S3 Ignition	Closed Loop Powered Explicit Guidance	Commanded Attitude
After Stage 3 Burnout	Payload Events as Required	None	Commanded as Required

Figure 2-5. *Typical Attitude and Guidance Modes Sequence.* PEG008

2.1.7.2 Aft Skirt Assembly

The aft skirt assembly is composed of the aft skirt, three fins, and the fin actuator subsystem. The aft skirt is an all-aluminum structure of conventional ring and stressed-skin design with machined bridge fittings for installation of the electromechanical fin actuators. The skirt is segmented to allow installation around the first stage nozzle. Fin construction is one-piece solid foam core and wet-laid graphite composite construction around a central titanium shaft.

2.1.7.3. Payload Interface Systems

Multiple mechanical and electrical interface systems currently exist to accommodate a variety of spacecraft designs. Section 5.0 describes these interface systems. To ensure optimization of spacecraft requirements, payload specific mechanical and electrical interface systems can be provided to the payload customer. Payload mechanical fit checks and electrical interface testing with these spacecraft unique interface systems are encouraged to ensure all spacecraft requirements are satisfied.

2.2 Orbital Carrier Aircraft

Orbital furnishes and operates the Orbital Carrier Aircraft (OCA). After integration at Orbital's West Coast integration site at VAFB, the OCA can provide polar and high-inclination launches utilizing the tracking, telemetry, and command (TT&C) facilities of the WR. The OCA can provide lower inclination missions from the East Coast using either the NASA or ER TT&C facilities, as well as equatorial missions from the Kwajalein Atoll or Alcantara, Brazil. The OCA is made available for mission support on a priority basis during the contract-specified launch window.

The unique OCA-Pegasus launch system accommodates two distinctly different launch processing and operations approaches for non-VAFB launches. One approach (used by the majority of payload customers) is to integrate the Pegasus and payload at the VAB and then ferry the integrated Pegasus and payload to another location for launch. This approach is referred to as a “ferry mission.” The second approach is referred to as a “campaign mission.” A campaign mission starts with the build up of the Pegasus at the VAB. The Pegasus is then mated to the OCA at VAFB and then ferried to the integration site where the Pegasus and payload are fully integrated and tested. At this point, the launch may either occur at the integration site or the integrated Pegasus and payload may be ferried to another location for launch.

The OCA also has the capability to ferry Pegasus trans-continentally or trans-oceanically (depending on landing site) to support ferry and campaign missions.

Section 3.0—General Performance Capability

This section describes the orbital performance capabilities of the Pegasus XL vehicle with and without the optional Hydrazine Auxiliary Propulsion System (HAPS) described in Section 10. Together these configurations can deliver payloads to a wide variety of circular and elliptical orbits and trajectories, and attain a complete range of prograde and retrograde inclinations through a suitable choice of launch points and azimuths. In general, HAPS will provide additional performance at higher altitudes.

From the Western Range (WR), Pegasus can achieve inclinations between 70° and 130°. A broader range of inclinations may be achievable, subject to additional analyses and coordination with Range authorities. Additionally, lower inclinations can be achieved through dog-leg trajectories, with a commensurate reduction in performance. Some specific inclinations within this range may be limited by stage impact point or other restrictions. Other inclinations can be supported through use of Wallops Flight Facility (WFF), Eastern Range (ER) or other remote TT&C sites. Pegasus requirements for remote sites are listed in Appendix D.

3.1 Mission Profiles

This section describes circular low earth orbit mission profiles. Performance quotes for non-circular orbits will be provided on a mission-specific basis.

Profiles of typical missions performed by Pegasus XL with and without HAPS are illustrated in **Figure 3-1** and **Figure 3-2**. The depicted profile begins after the OCA has reached the launch point, and continues through orbit insertion. The time, altitude, and velocity for the major ignition, separation, and burnout events are shown for a typical trajectory that achieves a 741 km (400 nm) circular, polar (90° inclination) orbit after launch from WR. These events will vary based on mission requirements.

The typical launch sequence begins with release

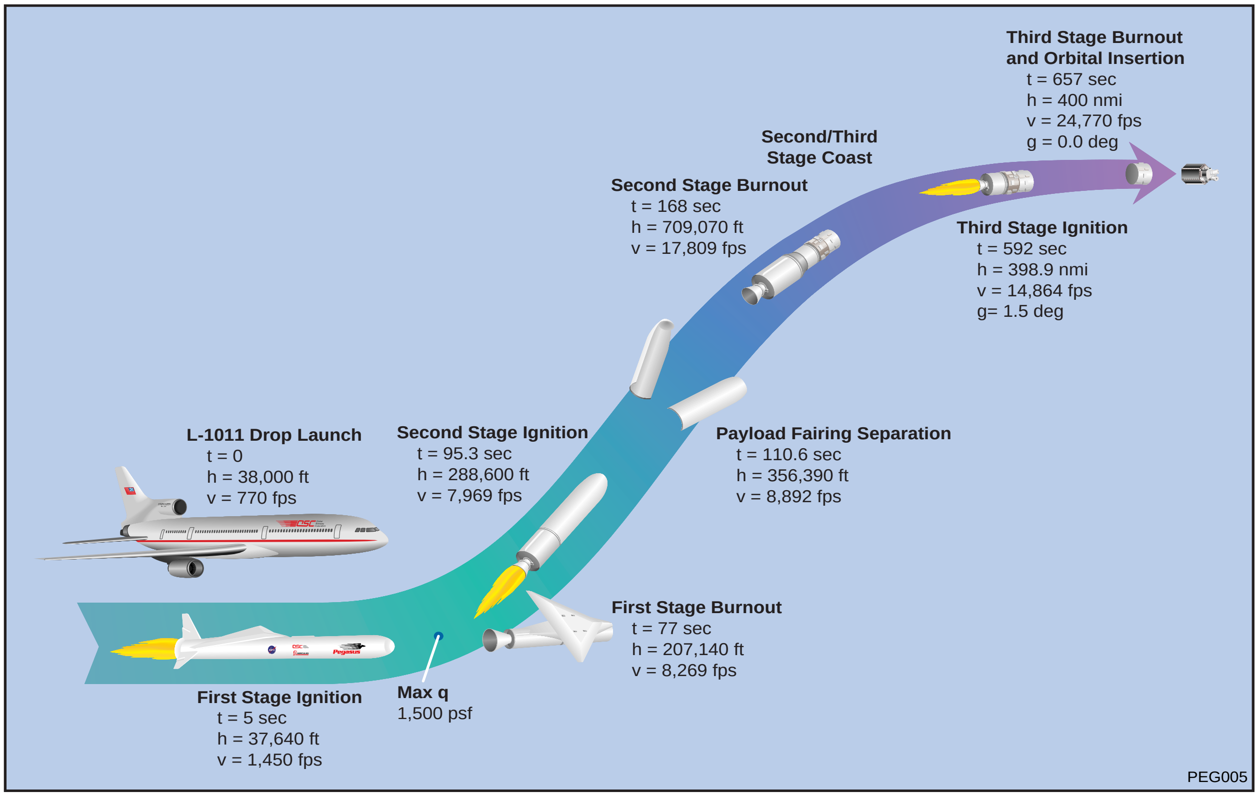


Figure 3-1. *Pegasus XL Mission Profile to 741 km (400 nmi) Circular, Polar Orbit with a 227 kg (501 lbm) Payload.*

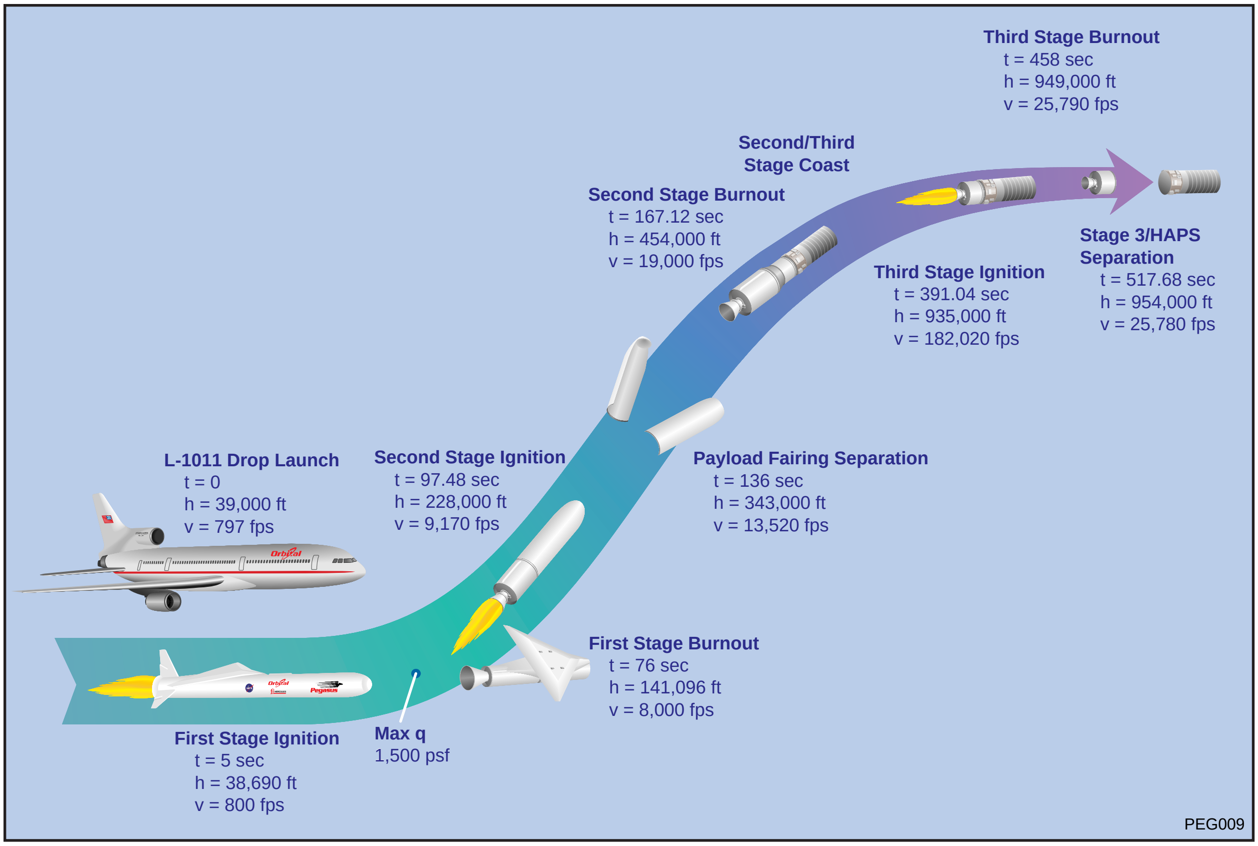


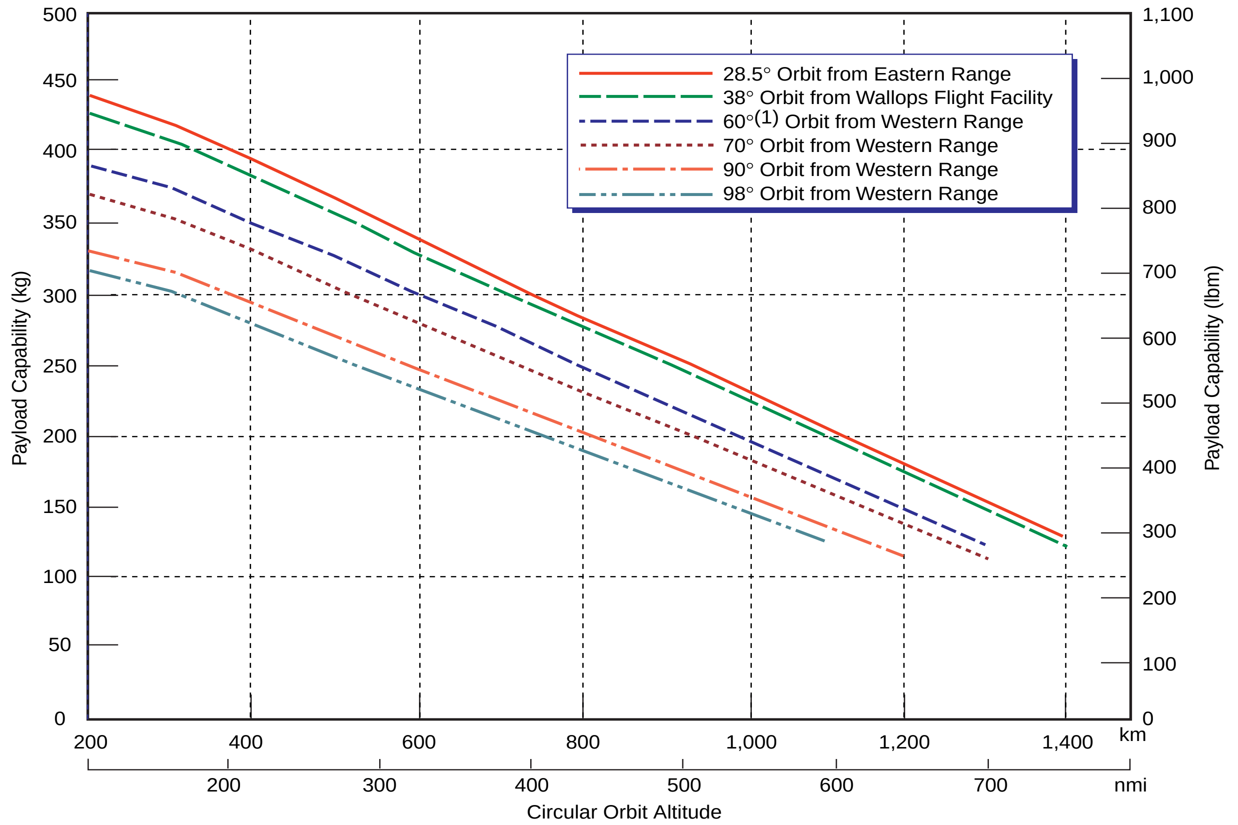
Figure 3-2. *Pegasus XL With HAPS Mission Profile to a 741 km (400 nmi) Circular, Polar Orbit With a 251 kg (554 lbm) Payload.*

of Pegasus from the carrier aircraft at an altitude of approximately 11,900 m (39,000 ft) and a speed of Mach 0.80. Approximately 5 seconds after drop, once Pegasus has cleared the aircraft, Stage 1 ignition occurs. The vehicle quickly accelerates to supersonic speed while beginning a pull up maneuver. Maximum dynamic pressure is experienced approximately 25 seconds after ignition. At approximately 20-25 seconds, a maneuver is initiated to depress the trajectory and the vehicle angle of attack quickly approaches zero.

Stage 2 ignition occurs shortly after Stage 1 burnout and the payload fairing is jettisoned during Stage 2 burn as quickly as fairing dynamic pressure and payload aerodynamic heating limitations will allow, approximately 110,000 m (361,000 ft) and 112 seconds after drop. Stage 2 burnout is followed by a long coast, during which the payload and Stage 3 achieve orbital altitude. Stage 3 then provides the additional velocity necessary to circularize the orbit. Stage 3 burnout typically occurs approximately 10 minutes after launch and 2,200 km (1,200 nm) downrange of the launch point. Attitude control during Stage 2 and Stage 3 powered flight is provided by the motor Thrust Vector Control (TVC) system for pitch and yaw and by the nitrogen cold gas Reaction Control System (RCS) for roll. The RCS also provides control about all three axes during coast phases of the trajectory.

3.2 Performance Capability

Performance capabilities to various orbits for the Pegasus XL are illustrated in **Figure 3-3**. These performance data were generated using the Program to Optimize Simulated Trajectories (POST), which is described below. Precise performance capabilities to specific orbits are provided per the timeline shown in Section 8.0.



- Drop Conditions:
  11,900 m (39,000 ft)
  Mach 0.80
- Entire Mass of the Separation System Is Bookkept on the Launch Vehicle Side
- 67 m/sec (220 ft/sec) Guidance Reserve Maintained
- Fairing Jettison at .48 Pa (0.01 lbf/ft^2)

(1)Requires VAFB Waiver

PEG010

Figure 3-3. *Pegasus XL Performance Capability.*

3.3 Trajectory Design Optimization

Orbital designs a unique mission trajectory for each Pegasus flight to maximize payload performance while complying with the satellite and launch vehicle constraints. Using POST, a desired orbit is specified and a set of optimization parameters and constraints are designated. Appropriate data for mass properties, aerodynamics, and motor ballistics are input. POST then selects values for the optimization parameters that target the desired orbit with specified constraints on key parameters such as angle of attack, dynamic loading, payload thermal, and ground track. After POST has been used to determine the optimum launch trajectory, a Pegasus-specific six degree of freedom simulation program is used to verify trajectory acceptability with realistic attitude dynamics, including separation analysis on all stages.

3.4 Injection Accuracy

Figure 3-4 provides estimates of 3-sigma orbital injection errors for a 227 kg (501 lbm) payload to a 741 km (400 nm), circular, 90° inclination reference orbit. These errors are dominated by errors of the final propulsive stage. In general, the insertion apse experiences smaller errors than the non-insertion apse.

Orbital injection errors are inherently mission specific for solid stage vehicles. In general however, for most missions, insertion accuracies will not be radically different than the values quoted in **Figure 3-4**. Total orbital altitude errors are dominated by errors associated with the final propulsive stage. Several factors affect orbital accuracy directly. Payload masses have the largest effect because they affect the velocity error resulting from a given motor impulse error. Lighter payloads will net greater non-insertion apse errors

Configuration	Insertion Apse Error	Non-Insertion Apse Error	Inclination Error
Pegasus XL	±19 km	±90 km	±0.15°
Pegasus XL with HAPS	±15 km	±15 km	±0.08°

PEG070

Figure 3-4. *3-Sigma Injection Accuracies Typical Pegasus XL Missions.*

than a heavy payload for a given target. Additionally the choice of guidance strategy to meet particular mission requirements can also affect orbital errors.

3.4.1 Actual Pegasus Injection Accuracies

Figure 3-5 shows actual Pegasus orbital injection accuracies for missions in 1996 and 1997 have been consistently within one sigma bounds. As a benchmark, on a typical Pegasus mission, one sigma corresponds to an insertion apse accuracy of ±5 km and a non-insertion apse accuracy of ±30 km. Orbital inclination accuracies have also been well within one sigma. Typical inclination errors are within ±0.05°.

Accuracies are highly mission-specific, depending on payload mass, targeted orbit, and the particular guidance strategy adopted for the mission. In particular, light payloads and high orbits experience increased injection error. Conversely, heavy payloads and low orbits experience reduced injection error. Preliminary and final mission specific orbital dispersions are provided in the Preliminary and Final Mission Analyses.

3.4.2 Error-Minimizing Guidance Strategies

Pegasus motor performance, mass properties and guidance system are understood very well due to large amount of actual flight experience to date. This historical record has enabled the Pegasus Program to update the vehicle models to accurately predict mission performance.

In order to assure that even a 3σ low-performance Pegasus will achieve the required orbit, Pegasus trajectories include a 54 m/sec (180 ft/sec)

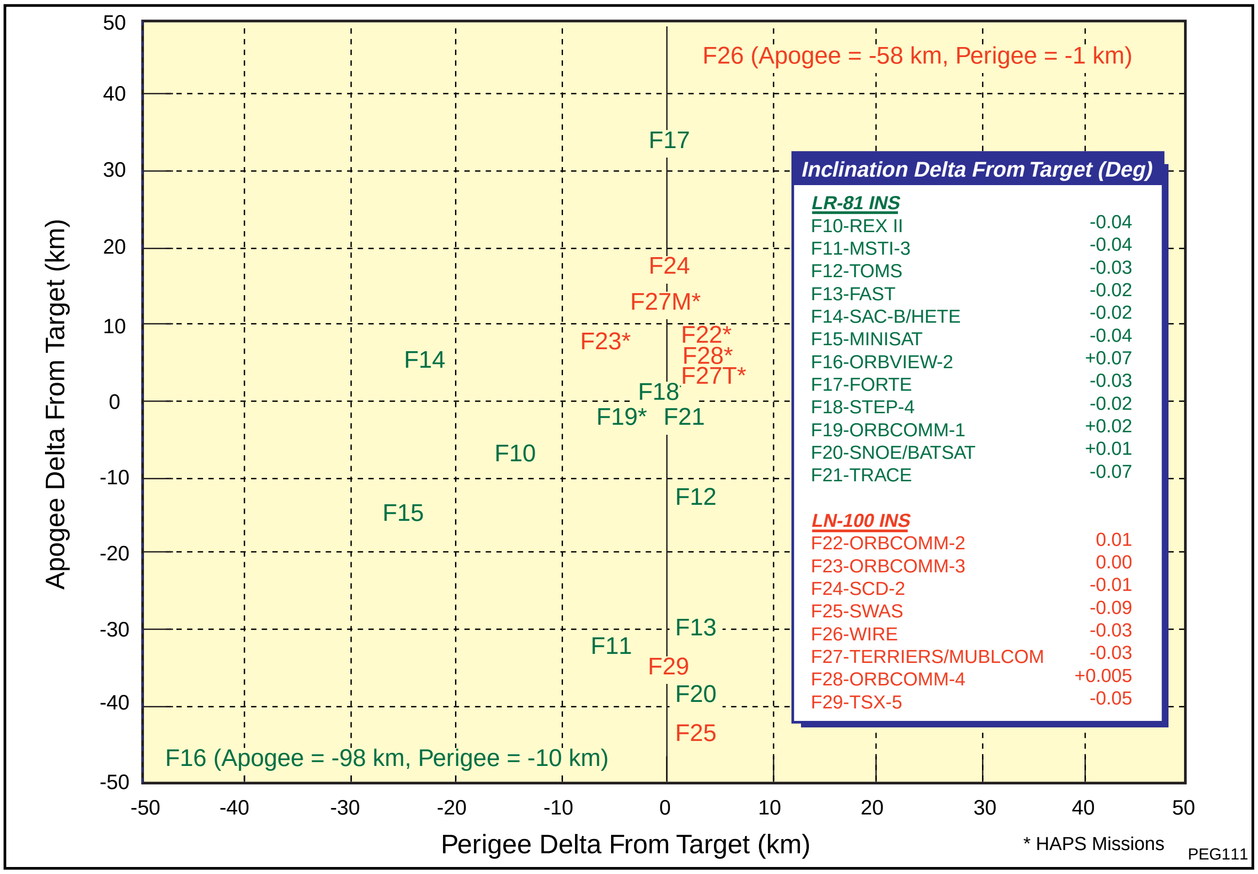


Figure 3-5. *Typical and Recent Pegasus Orbital Accuracy.*

guidance reserve. Pegasus software allows a variety of error-minimizing guidance strategies to be used with this reserve. These strategies fall into three basic categories:

(1) *Minimize Insertion Errors.* Using this strategy, the guidance system scrubs off excess energy via out of plane turning during Stage 2 and 3 burns and modifying the coast duration between Stage 2 and 3 burns. This strategy results in the smallest possible insertion errors for both apogee and perigee.

(2) *Maximize Apogee Altitude.* Using this strategy, all excess velocity is conserved in order to maximize velocity at insertion. This allows the customer to take advantage of the guidance reserve by increasing the expected apogee altitude while maintaining a precise perigee altitude.

(3) *Some Combination of (1) and (2).* Options 1 and 2 are the two endpoints of a spectrum of potential guidance strategies. A third option can target a particular insertion velocity higher than the 3-DOF nominal capability, but lower than the vehicle's 3σ high capability. Using this "hybrid" approach, if the desired apogee altitude corresponds to an insertion velocity which is "X" m/sec higher than the nominal 3-DOF insertion velocity, then the vehicle will not scrub energy unless an excess of greater than "X" m/sec above the nominal 3-DOF value is achieved. This strategy results in an apogee distribution where the mean value falls between the results from options 1 and 2. The total apogee dispersions will be larger than those resulting from option 1, but smaller than those from option 2.

3.5 Collision/Contamination Avoidance Maneuver

Following orbit insertion, the Pegasus Stage 3 RCS or HAPS will perform a series of maneuvers called a Collision/Contamination Avoidance Maneuver (C/CAM). The C/CAM minimizes both payload contamination and the potential for recontact between Pegasus hardware and the separated payload. It also depletes all remaining nitrogen and/or hydrazine.

Orbital will perform a recontact analysis for post separation events. Orbital and the payload contractor are jointly responsible for determination of whether a C/CAM is required.

A typical C/CAM consists of the following steps:

1) At payload separation +3 seconds, the launch vehicle performs a 90° yaw maneuver designed to direct any remaining State 3 motor impulse in a direction which will increase the separation distance between the two bodies.

2) At payload separation +300 seconds, the launch vehicle begins a “crab-walk” maneuver. This maneuver, performed through a series of RCS thruster firings, is designed to impart a small amount of delta velocity in the negative velocity vector direction, increasing the separation velocity between the payload and the third stage of the Pegasus. The maneuver is terminated approximately 600 seconds after separation.

3) Following the completion of the C/CAM maneuver as described above, the RCS valves are opened and the remaining gas is expelled.

Section 4.0—Payload Environments

This section describes the payload environments experienced through the ground, captive carry and flight mission phases. In most cases both design limit loads and measured flight data are characterized. These limit loads encompass the environments imposed by the XL and HAPS configured vehicles and by the Orbital Carrier Aircraft (OCA).

4.1 Design Loads

The primary support structure for the spacecraft shall possess sufficient strength, rigidity, and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements, including worst case predicted ground, flight, and orbital loads. It shall survive those conditions in a manner that assures safety and that does not reduce the mission success probability. The primary support structure of the spacecraft shall be electrically conductive to establish a single point electrical ground. Spacecraft design loads are defined as follows:

- ***Design Limit Load*** —The maximum predicted ground-based, captive carry or powered flight load, including all uncertainties.
- ***Design Yield Load*** — The Design Limit Load multiplied by the required Yield Factor of Safety (YFS) indicated in **Figure 4-1**. The payload structure must have sufficient strength to withstand simultaneously the yield loads, applied temperature, and other accompanying environmental phenomena for each design condition without experiencing detrimental yielding or permanent deformation.
- ***Design Ultimate Load*** — The Design Limit Load multiplied by the required Ultimate Factor of Safety (UFS) indicated in **Figure 4-1**. The payload structure must have sufficient strength to withstand simultaneously the ultimate loads, applied temperature, and other accompanying environmental phenomena without experiencing any fracture or other failure mode of the structure.

4.2 Payload Testing and Analysis

Sufficient payload testing and/or analysis must be performed to ensure the safety of ground and aircraft crews and to ensure mission success. The payload design must comply with the testing and design factors of safety in **Figure 4-1** and the FAA regulations for the carrier aircraft listed in CFR14 document, FAR Part 25. Ultimate Factors of Safety shown in **Figure 4-1** must be maintained per Orbital SSD TD-0005. At a minimum, the following tests must be performed:

Structural Integrity — Static loads, sine vibration, or other tests shall be performed that combine to encompass the acceleration load environment presented in Section 4.3. Test level requirements are defined in **Figure 4-1**.

Random Vibration — Test level requirements are defined in **Figure 4-2**.

4.3 Payload Acceleration Environment

Figure 4-3 illustrates the primary acceleration load conditions experienced during a nominal Pegasus integration and launch operation using the Orbital Carrier Aircraft. The accelerations listed are design limit loads. The axial accelerations for each stage at burnout are presented in **Figure 4-4**.

Design and Test Options	Design Factor of Safety on Limit Loads			Test Level
	Yield	Ultimate		
	(YFS)	(UFS) Unmanned Events	(UFS) Manned Events	
Dedicated Test Article	1.00	1.25	1.50	UFS
Proto-Flight Article	1.25	1.50	1.50	1.25
Proof Test Each Flight Article	1.10	1.25	1.50	1.10
No Static Test	1.60	2.00	2.25	N/A

Figure 4-1. *Factors of Safety for Payload Design and Test.*

PEG012

Test Type	Test Purpose	Test Level
Random Vibration: the Flight Limit Level Is Characterized in Figure 4-7	Qualification	Flight Limit Level + 6dB
	Acceptance	Flight Limit Level
	Protoflight	Flight Limit Level + 3dB

PEG013

Figure 4-2. *Payload Testing Requirements.*

4.3.1 Drop Transient Acceleration

The Pegasus has no significant sustained sinusoidal vibration environments during captive carry or powered flight. There is a transient acceleration event, which occurs during the drop of the Pegasus from the carrier aircraft. Prior to the Pegasus separation, the Pegasus/payload structure is deformed due to the gravitational pre-load. At drop, the pre-load is suddenly removed. The resulting transient response is dominated by the Pegasus/Payload first bending mode (8-9 Hz). However, higher frequency Pegasus and payload modes are excited as well. Because of the oscillatory nature of the drop transient response, which includes rotation of the interface plane, significant dynamic amplification of the accelerations is expected throughout the spacecraft. The mass distribution, stiffness and length of the primary payload structure greatly impact the amplification level. Accurate estimation of the drop transient loading requires a coupled loads analysis (CLA) which uses Orbital and customer provided finite element models to predict the drop transient environment. Prior to performing a CLA, **Figure 4-5** can be used to estimate the payload c.g. Net Load Factors (for the Pegasus Z-axis) and the payload interface estimates are shown in **Figure 4-6**. Load factors for other payload interface configurations, or for modified 23" and 38" separation systems (i.e., load suppression), require mission specific analyses for accurate predictions. To minimize coupling of the payload bending modes with the launch vehicle first bending mode, the first fundamental lateral frequency must be greater than 20 Hz, cantilevered from the base of the spacecraft, excluding the spacecraft separation system.

4.4 Payload Vibration Environment

Based on flight data taken during OCA captive carry flights, the in flight random vibration curve shown in **Figure 4-7** encompasses the captive carry vibration environment.

4.4.1 Long Duration Captive Carry

The maximum envelope shown in **Figure 4-7** is not constant during a Pegasus mission. The actual flight random vibration levels vary considerably throughout each phase of the Pegasus flight and are typically well below the maximum levels.

4.5 Payload Shock Environment

The maximum shock response spectrum at the base of the payload from all launch vehicle events will not exceed the flight limit levels in **Figure 4-8**.

4.6 Payload Acoustic Environment

The acoustic levels during OCA take-off, captive carry and powered flight will not exceed the flight limit levels shown in **Figure 4-9**. The +6dB spectrum is recommended for payload standard acoustic testing to account for fatigue duration effects.

Environment	X-Axis (g's)		Y-Axis (g's)		Z-Axis (g's)	
	Steady-State	Quasi-Static*	Steady-State	Quasi-Static*	Steady-State	Quasi-Static*
Taxi, Captive Flight & Abort Landing (Man-Rated)[2]	N/A	±1.0	N/A	±0.7	N/A	+3.6/-1.0
Aerodynamic Pull-Up	-3.7	±1.0	±0.2	±1.0	±2.33	+1.0
Stage Burn-Out	See Fig. 4-4	±1.0	±0.2	±1.0	±0.2	±1.0
Post Stage Burn-Out	±0.2	±1.0	±0.2	±2.0	±0.2	±2.0

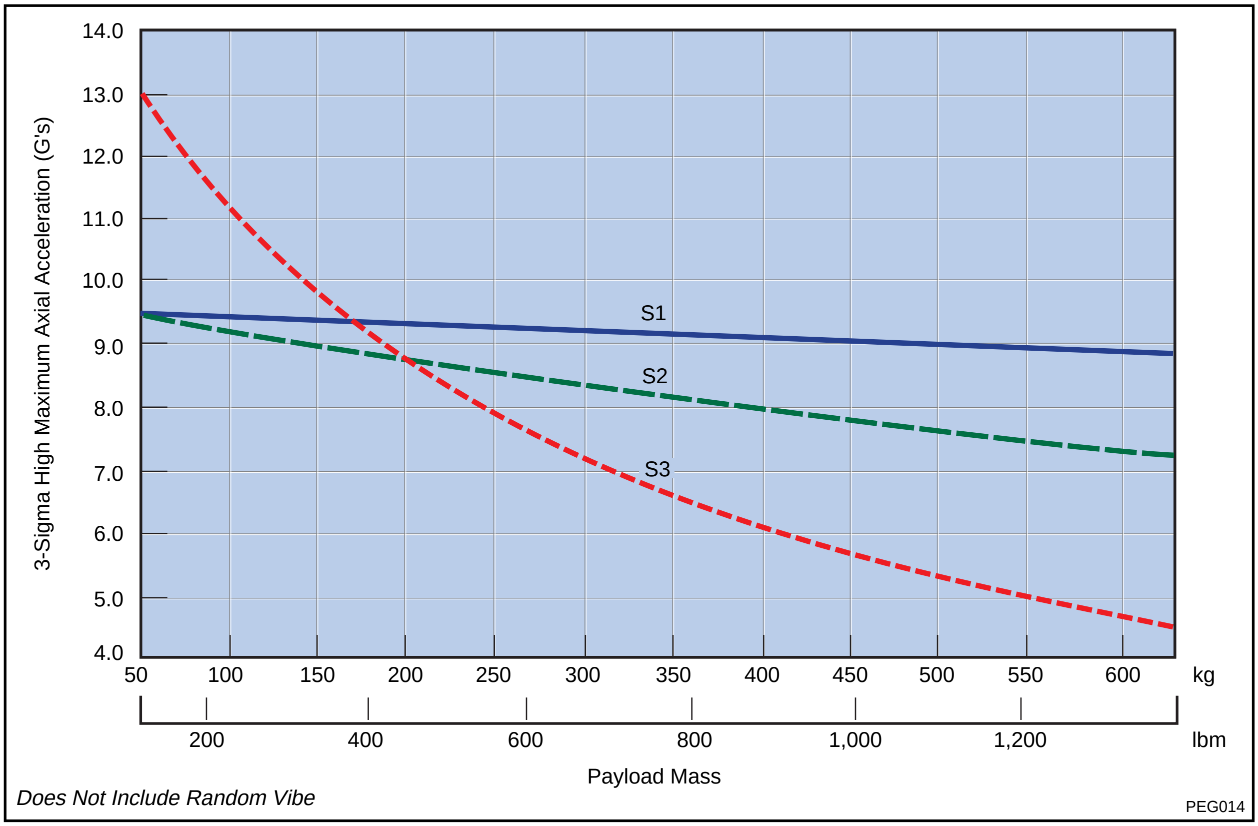
Notes:

1) Static Equivalent of Mixed Dynamic Environments

2) Dominated by Abort and Ferry Landing Events.

PEG017

Figure 4-3. *Pegasus Design Limit Load Factors.*



Does Not Include Random Vibe

Figure 4-4. *Pegasus XL 3-Sigma High Maximum Acceleration as a Function of Payload Weight.*

4.7 Payload Thermal and Humidity Environment

The payload temperature and humidity environments are controlled inside the fairing using the Ground and Airborne Air Conditioning Systems (GACS and AACS). The GACS provides conditioned air to the payload in the VAB, on the flight line. The AACS is used prior to OCA take-off and during captive carry flight. The conditioned air enters the fairing at a location forward of the payload, exits aft of the payload and is provided up to the time of launch vehicle drop. Baffles are provided at the air conditioning inlet to reduce impingement velocities on the

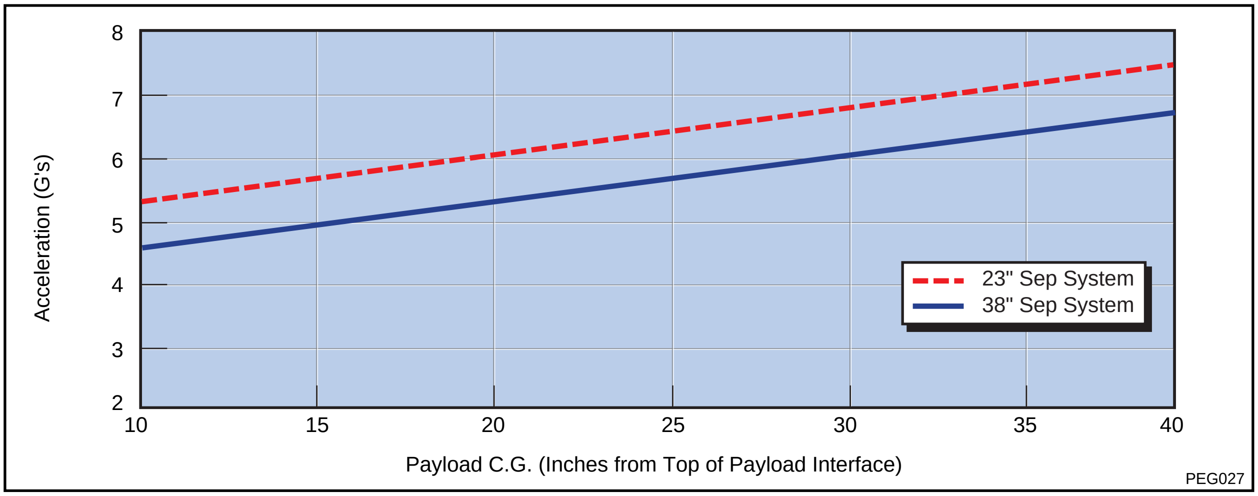


Figure 4-5. *Pegasus Net C.G. Load Factor Predictions.*

Location	Ax (g's)	Ay (g's)	Az (g's)
Payload Interface	±0.5 g	±0.5 g	±3.85

PEG015

Figure 4-6. *Drop Transient Design Limit Load Environment.*

payload if required. The nominal payload thermal and humidity environments for vehicle assembly, flight line, and captive carry operations are listed in **Figure 4-10**.

The component that exhibits the maximum temperature inside the payload fairing, with a view factor to the payload, is the inner surface of the fairing. The temperature of the fairing increases due to aerodynamic heating. **Figure 4-11** shows the worst case transient temperature profile of the inner fairing surface adjacent to the payload. The temperature profile was derived using the worst case heating trajectory, the minimum tolerance TPS thickness, and worst case warm initial temperatures.

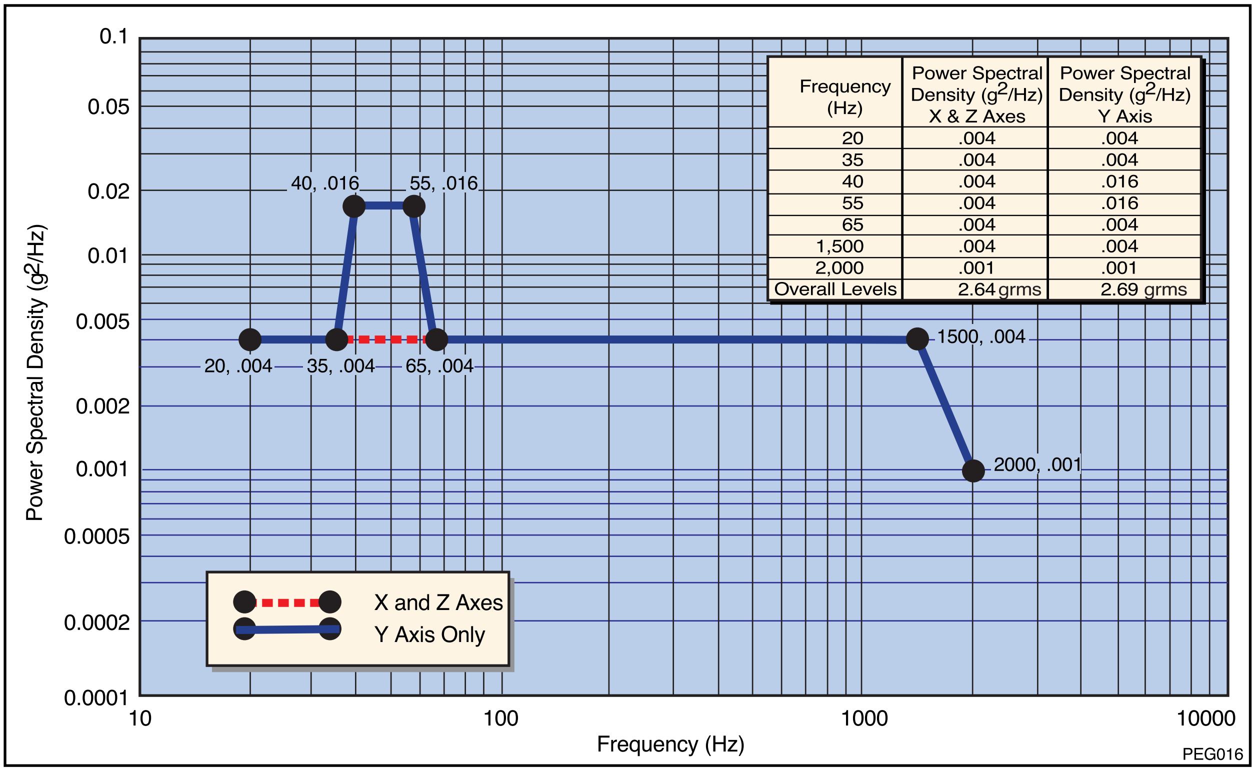
The component with a view factor to the payload, that exhibits the minimum temperature inside the payload fairing, is also the inner surface of the fairing. During captive carry, the payload temperature is primarily driven by radiative cooling. The fairing surface adjacent to the payload can reach a minimum temperature of -40°C (-40°F). This temperature is reached approximately 30 minutes after OCA takeoff.

Fairing thermal emissivity on the inner surface will not exceed 0.9. As a non-standard service, a low emissivity coating can be applied to reduce emissivity to less than 0.1.

4.7.1 Nitrogen Purge

If required for spot cooling of a payload component, Orbital will provide localized GN_2. The GN_2 will meet Grade B specifications, as defined in MIL-P-27401C and can be regulated between 2.4-11.8 l/sec (5-25 scfm). The GN_2 is on/off controllable at the LPO station. One cooling location on the payload can be provided up to a total of 91 kg (200 lbm) of GN_2 during taxi and captive carry. This cooling will be available from payload mate through launch.

The system uses a ground nitrogen source until



Frequency (Hz)	Power Spectral Density (g^2/Hz) X & Z Axes	Power Spectral Density (g^2/Hz) Y Axis
20	.004	.004
35	.004	.004
40	.004	.016
55	.004	.016
65	.004	.004
1,500	.004	.004
2,000	.001	.001
Overall Levels	2.64 grms	2.69 grms

Figure 4-7. *Payload Interface Random Vibration Specification.*

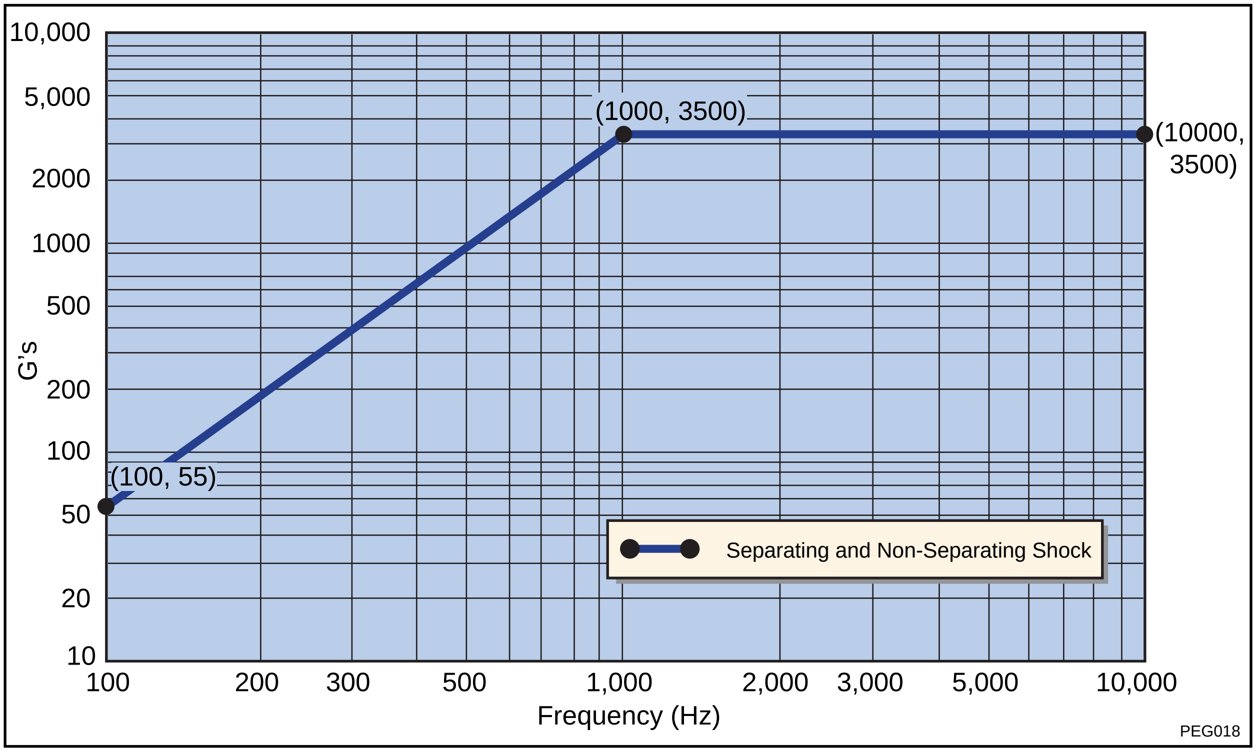


Figure 4-8. *Shock at the Base of the Payload.*

OCA engine 2 starts, then it transfers to the OCA nitrogen system for captive carry. The system's regulators are set to a desired flow rate, normally 0.7 kg/min (1.5 lbm/min), then lockwired in place. The system cannot be adjusted in-flight. This should be considered during payload requirement definition (i.e., volumetric flow rate will increase as the OCA climbs to launch altitude).

Payload purge requirements must be coordinated with Orbital via the ICD to ensure that the requirement can be achieved. Any payload purge requirement that cannot be met with the existing system will be considered "out of scope" from the nominal Pegasus launch services.

4.8 Payload Electromagnetic Environment

All power, control and signal lines inside the payload fairing are shielded and properly terminated to minimize the potential for EMI.

The Pegasus payload fairing is radio frequency (RF) opaque, which shields the payload from external RF signals while the payload is encapsulated. Based on analysis and supported by test, the fairing provides 20 db attenuation between 1 and 10000 MHz. **Figure 4-12** lists the frequencies and maximum radiated signal levels from vehicle antennas that are located near the payload during powered flight. Antenna located inside the fairing are inactive until after fairing deployment. **Figure 4-13** lists carrier aircraft emitters and receivers. The payload electromagnetic environment (EME) results from three categories of emitters: Pegasus onboard antennas, Carrier Aircraft antennas, and Range radar. EME varies with mission phase. For example, the VAB environment is more benign than the flight line/Carrier Aircraft environment. A worst case composite EME is defined in **Figure 4-14** and **Figure 4-15**, taking into account all mission phases. This EME should be compared to the payload's RF susceptibility levels (MIL-STD-461, RS03) to define margin.

4.9 Payload Contamination Control

Orbital operates the Pegasus launch vehicle system under one of two contamination control plans, depending on specific mission requirements. These plans are:

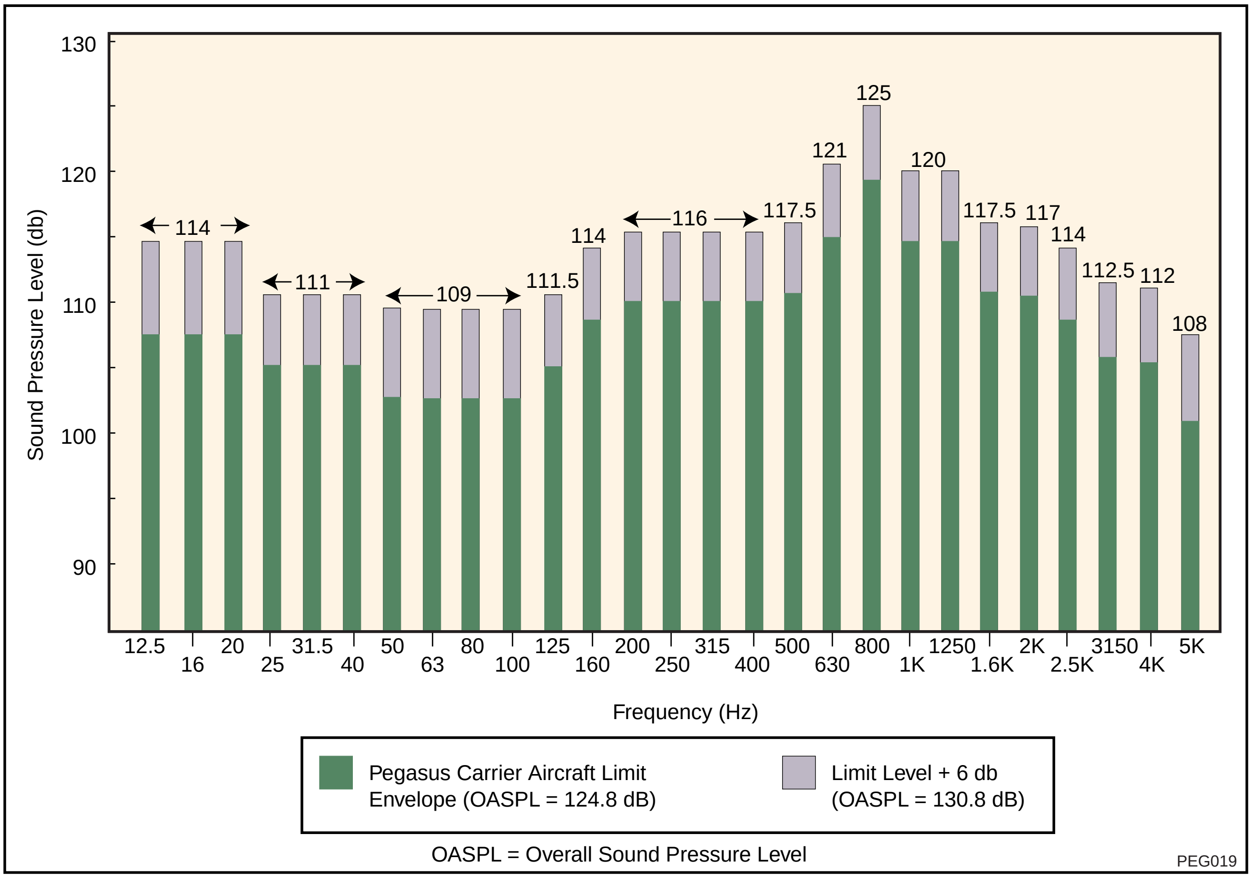


Figure 4-9. *Payload Acoustic Environment.*

TD-0198 - "Pegasus Payload Contamination Control Plan, Class 100,000 (Class M 6.5) Missions;" and

TD-289 - "Pegasus Payload Contamination Control Plan, Class 10,000 (Class M 5.5) Missions."

Class 10,000 (M 5.5) contamination control is available as a non-standard service.

These two plans are based on industry standard contamination reference documents, including the following:

MIL-STD-1246C, "Product Cleanliness Levels and Contamination Control Program"

FED-STD-209E, "Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones."

NRP-1124, "Outgassing Data for Selecting Spacecraft Materials"

The Pegasus vehicle and all payload integration procedures have been designed to minimize the payload's exposure to contamination from the time the payload arrives at the field integration facility through orbit insertion and separation. The VAB is maintained at all times as a visibly clean, air-conditioned, humidity-controlled work area.

As a nonstandard service, the payload can be provided with a soft-walled cleanroom (SWC) with a Class 100,000 (Class M6.5) environment for payload integration operations at the VAB. Air is supplied to the SWC through a bank of High-Efficiency Particulate Air (HEPA) filters, which are 99.97% effective in removing particles of ≥0.3 microns in size. These filters are located in the ceiling of the enclosure from which air is drawn from the VAB interior. Particulate size vs. time data is recorded in accordance with the guidelines of FED-STD-209E. The SWC is certified

Event	Temp Range		Control	Humidity (%)	Purity Class (Note 3)
	Deg C	Deg F			
Pre-Payload Fairing Installation					
• Outside VAB Clean Tent	23 ± 5	74 ± 10	A/C	45 ± 15	None
• Inside VAB Clean Tent	23 ± 5	74 ± 10	Filtered A/C	45 ± 15	100 K (M6.5)
Post-Payload Fairing Installation (GSE)	PLF Inlet	PLF Inlet			
• VAB	23 ± 5	74 ± 10	Filtered A/C	45 ± 15	100 K (M6.5)
• Roll-Out to Carrier Aircraft (VAFB)	Ambient	Ambient	Filtered Ambient	<60	
	(Generally 13 ± 11)	(Generally 55 ± 20)	Filtered A/C	(Note 1)	
• Carrier Aircraft Mate/Hot Pad	23 ± 5	74 ± 10			
OCA AACS (Ground)	PLF Inlet	PLF Inlet	Filtered A/C	<70	100 K (M6.5)
• Taxi	23 ± 5	74 ± 10	Filtered A/C	(Note 2)	
OCA AACS (Altitude)	PLF Inlet	PLF Inlet	Filtered A/C	<50	100 K (M6.5)
• Captive Carry	23 ± 5	74 ± 10	Filtered A/C		
• Abort/Contingency	23 ± 5	74 ± 10	Filtered A/C		
– Above 4.9 km (16 K ft)	GN_2	GN_2	Clean Nitrogen		
– Below 4.9 km (16 K ft)					

Notes:

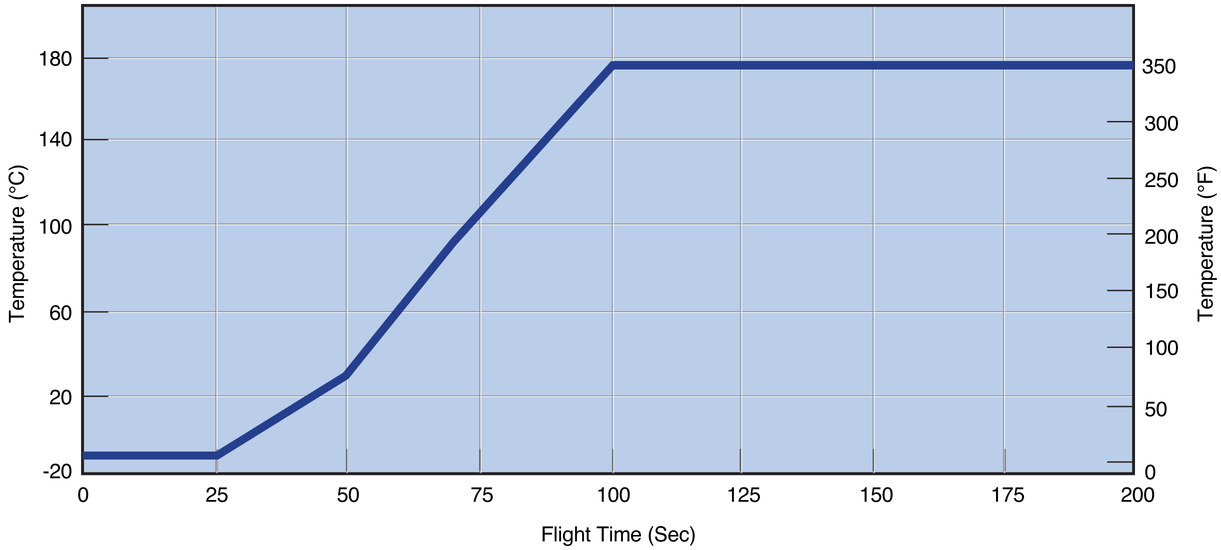
1. GSE A/C Performance Is Dependent Upon Ambient Conditions. Temperature Is Selectable and Controlled to Within ±2°C (±4°F) of Set Point. Resultant Relative Humidity Is Maintained to 45 ± 15%.
2. AACS Ground Performance Is Dependent Upon Ambient Conditions (Dew Point). Temperature Is Selectable and Controlled Within ±2°C (±4°F) of Set Point. Resultant Relative Humidity Is Maintained to 45 ± 15%.
3. Class 10K (M5.5) Can Be Provided Inside the VAB Clean Tent and at the Payload Fairing Air-Conditioning Inlet on a Mission Specific Basis As a Non-Standard Service.

PEG020

Figure 4-10. *Payload Thermal and Humidity Environment.*

between 5 and 30 days prior to payload arrival at the VAB.

During encapsulation, the payload fairing will be provided with Class 100,000 air supplied by the



- Data Analytically Derived
- Worst Case Heating Profile (Hot Trajectory)
- Fairing Inner Surface Temperature at the Ogive/Cylinder Interface

PEG021

Figure 4-11. *Pegasus XL Predicted Worst-Case Payload Fairing Inner Surface Temperatures During Ascent to Orbit.*

Source	1	2	3	4	5	6	7
Function	Command Destruct	Tracking Transponder	Tracking Transponder	Instrument Telemetry	Booster Telemetry	GPS	Camera
Role	Receive	Transmit	Receive	Transmit	Transmit	Receive	Transmit
Band	UHF	C-Band	C-Band	S-Band	S-Band	L-Band	S-Band
Frequency (MHz)	416.5 or 425	5765	5690	2269.5	2288.5	1575.42 – 10.23 1227.60 – 10.23	2200-2400
Bandwidth	N/A	N/A	14 MHz at 3 dB	750 KHz at 3 dB	315 KHz at 3 dB	20.46 MHz	12 MHz
Power Output	N/A	400 W Peak	N/A	5 W	5 W	N/A	8 W
Sensitivity	-107 dBm	N/A	-70 dBm	N/A	N/A	N/A	N/A
Modulation	Tone	Pulse Code	Pulse Code	FM/FM	PCM/FM	PRN Code	N/A

Figure 4-12. *Pegasus XL RF Emitters and Receivers.* PEG022

VAB air conditioning HEPA system. A diffuser is used at the fairing inlet to direct the airflow away from the payload. During Pegasus transport to the OCA and during Pegasus/OCA mate, a blower/desiccant system provides Class 100,000 air to the fairing. These blowers process ambient air though a desiccant canister and a HEPA filter. For hot pad operations after Pegasus/OCA mate, the Ground Air Conditioning System (GACS) is used; during taxi and captive carry on the OCA, the aircraft's Airborne Air Conditioning System (AACS) is used. Both deliver HEPA-filtered Class 100,000 air to the fairing, and both employ a diffuser to direct the airflow away from the payload. The face velocity will not exceed 11 m/min (35 ft/min).

Particle count measurements will be made for each fairing air supply (i.e. - the VAB air supply, the blower/desiccant system, the GACS, and the AACS) before hookup to the fairing. This certification will be made after each system has been running a minimum of 30 minutes, to ensure that the downstream ducting has been purged.

Also as a non-standard service, carbon filters can be provided to remove volatile hydrocarbons of molecular weight 70 or greater from the fairing air supply, with better than 95% efficiency.

The Pegasus payload fairing inner surface is constructed of graphite/epoxy composite material, meeting the NRP-1124 outgassing standards of Total Mass Loss (TML) ≤1.0%, and Collected Volatile Condensable Material (CVCM) ≤ 0.1%.

The baseline cleanliness of the fairing inner surface is “visibly clean.” “Visibly clean” is defined as appearing clean of all particulate and

Source	1	2	3	4	5	6	7	8
Function	VHF Comm	HF Comm	UHF Comm	GPS/Loran	GPS Relay	Video Telemetry	ATC Transponder	Weather Radar
Role	Receive/ Transmit	Receive/ Transmit	Receive/ Transmit	Receive	Receive/ Transmit	Transmit	Receive/ Transmit	Receive/ Transmit
Band	VHF	HF	UHF	L-Band	L-Band	S-Band	L-Band	X-Band
Frequency (MHz)	118.0-135.975	2.0-29.999	225.0-399.975	1575.42	1575.42	2210.50 or 2383.5	R: 1030 ±0.2 T: 1090 ±3	9345 ±30
Bandwidth	90 KHz @-60 dB	SSB: 3 KHz AM: 6 KHz	Standard A/C Radio	20.46 MHz	20.46 MHz	12 MHz	25 MHz @ -60 dB	R: 700 KHz
Power Output	25 W	SSB: 400 W AM: 125 W	10 W	N/A	<1 W	10 W	500 W	65 kW
Sensitivity	3μV	SSB: 1μV AM: 3μV	4 mV	N/A	N/A	N/A	-76 dBm	Not Specified
Modulation	AM	SSB AM	AM	PRN Code	PRN Code	FM	Pulsed 1% Duty Cycle	5.74 μS Pulse, 200 pps

Figure 4-13. *Carrier Aircraft RF Emitters and Receivers.* PEG023

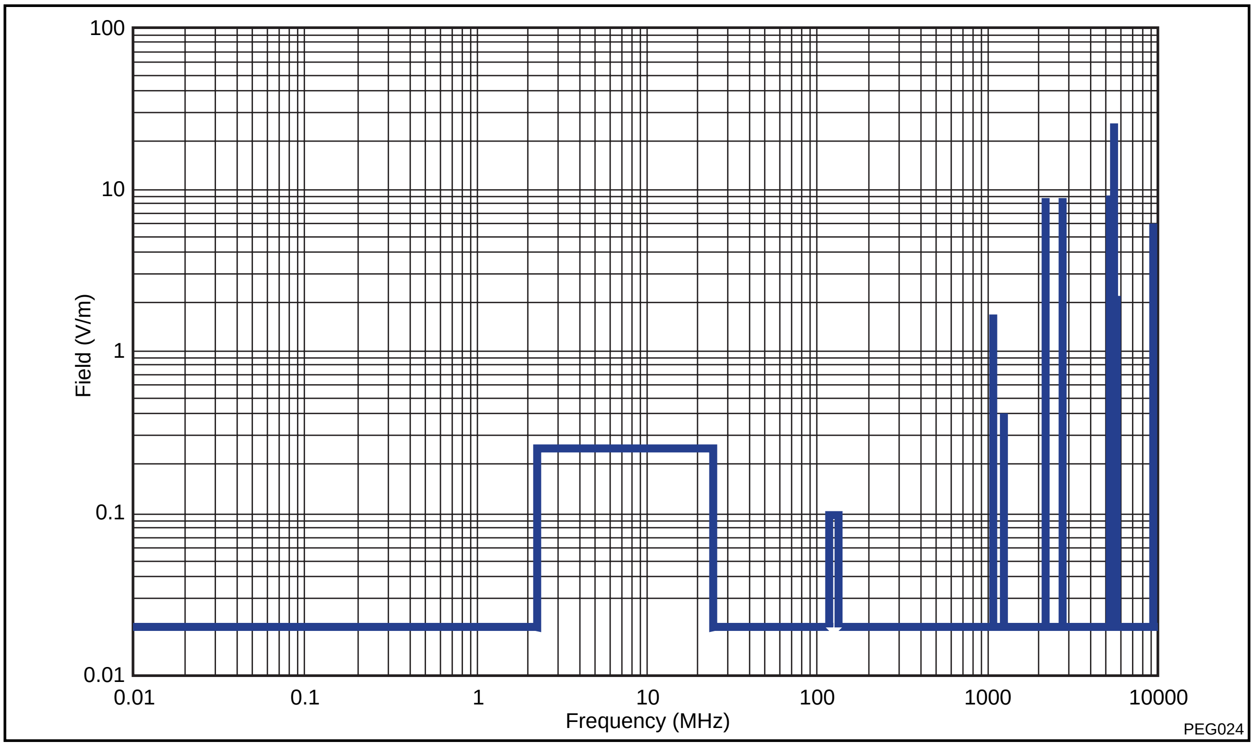


Figure 4-14. *Western Range Worst Case Composite Electromagnetic Environment.*

nonparticulate substances when examined by normal 20/20 vision at a distance of 15-46 cm (6-18 in) under incident light of 1,076-1,346 lux (100-125 foot-candles).

Source	Frequency (MHz)	Field (V/m)	Comment
HF Comm	2.8-26	<0.16	Aircraft Communications
VHF Comm	118-136	<0.1	Aircraft Communications
ATC Transponder	1090	1.7	Aircraft Transponder (Pathfinder Data)
ARSR-1E	1320	0.4	VAFB Air Surveillance Radar
PEG S-Band	2269.5, 2288.5	9.0	Vehicle Accel/Telemetry Transmitter
AN/GPN-12	2800	8.8	VAFB RAPCON
Range C-Band (Tracking Transponder)	5690	8.7	FPS-16-1, TPQ-18, HAIR, MOTR, FPQ-6, MPS-36 (Pathfinder Data)
PEG C-Band	5765	28.0	Vehicle Transponder
Range C-Band (Skin Tracking)	5890	2.3	Multiple Objects Tracking Radar (Pathfinder Data)
Weather Radar	9345	<6	OCA During Pathfinder, Full Slew

PEG025

Figure 4-15. *Worst Case Composite Electromagnetic Environment.*

Level 750A, Level 600A, or Level 500A cleanliness requirements of MIL-STD-1246C can be provided as a non-standard service.

4.10 Payload Deployment

Following orbit insertion, the Pegasus avionics subsystem can execute a series of pre-programmed Reaction Control System (RCS) commands from the MDL to provide the desired initial payload attitude prior to payload separation. This capability may also be used to incrementally reorient for the deployment of multiple spacecraft with independent attitude requirements. Either an inertially-fixed or spin-stabilized attitude may be specified by the user.

Pegasus can accommodate a variety of payload spinup requirements up to 60 rpm. The maximum rate for a specific mission depends upon the spin axis moment of inertia of the payload and the amount of nitrogen needed for other attitude maneuvers. **Figure 4-17** shows the accuracy of control and spin rate. Post-separation rate errors

Error Type (Pegasus Vehicle Axes)		Angle (Degrees)	Rate (Degrees per Sec)
Pointing	Yaw (Z)	±4	±0.5
	Pitch (Y)	±4	±0.5
	Roll (X)	±4	±1.0
Spin Rate		–	±2.0

Notes:

(1) Accuracies are Dependent on Payload Mass Properties.

(2) Pointing Angle of ±4° Is for Sun-Pointing Payloads. For Non-Sun-Pointing Payloads, Accuracies of ±3° Are Possible.

PEG026

Figure 4-16. *Typical Pre-Separation Payload Pointing and Spin Rate Accuracy.*

are dependent on payload mass properties.

4.11 Payload Tip-off

Payload tip-off refers to the angular velocity imparted to the payload upon separation due to an uneven distribution of torques and forces.

If a Marmon Clamp-band separation system is used, payload tip-off rates are generally under 4°/sec per axis. This can vary depending on the mass properties of the payload and the configuration of the separation system. Orbital performs a mission-specific tip-off analysis for each payload.

Section 5.0—Spacecraft Interfaces

5.1 Payload Fairing

This section describes the fairing, fairing separation sequence, payload dynamic envelope, and payload access panel. The standard payload fairing consists of two graphite composite halves, with a nosecap bonded to one of the halves, and a separation system. Each composite half is composed of a cylinder and an ogive section. The two halves are held together by two titanium straps, both of which wrap around the cylinder section, one near its midpoint and one just aft of the ogive section. Additionally, an internal retention bolt secures the two fairing halves together at the surface where the nosecap overlaps the top surface of the other fairing half. The base of the fairing is separated using a non-contaminating frangible joint. Severing the aluminum attach joint allows each half of the fairing to then rotate on hinges mounted on the Stage 2 side of the interface.

5.1.1 Fairing Separation Sequence

The fairing separation sequence consists of sequentially actuating pyrotechnic devices that release the right and left halves of the fairing from a closed position, and deploy the halves away from either side of the core vehicle. The nose bolt is a non-contaminating device. The pyrotechnic devices include a separation nut at the nose, forward and aft bolt cutter pairs for the external separation straps at the cylindrical portion of the fairing, a frangible joint separation system at the base, and a pyrogen gas thruster system for deployment.

5.1.2 Payload Dynamic Design Envelope

The fairing drawings in **Figures 5-1** and **Figures 5-2** show the maximum dynamic envelopes available for the payload during captive-carry and powered flight for the XL and HAPS configurations. The dynamic envelopes shown account for fairing and Pegasus structural deflections only. The customer must take into account payload deflections due to manufacturing/design and tolerance stack-up within the dynamic envelope. Proposed payload envelope violations must be approved by Orbital. No part of the payload may extend aft of the payload interface plane without specific Orbital approval. These areas are considered stayout zones for the payload and are shown in **Figure 5-1** and **Figure 5-2**.

Incursions to these zones may be approved on a case-by-case basis. Additional analysis is required to verify that the incursions do not cause any detrimental effects. Vertices for payload deflection must be given with the Finite Element Model to evaluate payload dynamic deflection with the Coupled Loads Analysis (CLA). The payload contractor should assume that the interface plane is rigid; Orbital has accounted for deflections of the interface plane. The CLA will verify that the payload does not violate the dynamic envelope.

5.1.3 Payload Access Door

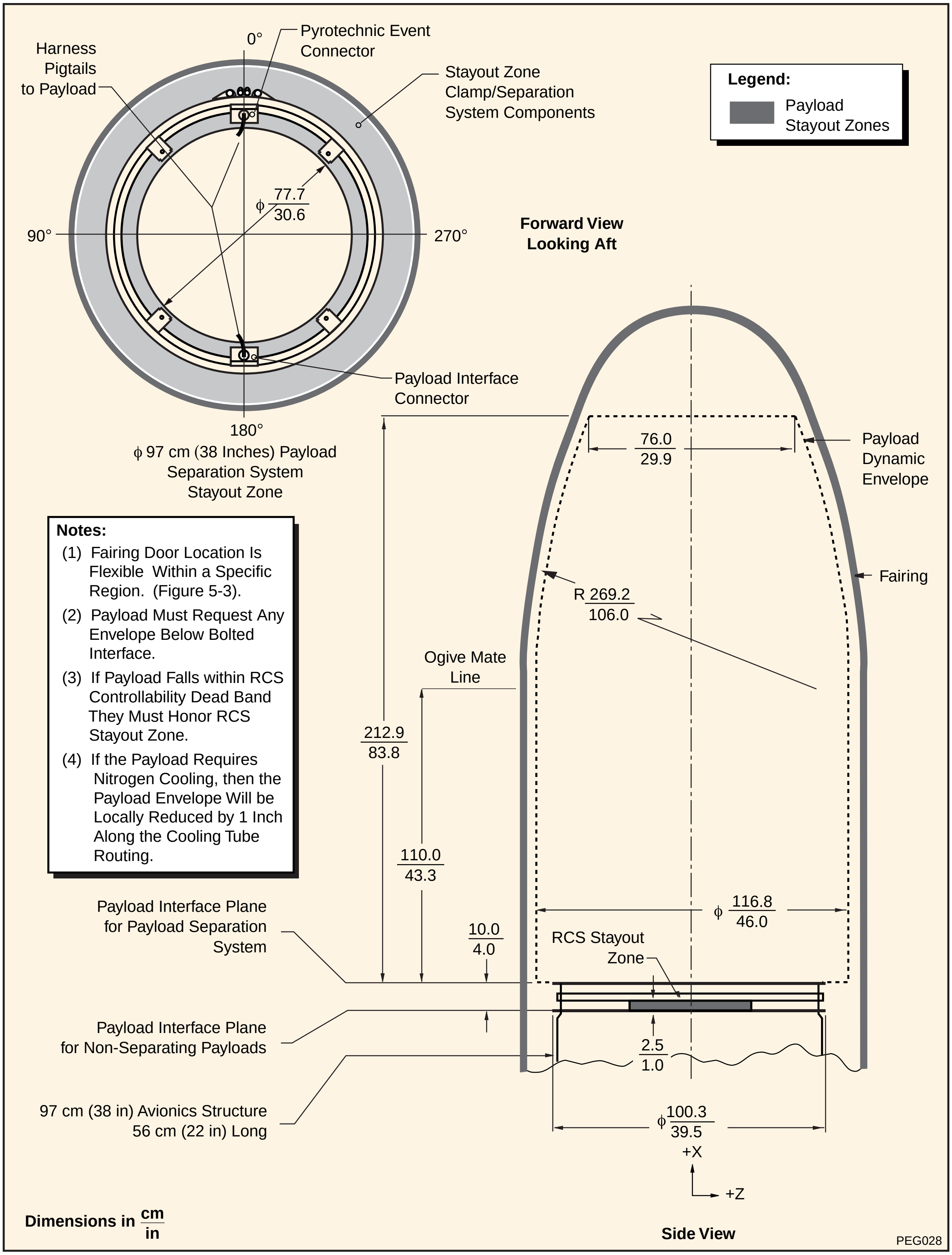
Orbital provides one 21.6 cm x 33.0 cm (8.5 in x 13.0 in), graphite, RF-opaque payload fairing access door. The door can be positioned according to user requirements within the zone defined in **Figure 5-3**. The position of the payload fairing access door must be defined no later than L - 8 months.

5.2 Payload Mechanical Interface and Separation System

Orbital will provide all hardware and integration services necessary to attach non-separating and separating payloads to Pegasus. All attachment hardware, whether Orbital or customer provided, must contain locking features consisting of locking nuts, inserts or fasteners. Orbital provides identical bolt patterns for both separating and non-separating mechanical interfaces.

5.2.1 Standard Non-Separating Mechanical Interface

Figure 5-4 illustrates the standard, non-separating payload mechanical interface. This is for payloads that provide their own separation system and payloads that will not separate. Direct attachment of the payload is made on the Avionics Structure with sixty 0.48 cm (0.19 in) fasteners as shown in **Figure 5-4**. Orbital will provide a matched drill template to the payload contractor to allow



Notes:

(1) Fairing Door Location Is Flexible Within a Specific Region. (Figure 5-3).

(2) Payload Must Request Any Envelope Below Bolted Interface.

(3) If Payload Falls within RCS Controllability Dead Band They Must Honor RCS Stayout Zone.

(4) If the Payload Requires Nitrogen Cooling, then the Payload Envelope Will be Locally Reduced by 1 Inch Along the Cooling Tube Routing.

Figure 5-1. *Payload Fairing Dynamic Envelope With 97 cm (38 in) Diameter Payload Interface.*

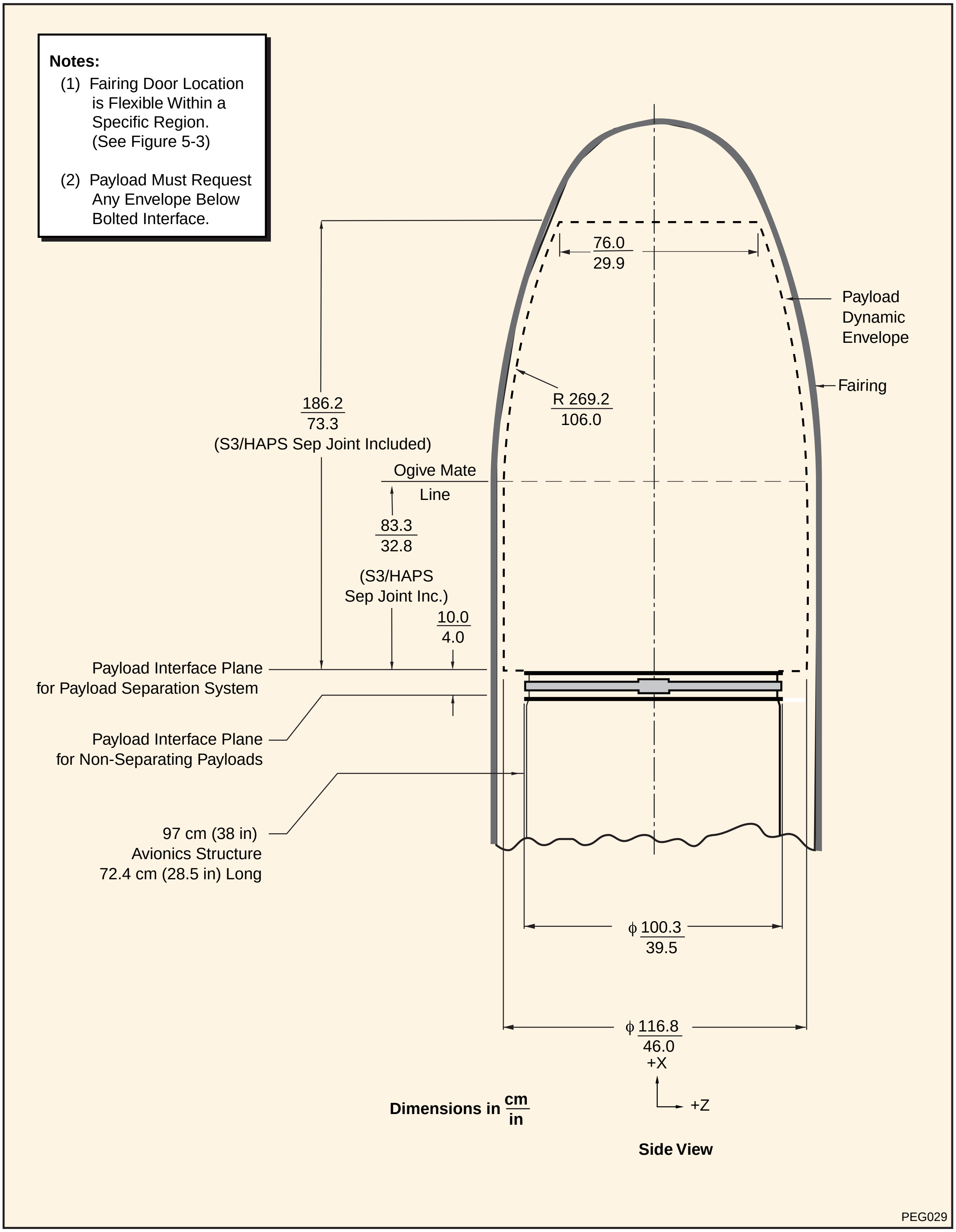
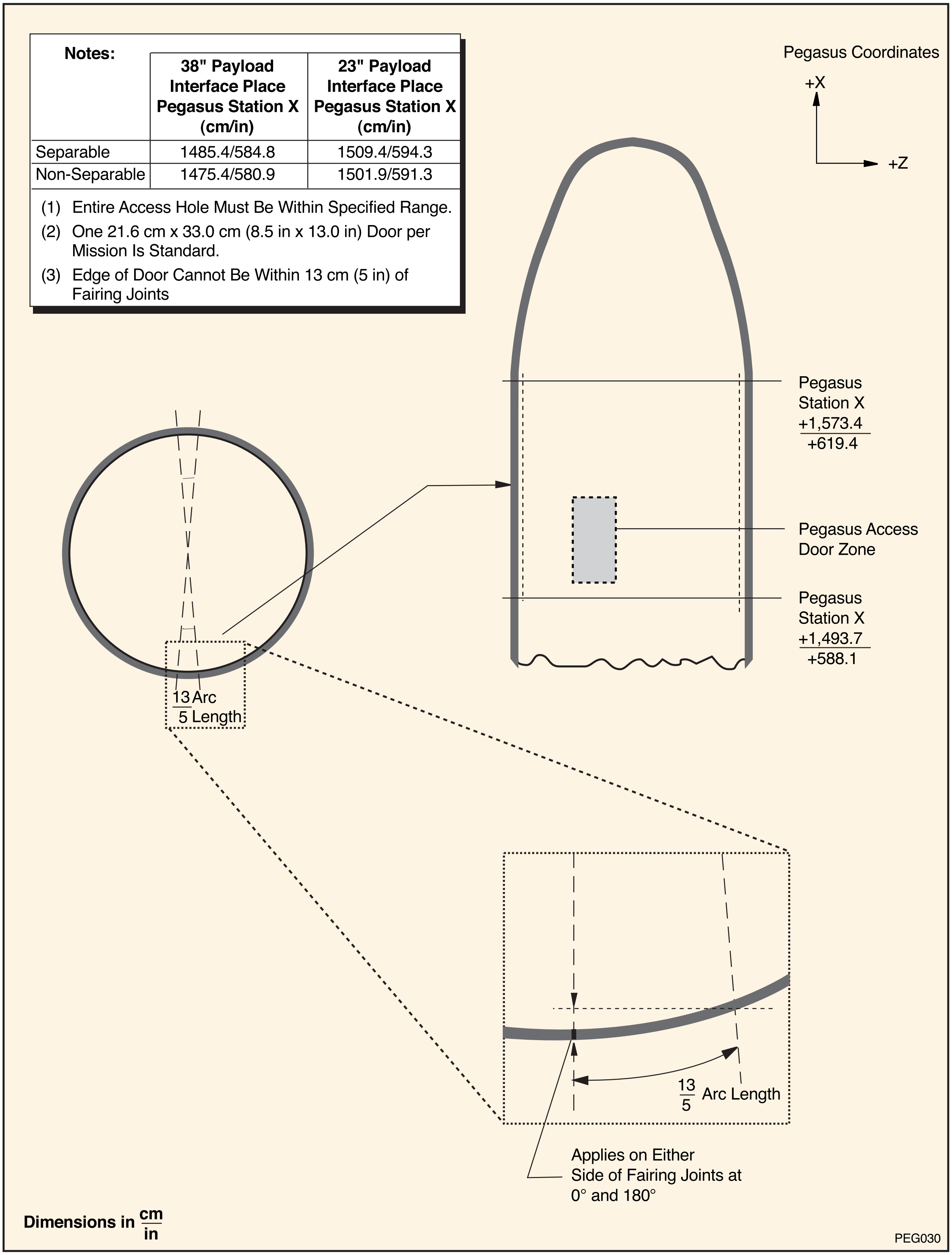


Figure 5-2. *Payload Fairing Dynamic Envelope with Optional Hydrazine Auxiliary Propulsion System (HAPS) and 97 cm (38 in) Diameter Payload Interface.*



Notes:

	38" Payload Interface Place Pegasus Station X (cm/in)	23" Payload Interface Place Pegasus Station X (cm/in)
Separable	1485.4/584.8	1509.4/594.3
Non-Separable	1475.4/580.9	1501.9/591.3

(1) Entire Access Hole Must Be Within Specified Range.
(2) One 21.6 cm x 33.0 cm (8.5 in x 13.0 in) Door per Mission Is Standard.
(3) Edge of Door Cannot Be Within 13 cm (5 in) of Fairing Joints

Figure 5-3. *Payload Fairing Access Door Placement Zone.*

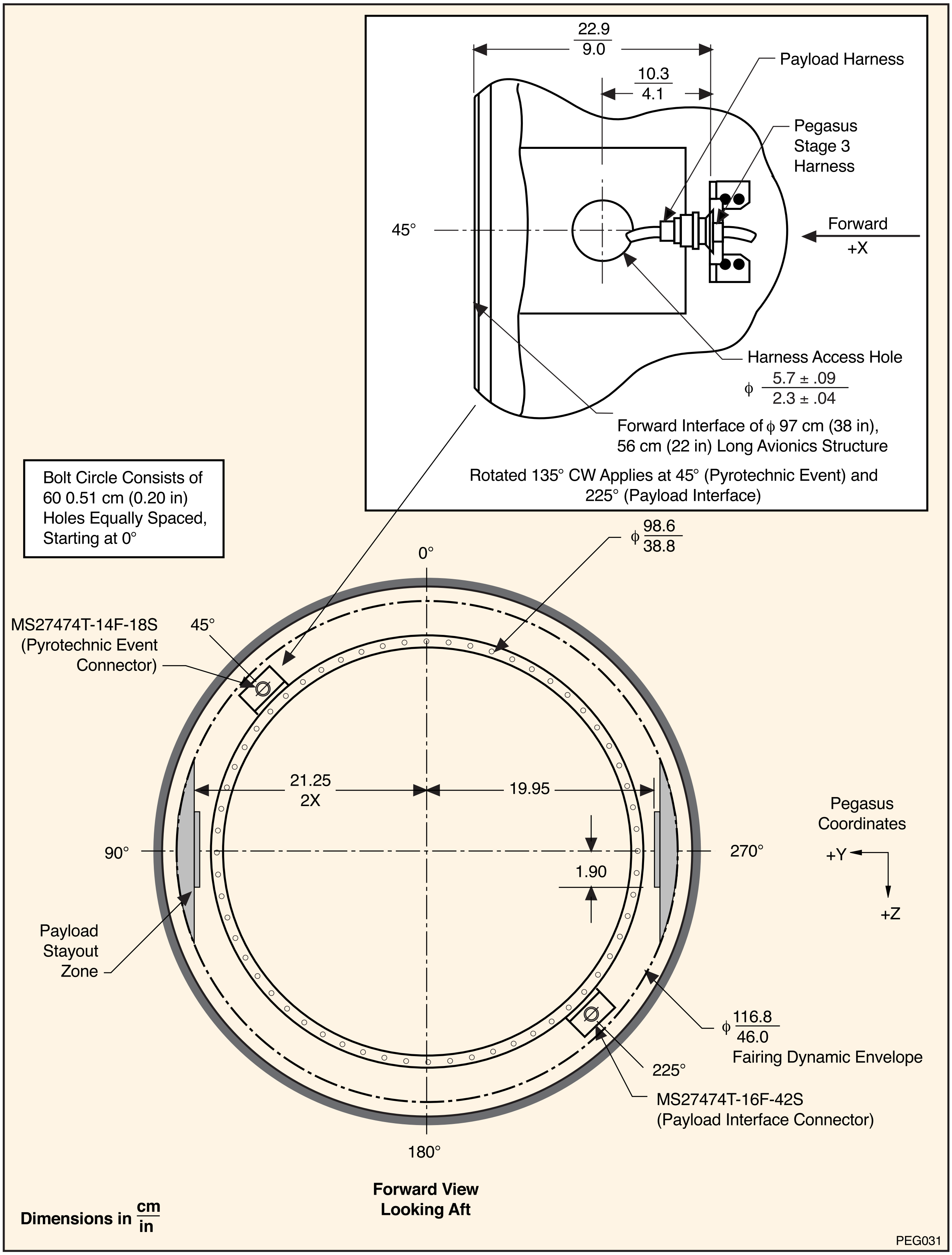


Figure 5-4. *Non-Separable Payload Mechanical Interface.*

accurate machining of the fastener holes and will supply all necessary attachment hardware per the payload specifications. The Orbital provided drill template is the only approved fixture for drilling the interface. The payload contractor will need to send a contracts letter requesting use, on a non-interference basis, of the drill template (no later than 30 days prior to needed date). The payload contractor should plan on drill template usage for a maximum of two weeks.

5.2.2 Standard Separating Mechanical Interface

If the standard Pegasus payload separation system is used, Orbital controls the entire spacecraft separation process. The standard separation system uses a Marmon clamp design. Three different separation systems are available, depending on payload interface and size. They are 97 cm (38 in), 59 cm (23 in), and 43 cm (17 in) separation systems. The 97 cm (38 in) separable payload interface is shown in **Figure 5-5**; the 59 cm (23 in) separable payload interface is shown in **Figure 5-6**; the 43 cm (17 in) separable payload interface is shown in **Figure 5-7**.

The separation ring to which the payload attaches is supplied with through holes. The weight of hardware separated with the payload is approximately 4.0 kg (8.7 lbm) for the 97 cm (38 in) system, 2.7 kg (6.0 lbm) for the 59 cm (23 in) system, and 2.1 kg (4.7 lbm) for the 43 cm (17 in) system. Orbital-provided attachment bolts to this interface can be inserted from either the launch vehicle or the payload side of this interface (NAS6303U, dash number based on payload flange thickness). The weight of the bolts, nuts, and washers connecting the separation system to the payload is allocated to the separation system. Orbital will provide a matched drill template to the payload contractor to allow accurate machining of the fastener holes and will supply the integration ring and all necessary attachment hardware to payload specifications. The payload contractor will need to send a contracts letter requesting use, on a non-interference basis, of the drill template (no later than 30 days prior to needed date). The payload contractor should plan on drill template usage for a maximum of two weeks. The flight separation system shall be mated to the spacecraft during processing at the VAB.

At the time of separation, the flight computer sends commands which activate redundant bolt cutters, which allows the titanium clampband and its aluminum shoes to release. The band and clamp shoes remain attached to the avionics structure by retention springs. The payload is then ejected by matched push-off springs with sufficient energy to produce the relative separation velocities shown in **Figure 5-8**. If non-standard separation velocities are needed, different springs may be substituted on a mission-specific basis.

5.3 Payload Electrical Interfaces

5.3.1 Umbilical Interfaces

A block diagram of the standard Pegasus electrical interface capabilities is shown in **Figure 5-9**.

The standard payload electrical connector and harness configuration is shown in **Figure 5-10** and in **Figure 5-11**. Note that two interface connectors are used to implement the standard interface. The formal electrical interface is defined as the separation plane of the connectors. Orbital will provide the payload side of the interface connectors (payload side - MS27474T-16F-42S for telemetry, and MS27474T-14F-18S for pyrotechnic commands) one year prior to launch. The payload should integrate these connectors to the spacecraft flight harness forward of the interface plane. This harness will be integrated to the separation system by Orbital two months before launch. The matching interface connectors and the associated electrical harnesses aft of the interface plane are provided by Orbital for non-separating and separating payloads.

All interface wires are shielded for EMI protection. The Orbital flight harnesses and payload-provided harness will be integrated with the flight separation system and will be available no earlier than one month prior to launch. The separation system/ harnessing will be mated to the spacecraft at the VAB. Physical and functional testing of the harnessing will be accomplished on a mutually

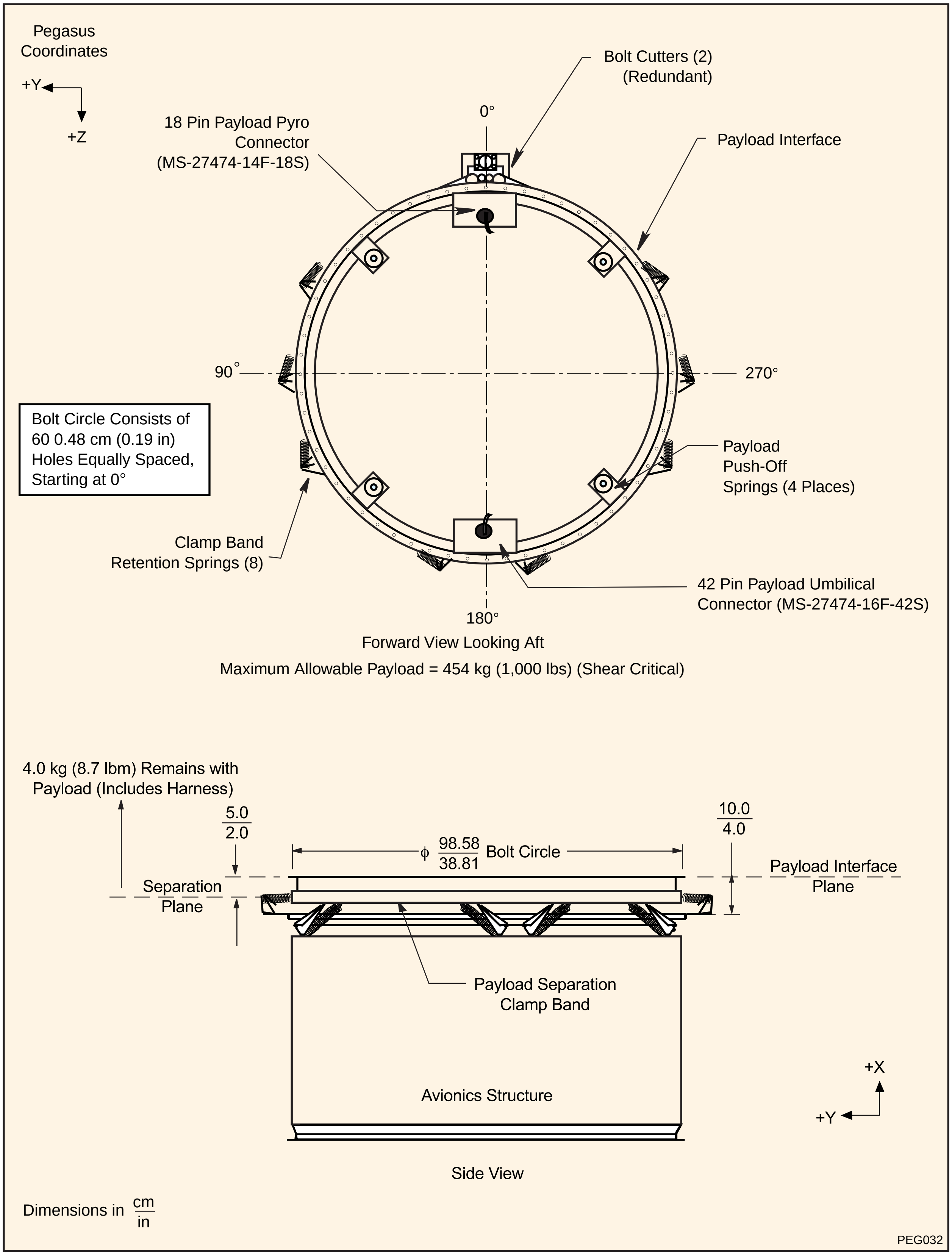


Figure 5-5. *97 cm (38 in) Separable Payload Interface.*

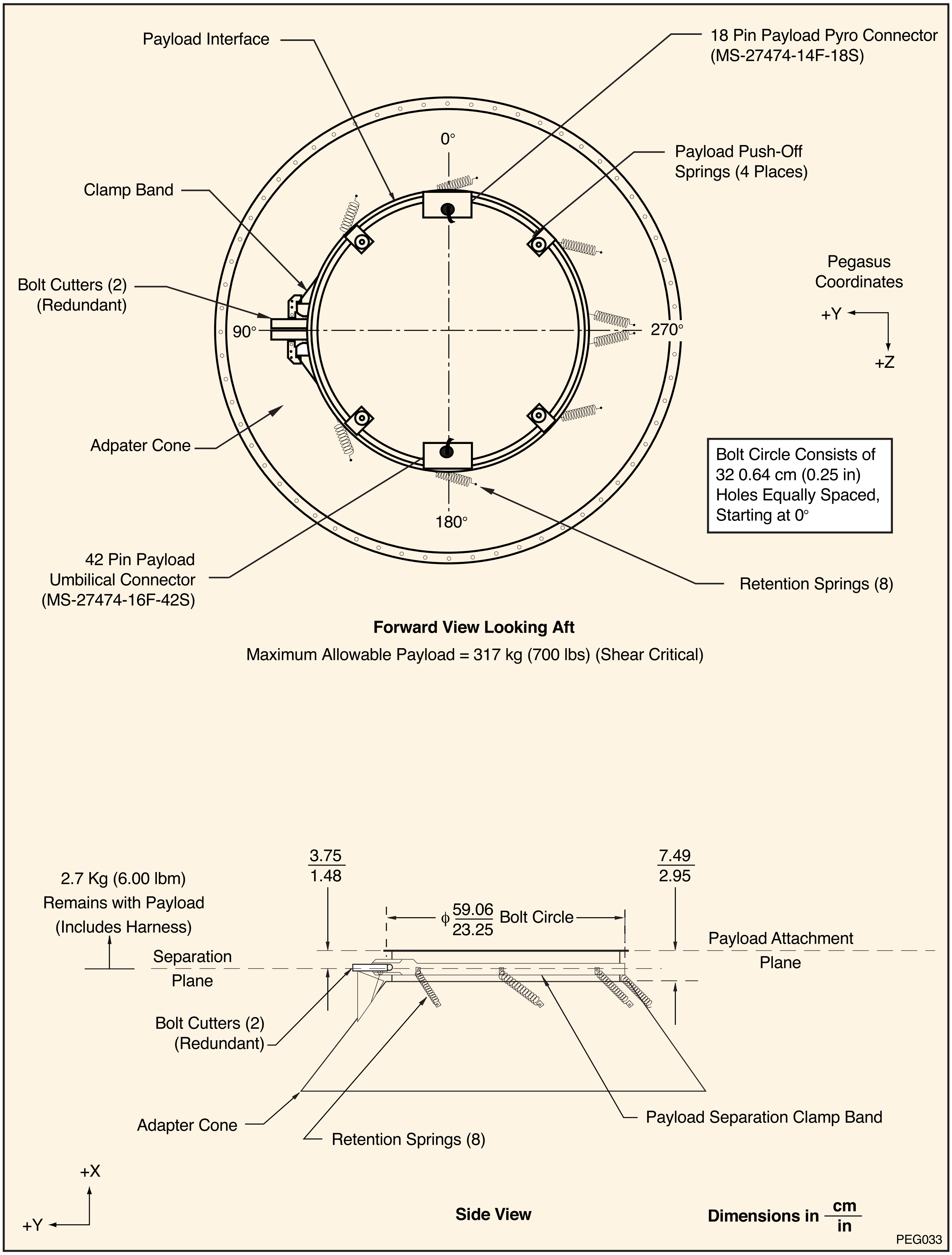


Figure 5-6. *59 cm (23 in) Separable Payload Interface.*

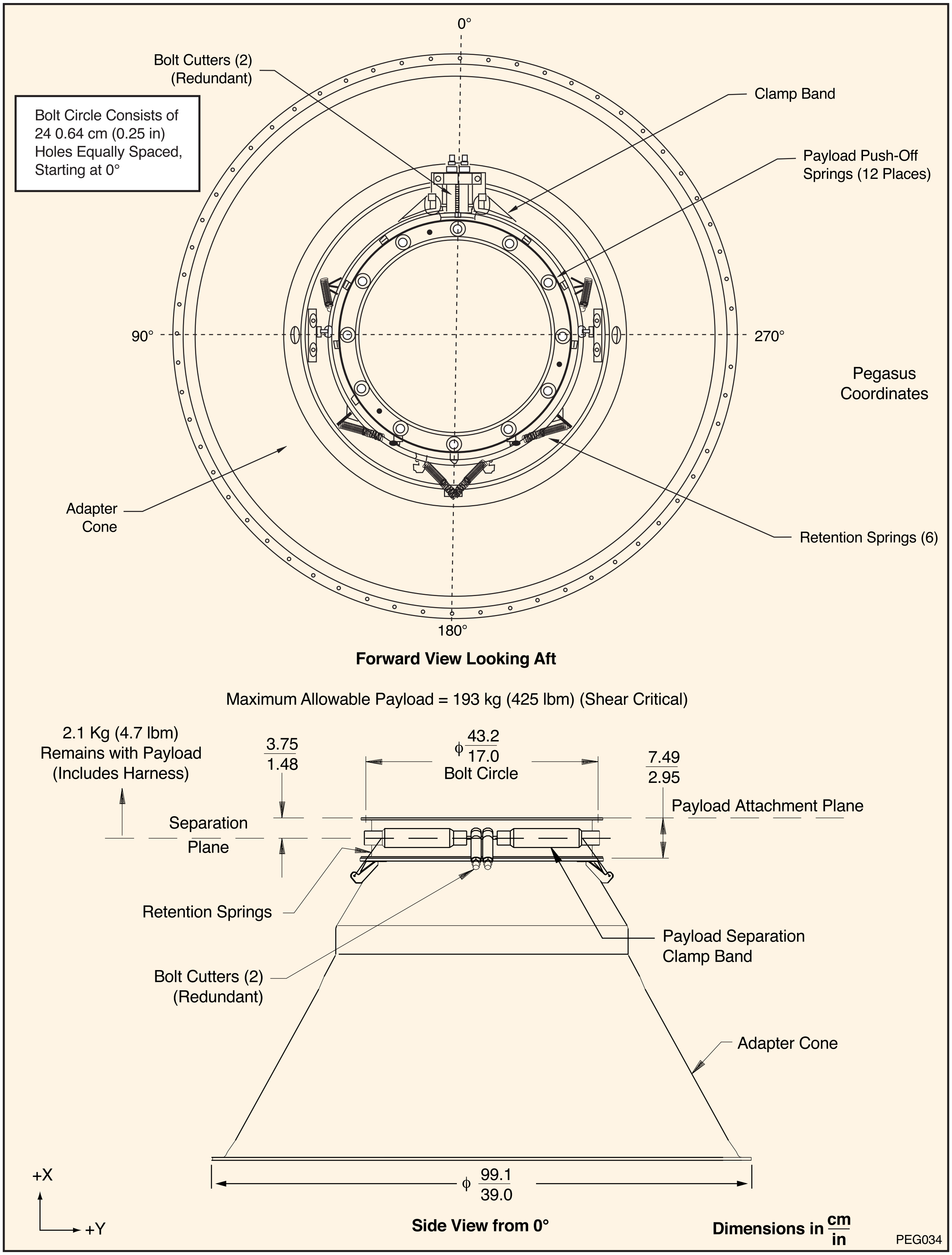


Figure 5-7. *43 cm (17 in) Separable Payload Interface.*

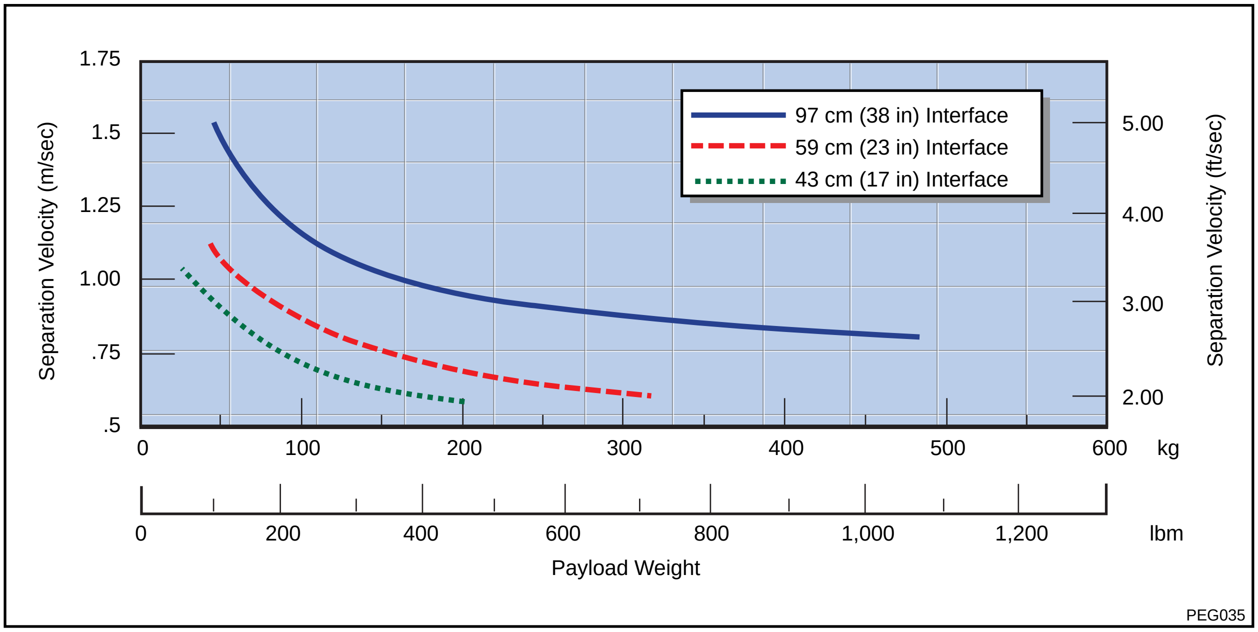


Figure 5-8. *Payload Separation Velocities Using the Standard Separation System.*

agreed to schedule between Orbital and the payload customer.

5.3.2 Payload Auxiliary Power

Payloads can receive power during ground operations and captive flight directly from the carrier aircraft or from payload-provided Airborne Support Equipment (ASE) via the five standard twisted shielded pair pass-throughs mounted to the Stage 3 avionics structure. The lines interface with the Pegasus or payload ASE through the Pegasus wing interface. The payload is accountable for the weight of cables on the payload side of the interface and all non-standard cables. No power is available during transport.

5.3.3 Payload Command and Control

Discrete sequencing commands, generated by the Pegasus flight computer, are available to the payload. These commands are opto-isolated pulses of programmable lengths in multiples of 40 ms. Up to eight command line pairs, each capable of multiple pulses, can be provided for the payload. Discrete lines are provided through the same interface connector used for the payload auxiliary power lines (connector MS27484T-16F-42P). The payload supplies the voltage (≤40 VDC) and must limit current to 500 milliamps (mA) nominal in a fashion similar to using a dry contact relay.

5.3.4 Payload Status Monitoring

Payload discrete telemetry downlink can be provided during ground processing (limited to Pegasus on-times), checkout, captive carry and during launch as part of the standard service. Up to four discrete telemetry signals can be accommodated in the Pegasus telemetry stream via the flight computer. This telemetry interface includes a signal and ground for each discrete transmitted on dedicated twisted shielded wire pairs. The flight computer contains a resistor to limit the current of a 5.0 VDC signal to approximately 10 mA. The interface must be optically isolated at the payload. See Section 10 for a description of the serial telemetry link option.

5.3.5 Payload Pyrotechnic Initiator Driver Unit

For a standard mission, one dual and four single 75 ms pulses at 5 amps are available for post-launch use by the spacecraft. Use of the standard separation system requires two of the single outputs. The firing commands are sent via the

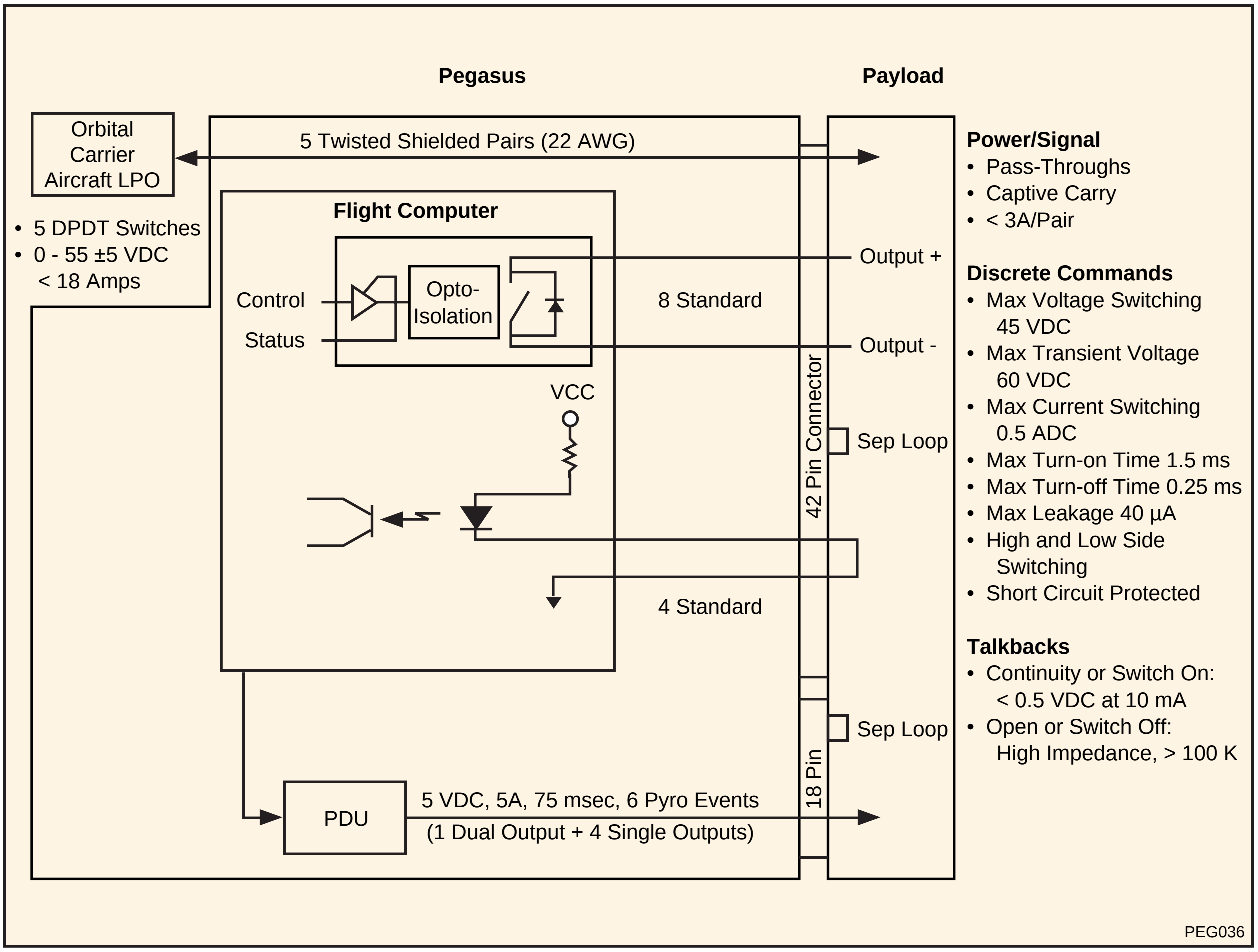


Figure 5-9. *Pegasus Payload Electrical Interface.*

Pegasus avionics subsystem Pyro Driver Unit (PDU). The pyro interface is provided through a separate connector from the power/command connector.

5.3.6 Range Safety Interfaces/Vehicle Flight Termination

The Pegasus air-launched approach minimizes interfaces with the test range. All ordnance on the Pegasus vehicle is in the safe condition while in captive carry mode under the carrier aircraft. Ordnance is armed during a sequence which is initiated upon release from the OCA. Procedures for arming ordnance on the spacecraft are determined on a mission-specific basis. No arming of the payload prior to drop from the Pegasus Carrier Aircraft is allowed.

Generally, the standard Pegasus FTS subsystem satisfies all range safety requirements without additional FTS support from the payload. However, information on the payload, such as a brief description, final orbit, spacecraft ordnance, hazardous operations and materials summary, will be requied to support range documentation. Additional range support for payload operations, such as orbit determination and command and control, can be arranged. Range-provided services have long lead times due to Department of Defense (DoD) and NASA support requirements; therefore, test range support requirements must be identified early in order for Orbital to ensure their availability.

5.3.7 Electrical Power

Power lines shall be isolated from the Pegasus XL and payload structures by at least 1 megohm.

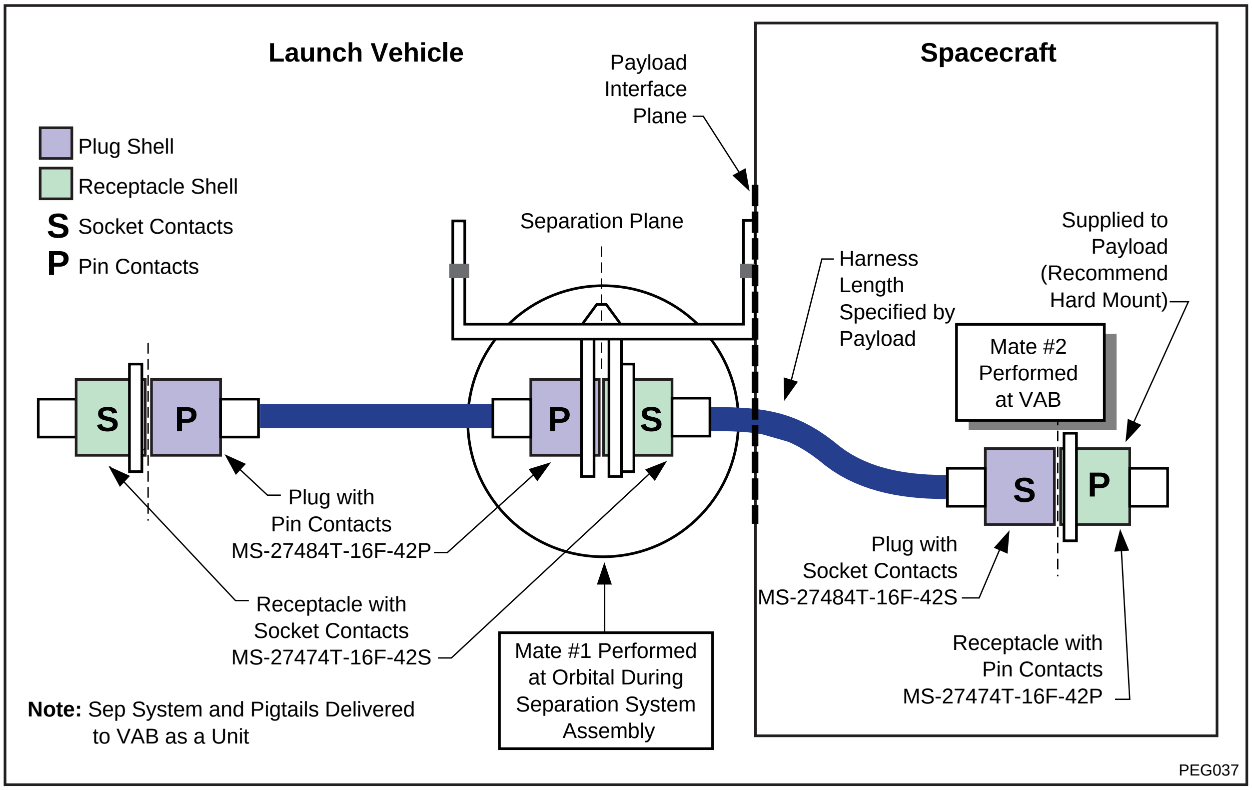


Figure 5.10. *Pegasus/Spacecraft Electrical Connectors and Associated Electrical Harnesses.*

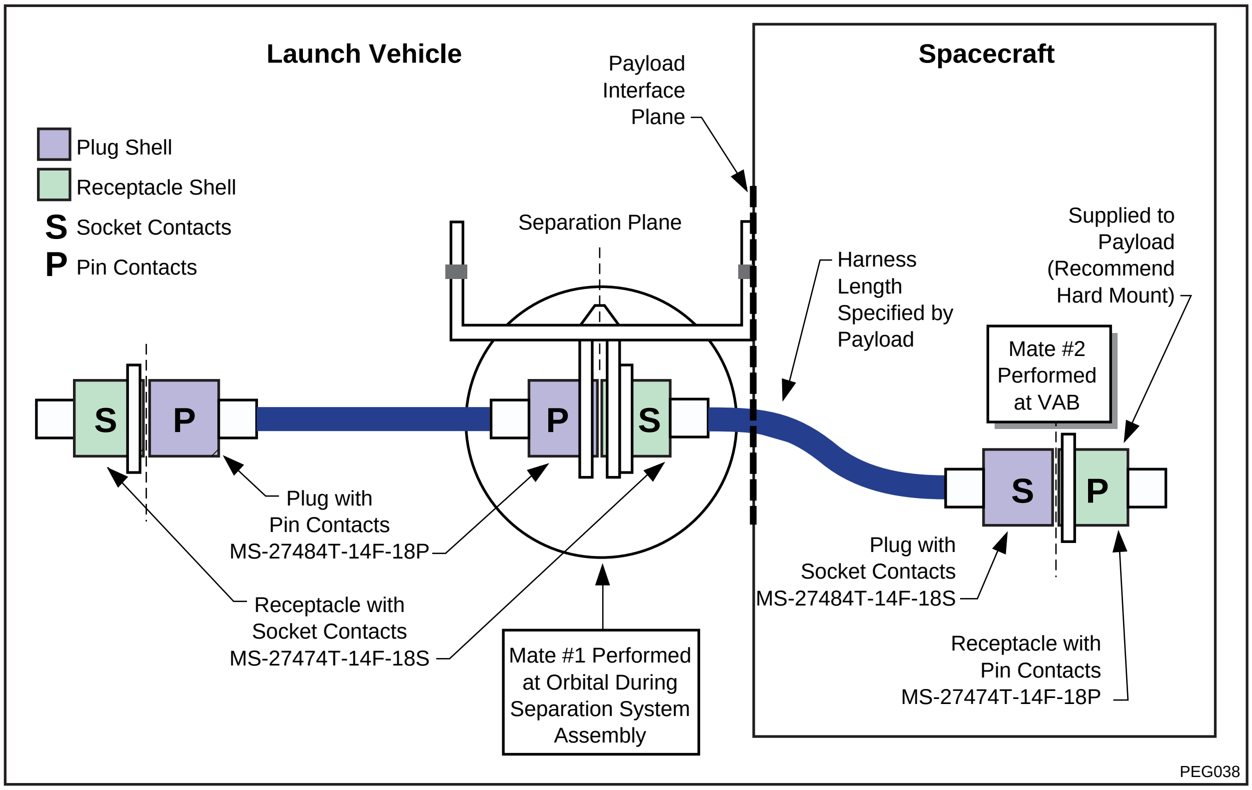


Figure 5.11. *Pegasus/Spacecraft Pyrotechnic Connectors and Associated Electrical Harnesses.*

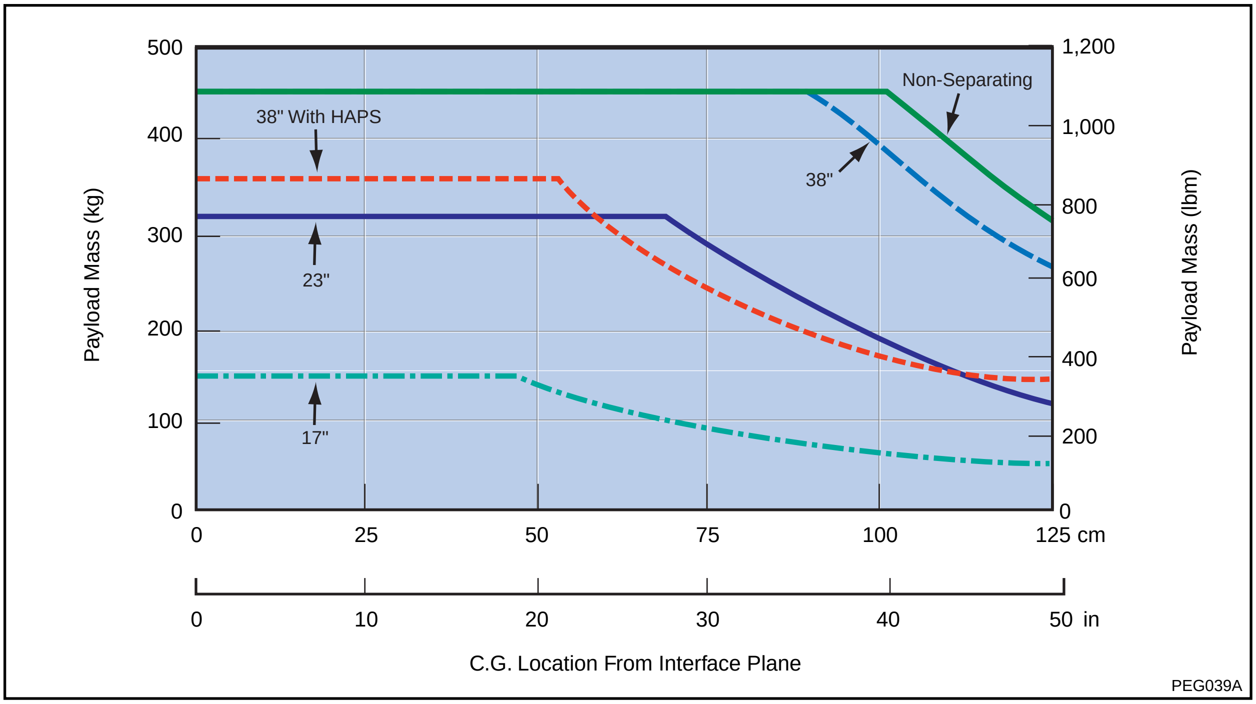


Figure 5-12. *Payload Mass vs. Axial C.G. Location on X Axis.*

The Launch Vehicle System (the Pegasus XL, the integration site facilities and the OCA) and Space Vehicle System (the payload and all ground based systems required to process, launch and monitor the payload during all phases of launch processing and flight operations) shall each utilize independent power sources and distribution systems.

5.3.8 Electrical Dead-Facing

Prior to T-0, all Space Vehicle System electrical ground support equipment electrical interfaces at the umbilical shall be dead-faced to ensure that there shall be no current flow greater than 10 mA across the umbilical interface. Prior to drop, all aircraft power shall be isolated from the launch vehicle and the payload.

5.3.9 Pre-Separation Electrical Constraints

Prior to initiation of the separation event, all payload and launch vehicle electrical interface circuits shall be constrained to ensure that there shall be no current flow greater than 10 mA DC across the separation plane during the separation event.

5.3.10 Non-Standard Interfaces

Additional interface options are available. See Section 9.0 for a description.

5.4 Payload Design Constraints

5.4.1 Payload Center of Mass Constraints

To satisfy structural constraints on the standard Stage 3 avionics structure, the axial location of the payload center of gravity (c.g.) along the X axis is restricted as shown in **Figure 5-12**. Along the Y and Z axes, the payload c.g. must be within 3.8 cm (1.5 in) of the vehicle centerline for the standard configuration and within 2.5 cm (1.0 in) of centerline if HAPS is used (including tolerances in **Figure 5-13**). Payloads whose c.g. extend

Measurement	Error Tolerance
Mass	±0.5 kg (±1 lbs)
Principal Moments of Inertia	±5%
Cross Products of Inertia	±0.7 kg - m^2 (±0.5 sl - ft^2)
Center of Gravity X, Y and Z Axes	±6.4 mm (±0.25 in)

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Figure 5-13. *Payload Mass Property Measurement Error Tolerances.*

beyond these lateral offset limits will require Orbital to verify that structural and dynamic limitations will not be exceeded. Payloads whose X-axis c.g. falls into the RCS Dead Band Zone referred to in **Figure 5-14** will require movement of the RCS thrusters which can be supported on a mission-specific basis.

Mass property measurements must adhere to the tolerances set forth in **Figure 5-13**. The payload center of mass must not transition through the RCS Dead Band Zone during the unpowered flight (before stage ignition or after burnout) or loss of attitude control capability will occur.

5.4.2 Final Mass Properties Accuracy

The final mass properties statement shall specify payload weight to an accuracy of 0.5 kg, the center of gravity to an accuracy to 6.4 mm in each axis, and the products of inertia to 0.7 kg-m^2. In addition, if the payload uses liquid propellant, the slosh frequency must be provided to an accuracy of 0.2 Hz, along with a summary of the method used to determine slosh frequency.

5.4.3 Payload EMI/EMC Constraints

The Pegasus avionics shares the payload area inside the fairing such that radiated emissions compatibility is paramount. The Pegasus avionics RF susceptibility levels have been characterized by test. Orbital places no firm radiated emissions limits on the payload other than the prohibition against RF transmissions within the payload fairing. Prior to launch, Orbital requires review of the payload radiated emission levels (MIL-STD-461, RE02) to verify overall launch vehicle EMI safety margin (emission) in accordance with MIL-E-6051. Payload RF transmissions are not permitted after fairing mate and prior to separation of the payload. An EMI/EMC analysis will be required to ensure RF compatibility.

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

5.4.4 Payload Stiffness

To avoid dynamic coupling of the payload modes with the 8-9 Hz natural frequency of the Pegasus XL vehicle, the spacecraft should be designed with a structural stiffness to ensure that the fundamental frequency of the spacecraft, fixed at the spacecraft interface, in the Pegasus Z axis is greater than 20 Hz.

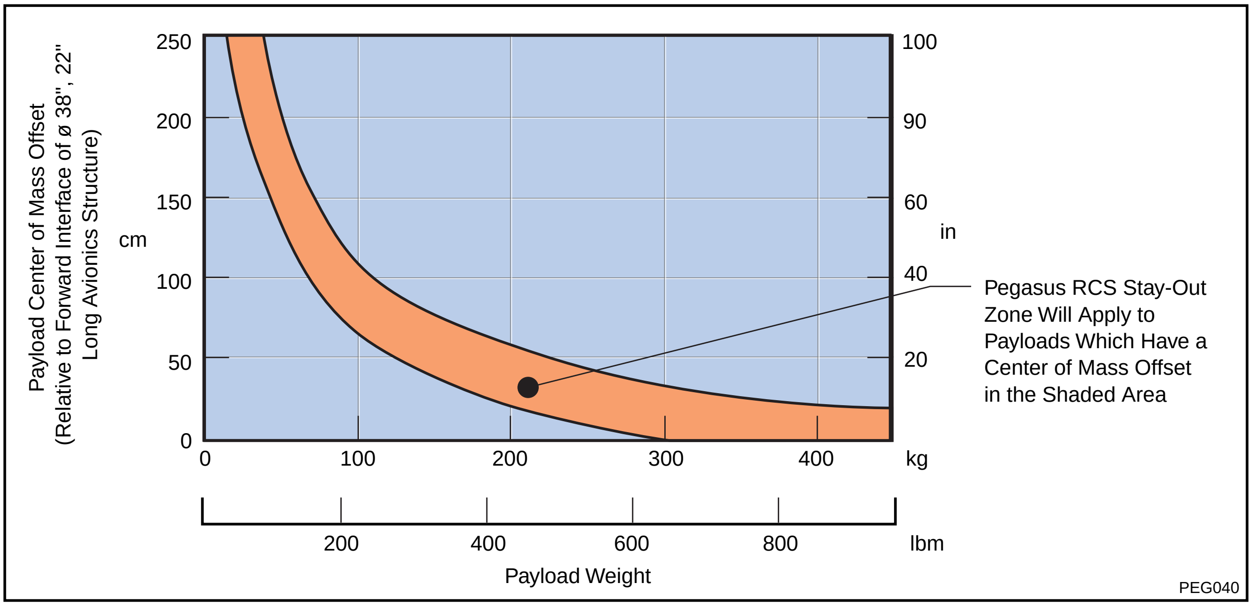


Figure 5-14. *Detailed RCS Dead Band Zone.*

5.4.5 Payload Propellant Slosh

A slosh model should be provided to Orbital in either the pendulum or spring-mass format. Data on first sloshing mode are required and data on higher order modes are desirable.

5.4.6 Customer Separation System Shock Constraints

If the payload employs a non-Orbital separation system, then the shock delivered to the Pegasus Stage 3 vehicle interface must not exceed the limit level characterized in **Figure 4-3**. Shock above this level could require a requalification of units or an acceptance of risk by the payload customer.

5.4.7 System Safety Constraints

Orbital considers the safety of personnel and equipment to be of paramount importance. The payload organization is required to conduct at least one dedicated payload safety review in addition to submitting to Orbital an Accident Risk Assessment Report (ARAR) or equivalent as defined in EWR 127-1.

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

EWR 127-1 and WFF RSM-93 outline the safety design criteria for spacecraft on Pegasus vehicles. These are compliance documents and must be strictly adhered to. It is the responsibility of the payload contractor to insure that the payload meets all Orbital and range imposed safety standards.

5.5 Carrier Aircraft Interfaces

5.5.1 Payload Services

The OCA can provide DC power to the payload during flight line operations and captive carry. This power is supplied by the OCA through the payload interface connector mounted to the Stage 3 avionics structure, as described in Section 5.3. **Figure 5-14** provides details on the Pegasus/OCA interface.

Orbital provides up to five twisted shielded pairs of pass-through wires (22 AWG) to the Launch

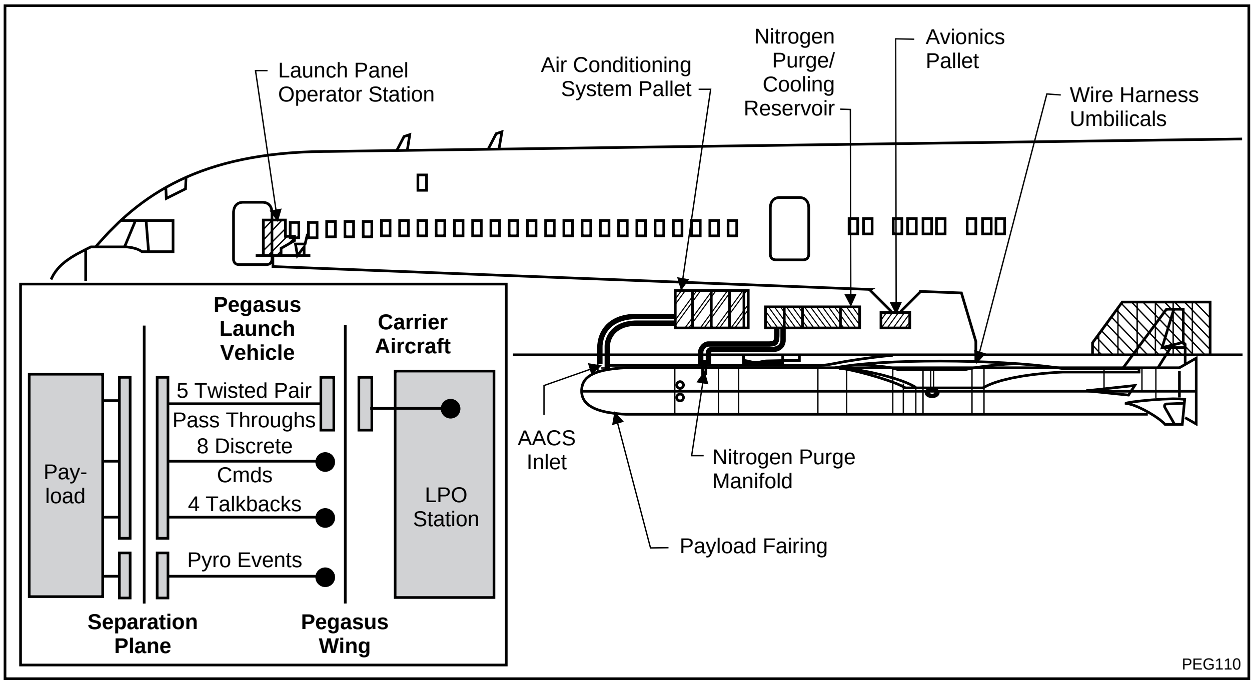


Figure 5.14. *Pegasus/OCA Interface Details.*

Panel Operator (LPO) Station as a standard service in the aircraft.

Orbital provides on-board payload monitoring capabilities through the Orbital-manned LPO station. The LPO station is equipped with communications and safety equipment, and can accommodate flight qualified rack-mounted payload support equipment if required.

5.5.2 Payload Support at Launch Panel Operator Station

The Pegasus Launch Panel Operator (LPO) Station provides a 48 cm (19 in) rack for payload specific airborne support equipment (ASE), up to a maximum volume equivalent to two rack-mounted PCs. Payload ASE must comply with MIL-STD-810D. The payload rack is supplied with four 5A circuits of unregulated 28 VDC power plus one 5A circuit of 115 VAC, 400 Hz power. Additional equipment provided includes an adjustable DC power supply and a switch panel. The power supply features a selectable voltage level of 0-55 ±5 VDC and a 0 to 18A adjustable current limit. Digital displays indicate both voltage and current. Maximum allowable current is limited to 3A per twisted, shielded pair of pass-through wires. The switch panel contains twelve double-pole, double-throw switches with five amp contacts. Five of the switches have momentary actuation. The seven remaining switches have alternate actuation. The switch panel is provided with two 5A circuits of unregulated 28 VDC power. No provisions are available for seating a payload representative at the LPO Station in-flight. The Pegasus LPO will be available to perform limited payload operations during non-critical portions of the flight checklist, as defined in the Mission Integration Working Groups (MIWGs) and documented in the LPO Checklist.

Section 6.0—Mission Integration

6.1 Mission Management Structure

Successful integration of payload requirements is paramount in achieving complete mission success. Pegasus has established a mission team approach to ensure all customer payload requirements and services are provided. As the mission evolves the team is responsible for documenting, tracking and implementing customer requirements and changes. A Configuration Control Board (CCB) ensures these requirements are supportable and appropriately implemented. The Pegasus mission team is responsible for providing the customer requirements, as well as changes to these requirements, to the CCB. Open communication between the Pegasus and payload customer is essential for ensuring total customer satisfaction. To facilitate the necessary communication and interaction, the Pegasus mission integration approach includes establishing a mission team, holding technical meetings and supporting readiness reviews.

An organizational structure is established for each Pegasus mission to manage payload integration, mission preparations and execute the mission. Open communication between Orbital and the customer, emphasizing timely transfer of data and prudent decision-making, ensures efficient launch vehicle/payload integration operations.

The Orbital and customer roles in mission integration is illustrated in **Figure 6-1**. The Program Managers, one from the customer and one from Orbital, execute the top-level management duties, providing overall management of the launch services contract. Within each organization, one person will be identified as the Mission Manager and will serve as the single point of contact in their respective organizations for that mission. The customer should appoint a Payload Mission Manager within its organization. All payload integration activities will be coordinated and monitored by the Mission Managers, including mission planning, launch range coordination,

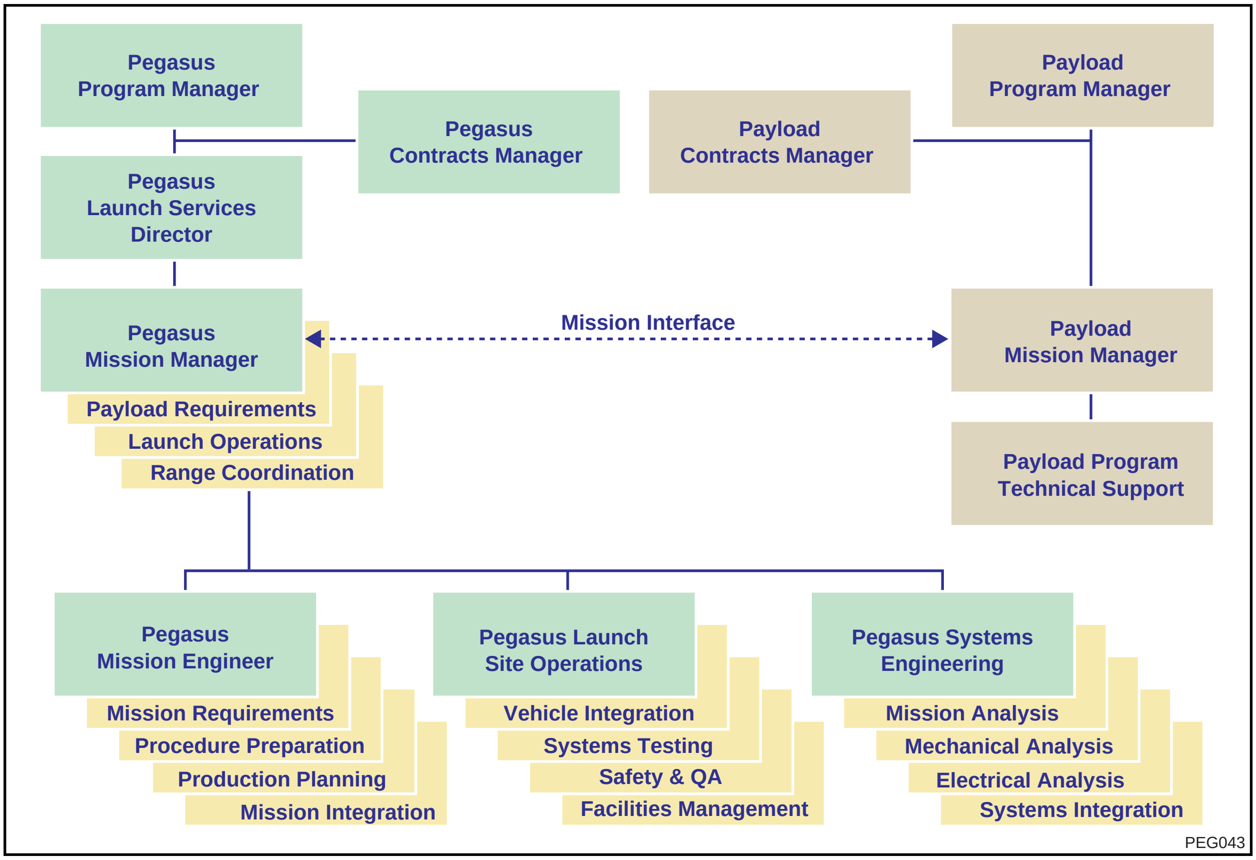


Figure 6-1. *Mission Integration Management Structure.*

and launch operations. The Payload Mission Manager is responsible for identifying the payload interface requirements and relaying them to the Pegasus Mission Manager. The Pegasus Mission Manager is responsible for ensuring all the payload launch service requirements are documented and met. Supporting the Pegasus Mission Manager with the detailed technical and operational tasks of the mission integration process are the Pegasus Mission Engineer, the system integration team, and the launch site team.

6.1.1 Orbital Mission Responsibilities

As the launch service provider, Orbital's responsibilities fall into five areas: 1) Program Management, 2) Mission Management, 3) Mission Engineering, 4) Launch Site Operations, and 5) Safety.

6.1.1.1 Pegasus Program Management

The Pegasus Program Manager has direct responsibility for Orbital's Pegasus Program. The Pegasus Program Manager is responsible for all financial, technical, and programmatic aspects of the Pegasus Program. Supporting the Pegasus Program Manager are the Contract Manager, Pegasus Chief Engineer, and Launch Services Director. All contractual considerations are administered between the payload and Pegasus Contract Managers. The Pegasus Chief Engineer is responsible for all technical aspects of the Pegasus launch vehicle, to include vehicle processing and launch operations. The Director of Launch Services is responsible for management of all activities associated with providing the Pegasus launch service, to include the Pegasus launch manifest, customer interface and mission planning. The Launch Service Director provides the customer with the management focus to ensure the specific launch service customer's needs are met. This individual assists the administration of the contract by providing the Contract Manager with technical evaluation and coordination of the contractual requirements.

6.1.1.2 Pegasus Mission Management

The Pegasus Mission Manager is the Pegasus program single point of contact for all aspects of a specific mission. This person has the responsibility to ensure contractual commitments are met within schedule and budget constraints. The Pegasus Mission Manager will co-chair the Mission Integration Working Groups (MIWGs) with the payload Mission Manager. The Pegasus Mission Manager's responsibilities include detailed mission planning, launch vehicle production coordination, payload integration services, mission-peculiar designs and analysis coordination, payload interface definition, launch range coordination, integrated scheduling, launch site and flight operations coordination.

6.1.1.3 Pegasus Mission Engineering

The Pegasus Mission Engineer is responsible for all engineering and production decisions for a specific mission. This person has overall technical program authority and responsibility to ensure that a vehicle is produced, delivered to the integration site, and integrated to support a specific mission requirements. The Mission Engineer supports the Pegasus Mission Manager to ensure that vehicle preparation is on schedule and satisfies all payload requirements for launch vehicle performance.

6.1.1.4 Pegasus Mechanical Engineering

The Pegasus Mission Mechanical Engineer is responsible for the mechanical interface between the satellite and the launch vehicle. This person works with the Pegasus Mission Engineer to verify mission specific envelopes are documented and environments, as specified in the ICD, are accurate and verified.

6.1.1.5 Pegasus Engineering Support

The Pegasus engineering support organization is responsible for supporting mission integration activities for all Pegasus missions. Primary support tasks include mission analysis, software development, mission-peculiar hardware design and testing, mission-peculiar analyses, vehicle integration procedure development and implementation, and flight operations support.

6.1.1.6 Pegasus Launch Site Operations

The Launch Site Manager is directly responsible for launch site operations and facility maintenance. All work that is scheduled to be performed at the Orbital launch site is directed and approved by the Pegasus Launch Site Manager. This includes preparation and execution of work procedures, launch vehicle processing, and control of hazardous operations. All hazardous procedures are approved by the appropriate customer launch site safety manager, the launch range safety representative, the Pegasus Launch Site Manager, and the Pegasus Safety Manager prior to execution. In addition, Pegasus Safety and Quality Assurance engineers are always present to monitor critical and hazardous operations. Scheduling of payload integration with the launch vehicle and all related activities are also coordinated with the Launch Site Manager.

6.1.1.7 Pegasus Systems Safety

Each of the Pegasus systems and processes are supported by the Pegasus safety organization. Systems and personnel safety requirements are coordinated and managed by the Safety Manager. The Safety Manager is primarily responsible for performing hazard analyses and developing relevant safety documentation for the Pegasus system. The Safety Manager works closely with the launch system development, testing, payload integration, payload and launch vehicle processing, and launch operations phases to ensure adherence to applicable safety requirements. The Safety Manager interfaces directly with the appropriate government range and launch site personnel regarding launch vehicle and payload ground safety matters. The Safety Manager assists the mission team with identifying, implementing and documenting payload and mission unique safety requirements.

6.2 Mission Integration Process

The Pegasus mission integration process ensures the launch vehicle and payload requirements are established and implemented to optimize both parties needs. The Pegasus integration process is structured to facilitate communication and coordination between the launch vehicle and payload customer. There are four major components to the integration process; 1) the Pegasus and payload mission teams, 2) Technical Interchange Meetings, 3) Mission Integration Working Groups and 4) the readiness review process.

6.2.1 Mission Teams

The mission teams are established in the initial phase of the mission planning activity to create a synergistic and cohesive relationship between the launch vehicle and payload groups. These teams consist of representatives from each of the major disciplines from each group, i.e., management, engineering, safety, and quality. The mission teams are the core of the integration process. They provide the necessary continuity throughout each phase of the integration process from initial mission planning through launch operations. The team is responsible for documenting and ensuring the implementation of all mission requirements via the payload to Pegasus Interface Control Document (ICD).

6.2.2 Integration Meetings

Two major types of meetings are used to accommodate the free-flow of information between the mission teams. The Technical Interchange Meeting (TIM) is traditionally reserved for discussions focusing on a single technical subject or issue. While TIMs tend to focus on technical and engineering aspects of the mission they may also deal with processing and operations issues as well. They are typically held via telecon to accommodate multiple discussion opportunities and/or quick reaction. TIM discussions facilitate the mission team decision process necessary to efficiently and effectively implement mission requirements. They are also used to react to an anomalous or unpredicted event. In either case, the results of the TIM discussions are presented in the Mission Integration Working Group (MIWG) meetings. The MIWG provides a forum to facilitate the communication and coordination of mission requirements and planning. MIWGs are usually held in a meeting environment to accommodate discussion and review of multiple subjects and face-to-face resolution of issues. Pre-established agendas will be used to ensure all appropriate discussion items are addressed at the MIWG. Launch Operations Working Groups (LOWG), Ground Operations Working Groups (GOWG), Range Working Groups (RWG) and Safety Working Groups (SWG) are all subsets of the MIWG process. Results of the MIWGs are published to provide historical reference as well as track action items generated by the mission teams. The number and types of MIWGs varies based on the mission unique requirements. **Figure 6-2** summarizes the typical working group meetings.

6.2.3 Readiness Reviews

Each mission integration effort contains a series of readiness reviews to provide the oversight and coordination of mission participants and management outside the regular contact of the MIWG environment. Each readiness review ensures all organizations are in a position to proceed to the next major milestone. At a minimum, two readiness reviews are baselined into the integration process; 1) the Mission Readiness Review (MRR) and 2) the Launch Readiness Review (LRR). The MRR is typically held 1-2 weeks prior to shipping the spacecraft to the integration facility. The MRR provides a prelaunch assessment of the launch vehicle, spacecraft, facilities, and range readiness for supporting the integration and launch effort. The LRR is typically conducted 1-3 days prior to launch. The LRR serves as the final assessment of all organizations and systems readiness prior to conducting the launch operation. Due to the variability in complexity of different payloads and missions the content, quantity and schedule of readiness reviews are tailored to support the mission unique considerations.

Timeframe	Meeting	Purpose
L-24 to L-8 Months	MIWGs	• Establish Mission Requirements • Document Mission Requirements • Coordinate Test and Support Requirements
L-18 to L-8 Months	RWGs	• Establish Mission Range Requirements • Document Mission Range Requirements • Coordinate Range Test and Support Documentation
L-18 to L-6 Months	SWGs	• Establish Mission Safety Requirements • Document Mission Safety Requirements • Coordinate Mission Safety Support Requirements
L-6 to L-2 Months	GOWGs	• Establish Mission Operations and Processing Requirements • Document Mission Operations and Processing Requirements • Coordinate Operations and Processing Support Requirements
L-4 to L-1 Months	LOWGs	• Establish Mission Launch Operations Requirements • Document Mission Launch Operations Requirements • Coordinate Launch Operations Support Requirements PEG044

Figure 6-2. *Summary of Typical Working Groups.*

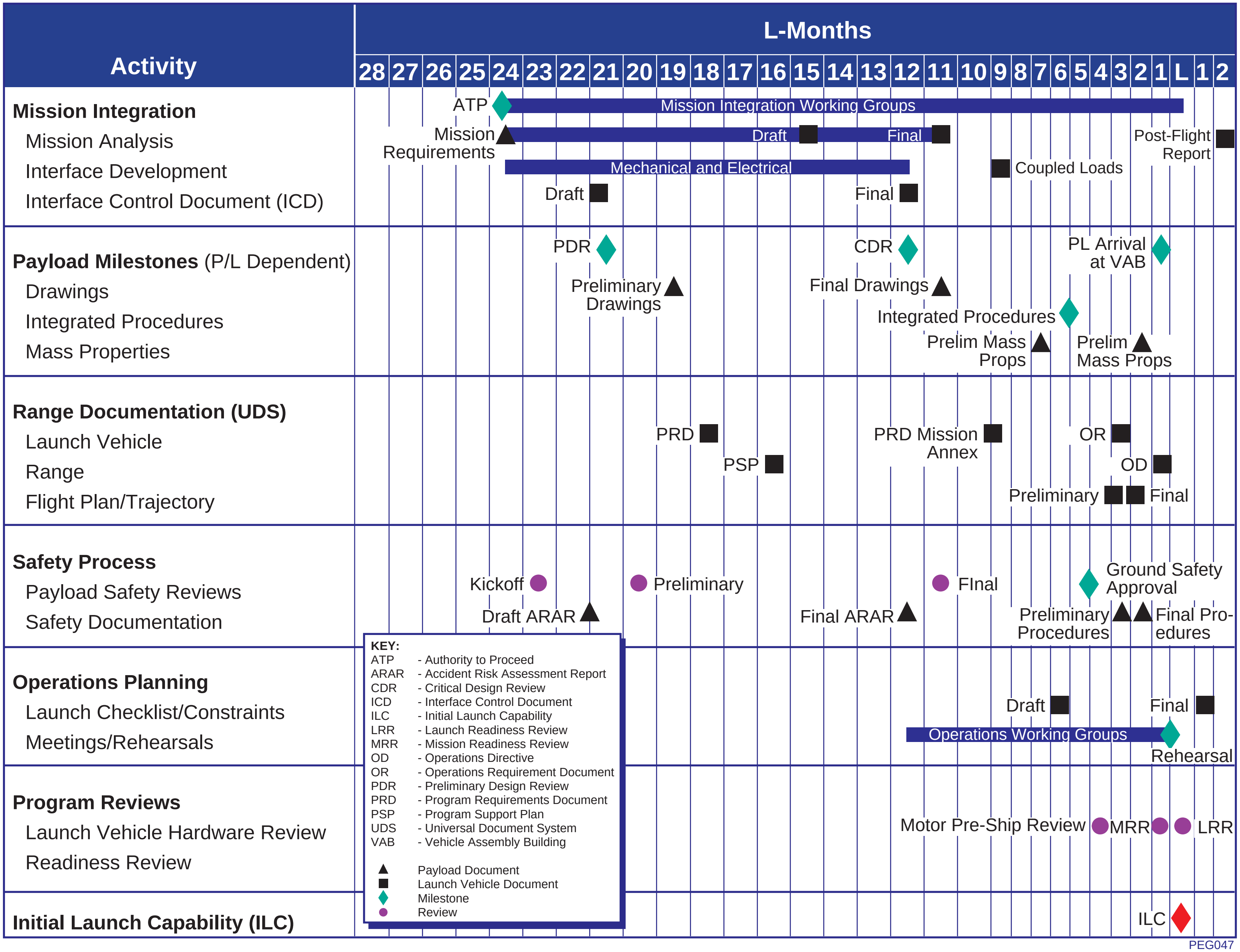
6.3 Mission Planning and Development

Orbital will assist the customer with mission planning and development associated with Pegasus launch vehicle systems. These services include interface design and configuration control, development of integration processes, launch and launch vehicle related analyses, facilities planning, launch campaign planning to include range services and special operations, and integrated schedules. Orbital will support the working group meetings described in this section, and spacecraft design reviews.

6.3.1 Baseline Mission Cycle

The procurement, analysis, integration and test activities associated with the Pegasus launch of a payload typically occur over a 24-30 month baseline mission cycle. This baseline schedule, detailed in **Figure 6-3**, is not meant to be a rigid structure, but a template for effective mission management and payload integration. Throughout this time, Orbital will work closely with personnel from the customer and other organizations involved in the launch to ensure a successful mission. The schedule in **Figure 6-3** shows a typical 24 month mission. The baseline mission cycle includes:

- Mission management, document exchanges,



KEY:

ATP	- Authority to Proceed
ARAR	- Accident Risk Assessment Report
CDR	- Critical Design Review
ICD	- Interface Control Document
ILC	- Initial Launch Capability
LRR	- Launch Readiness Review
MRR	- Mission Readiness Review
OD	- Operations Directive
OR	- Operations Requirement Document
PDR	- Preliminary Design Review
PRD	- Program Requirements Document
PSP	- Program Support Plan
UDS	- Universal Document System
VAB	- Vehicle Assembly Building
▲	Payload Document
■	Launch Vehicle Document
◆	Milestone
●	Review

Figure 6-3. *Typical Mission Cycle.*

meetings and reviews required to coordinate and manage the launch service;

- Mission and payload integration analysis;
- Design, review, procurement, testing and integration of all mission-peculiar hardware; and
- Range interface, safety, and launch site flight and operations activities and reviews.

6.4 Interface Design and Configuration Control

Orbital will develop a mission-unique payload ICD to define the interface requirements for the payload. The ICD documents the detailed mechanical, electrical and environmental interfaces between the payload and Pegasus as well as all payload integration specifics, including ground support equipment, interface testing and any unique payload requirements. The ICD is jointly approved by the customer and Orbital. An integrated schedule will also be developed.

6.5 Safety

Ground and flight safety is a top priority in any the launch vehicle activity. Pegasus launch vehicle processing and launch operations are conducted under strict adherence to US government safety standards. The lead range at the integration and launch sites are the ultimate responsibility for overall safety. These ranges have established requirements to conduct launch vehicle and satellite processing and launch operations in safe manner for both those involved as well as the public. Launch vehicle and payload providers must work together with the range safety organizations to ensure all safety requirements are understood and implemented.

6.5.1 System Safety Requirements

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

1) Baseline mission: Payload integration and launch operations are conducted at Vandenberg Air Force Base (VAFB), CA
2) Ferry mission: Payload integration is conducted at VAFB and launch operations are conducted from a non-VAFB launch location.
3) Campaign mission: Payload integration and launch operations are conducted at a site other than VAFB.

For the baseline and ferry missions, spacecraft prelaunch operations are conducted at Orbital's Vehicle Assembly Building (VAB), Building 1555,VAFB. For campaign style missions, the spacecraft prelaunch operations are performed at the desired launch site.

Before a spacecraft arrives at the processing site, the payload organization must provide the cognizant range safety office with certification that the system has been designed and tested in accordance with applicable safety requirements (e.g. EWR 127-1 Range Safety Requirements for baseline and ferry missions). Spacecraft that integrate and/or launch at a site different than the processing site must also comply with the specific launch site's safety requirements. Orbital will provide the customer coordination and guidance regarding applicable safety requirements.

Figure 6-4 provides a matrix of the governing safety requirements for demonstrated and planned Pegasus payload integration flow. The Orbital documents listed in the matrix closely follow the applicable range safety regulations.

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

6.5.2 System Safety Documentation

Range safety requires certification that spacecraft

Payload Integration Site	Launch Site	Applicable Safety Requirements Documents
VAFB	VAFB	EWR 127-1 / Orbital TD-0005 / Orbital TD-0018
VAFB	CCAFS	EWR 127-1 / Orbital TD-0005 / Orbital TD-0018
CCAFB	CCAFS	EWR 127-1 / Orbital TD-0005 / Orbital TD-0018
KSC	CCAFS	EWR 127-1 / KHB 1710 / Orbital TD-0005 / Orbital TD-0018
VAFB	WFF	EWR 127-1 / RSM-93 / Orbital TD-0005 / Orbital TD-0018
WFF	WFF	RSM-93 / Orbital TD-0005 / Orbital TD-0018
VAFB	KMR	EWR 127-1 / KMR Range Safety Manual / Orbital TD-0005 / Orbital TD-0018

PEG045

Figure 6-4. *Applicable Safety Requirements.*

systems are designed, tested, inspected, and operated in accordance with the applicable regulations. This certification takes the form of the Missile System Pre-Launch Safety Package (MSPSP) (also referred to as the Accident Risk Assessment Report (ARAR)) which describes all hazardous systems on the spacecraft and associated ground support equipment (GSE). Hazardous systems include ordnance systems, separation systems, solar array deployment systems, power sources, RF and ionizing radiation sources, and propulsion systems. The MSPSP must describe all GSE used at the processing and launch sites, with special attention given to lifting, handling GSE, and pressurization or propellant loading equipment. EWR 127-1 Chapter 3 Appendix 3A provides an outline of a typical MSPSP.

At certain sites, specific approval must be obtained for all radiation sources (RF and ionizing). Orbital will coordinate with the spacecraft organization and the specific site safety office to determine data requirements and obtain approval. Data requirements for RF systems normally include power output, center frequency, scheduling times for radiating, and minimum safe distances. Data requirements for ionizing sources normally include identification of the source, source strength, half-life, hazard control measures, and minimum safe distances.

The MSPSP must also identify all hazardous materials that are used on the spacecraft, GSE, or during operations at the processing and launch sites. Some examples of hazardous materials are purge gases, propellant, battery electrolyte, cleaning solvents, epoxy, and adhesives. A Material Safety Data Sheet must be provided in the MSPSP for each hazardous material. Also an estimate of the amount of each material used on the spacecraft or GSE, or consumed during processing shall be provided.

The MSPSP also shall specify the ground operations flow and identify those operations that are considered hazardous. Hazardous operations include lifting, pressurization, battery activation, propellant loading, and RF radiating operations.

All hazardous procedures that will be performed at the processing or launch site must be submitted to the specific site safety office for approval. Additionally, Orbital shall review and approve hazardous spacecraft procedures to ensure personnel at Orbital facilities will be adequately protected from harm. Orbital shall provide the coordination necessary for timely submission, review and approval of these procedures.

6.5.3 Safety Approval Process

Figure 6-5 depicts the typical safety approval process for a commercial Pegasus mission. If permitted by the processing and launch site safety organizations, it is recommended that tailoring of the applicable safety requirements be conducted early in the spacecraft design effort. This will result in greater understanding of the site-specific regulations, and may provide more flexibility in meeting the intent of individual requirements. This is especially critical for newly designed hazardous systems, or new applications of existing hardware.

It is encouraged that safety data be submitted as early as practical in the spacecraft development schedule. The review and approval process usually consists of several iterations of the MSPSP

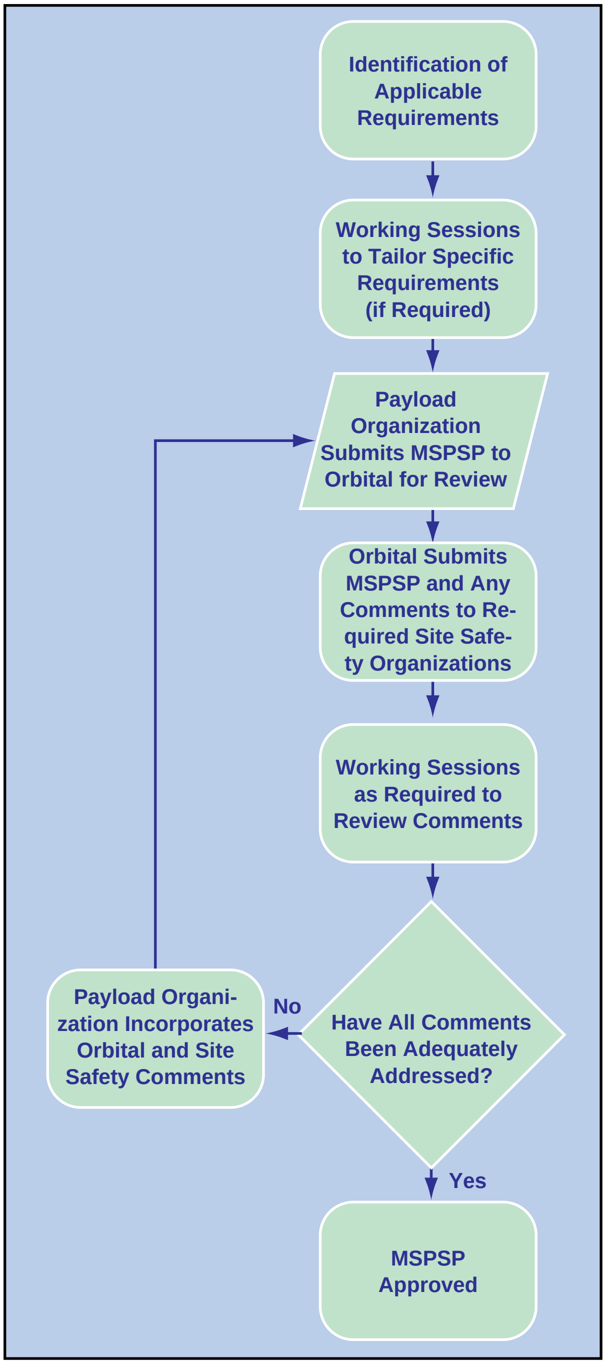


Figure 6-5. *Safety Approval Process.*

and hazardous procedures to ensure all requirements are met and all hazards are adequately controlled. Working sessions are held periodically to clarify the intent of requirements and discuss approaches to hazard control. These working sessions are normally scheduled to coincide with existing Mission Integration Working Groups and Ground Operation Working Groups.

When certain requirements cannot be satisfied as specifically stated in the regulation, the approving safety organization at the processing and launch sites may waive the requirement when provided sufficient justification. This request for variance must contain of an identification of the requirement, assessment of the risk associated with not meeting the letter of the requirement, and the design and procedural controls that are in place to mitigate this risk. As stated previously, the use of variances is discouraged and approval cannot be guaranteed.

Section 7.0—Ground and Launch Operations

7.1 Pegasus/Payload Integration Overview

The Pegasus system has been designed to minimize both vehicle and payload handling complexity as well as launch base operations time. Horizontal integration of the Pegasus vehicle simplifies integration procedures, increases safety and provides excellent access for the integration team. In addition, simple mechanical and electrical interfaces and checkout procedures reduce vehicle and payload integration times, and increase system reliability.

7.2 Ground and Launch Operations

Figure 7-1 shows a typical ground and launch operations flow which is conducted in three major phases:

- ***Launch Vehicle Integration:*** Assembly and test of the Pegasus vehicle;
- ***Payload Processing:*** Receipt and checkout of the satellite payload, followed by integration with Pegasus and verification of interfaces; and
- ***Launch Operations:*** Mating of Pegasus with the carrier aircraft, take-off and launch.

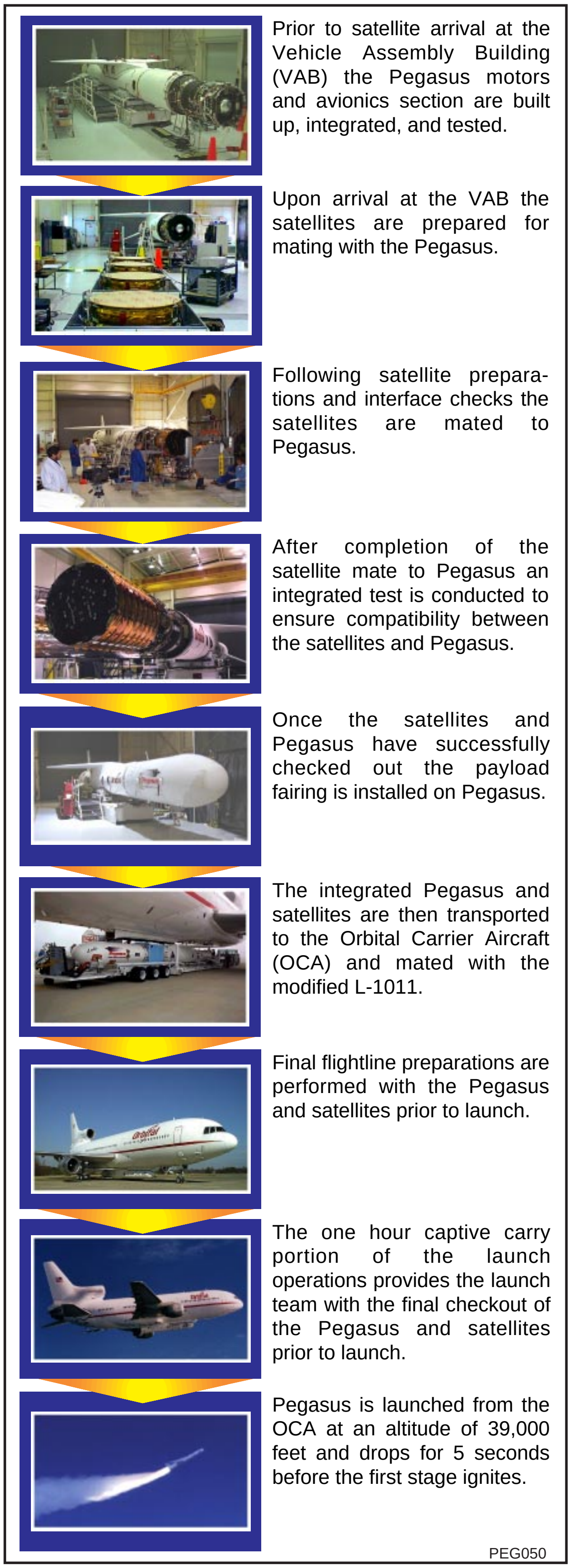
Each of these phases is more fully described below. Orbital maintains launch site management and test scheduling responsibilities throughout the entire launch operations cycle. **Figure 7-2** provides a typical schedule of the integration process through launch.

7.2.1 Launch Vehicle Integration

7.2.1.1 Integration Sites

All major vehicle subassemblies are delivered from the factory to the Vehicle Assembly Building (VAB) at Orbital's integration sites. Orbital's primary integration site is located at Vandenberg Air Force Base (VAFB), California. Through the use of the OCA, this integration site can support launches throughout the world. The VAFB OCA hotpad area is shown in **Figure 7-3**.

The following Pegasus GSE is maintained at the VAB:



Prior to satellite arrival at the Vehicle Assembly Building (VAB) the Pegasus motors and avionics section are built up, integrated, and tested.

Upon arrival at the VAB the satellites are prepared for mating with the Pegasus.

Following satellite preparations and interface checks the satellites are mated to Pegasus.

After completion of the satellite mate to Pegasus an integrated test is conducted to ensure compatibility between the satellites and Pegasus.

Once the satellites and Pegasus have successfully checked out the payload fairing is installed on Pegasus.

The integrated Pegasus and satellites are then transported to the Orbital Carrier Aircraft (OCA) and mated with the modified L-1011.

Final flightline preparations are performed with the Pegasus and satellites prior to launch.

The one hour captive carry portion of the launch operations provides the launch team with the final checkout of the Pegasus and satellites prior to launch.

Pegasus is launched from the OCA at an altitude of 39,000 feet and drops for 5 seconds before the first stage ignites.

Figure 7-1. *Typical Processing Flow.*

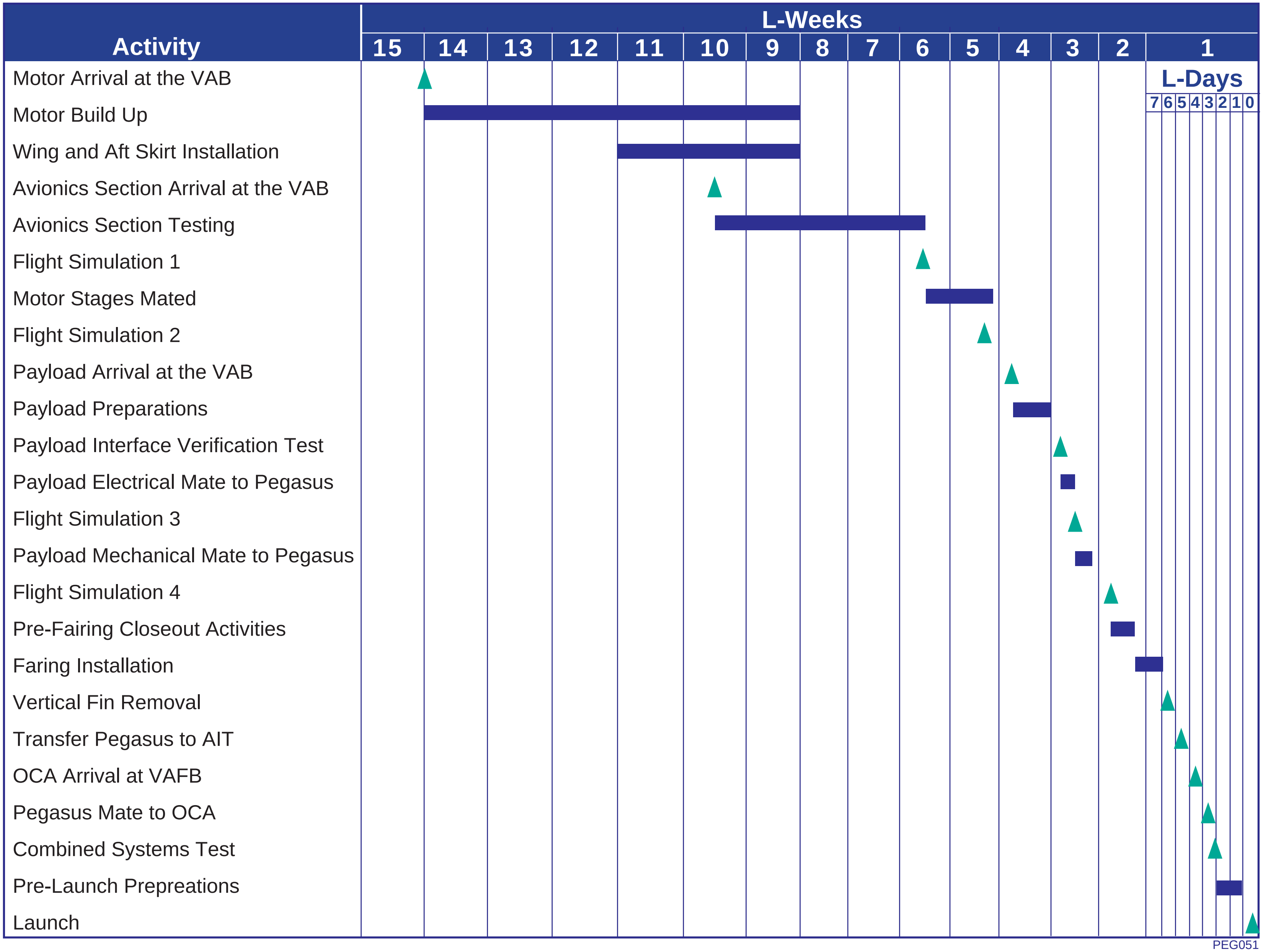


Figure 7-2. *Typical Pegasus Integration and Test Schedule.*

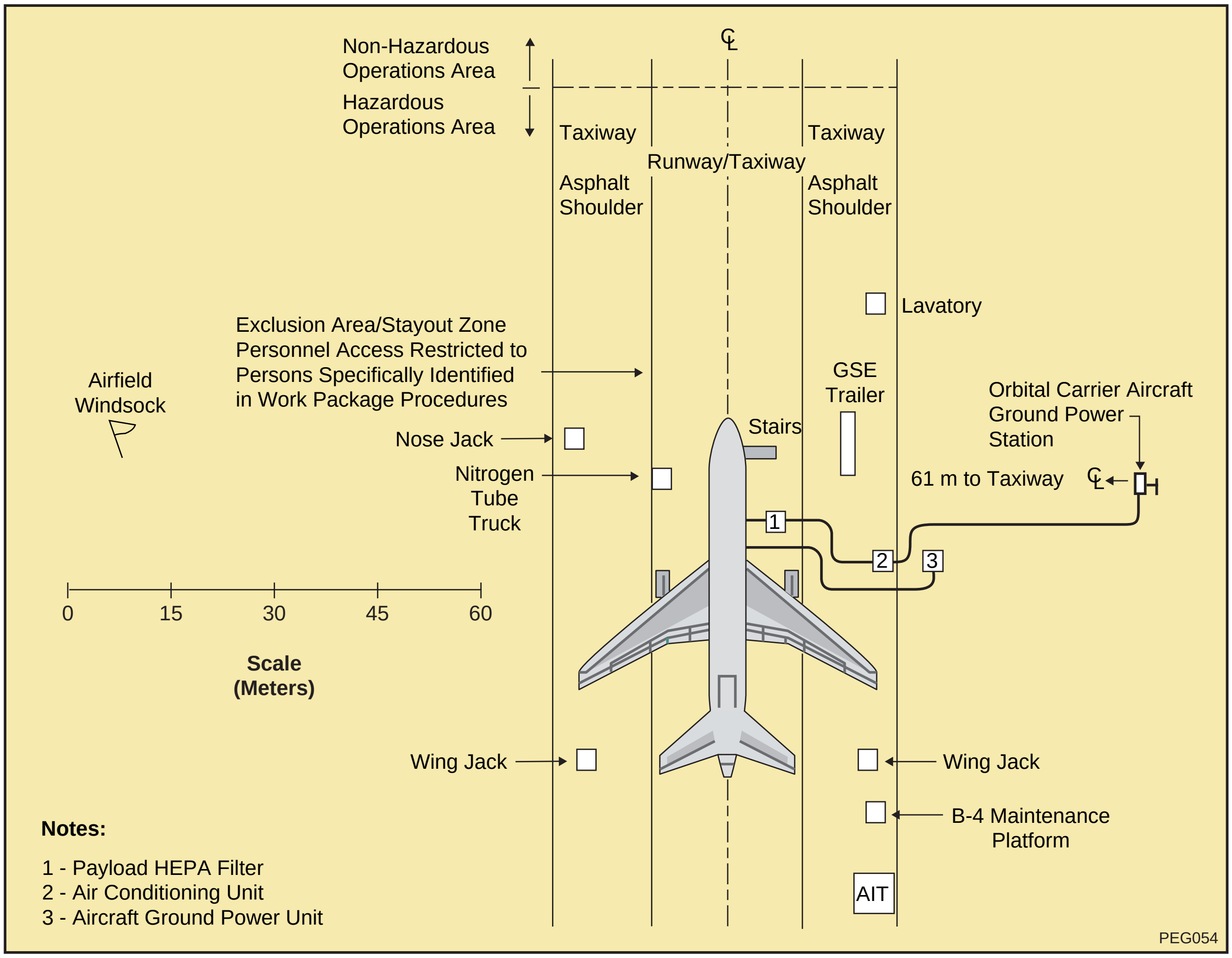


Figure 7-3. *Orbital Carrier Aircraft Hot Pad Area at VAFB.*

- An Assembly and Integration Trailer (AIT), stationary rails, and motor dollies for serial processing of Pegasus missions.
- Equipment for transportation, delivery, loading and unloading of the Pegasus vehicle components.
- Equipment for nominal integration and test of a Pegasus vehicle.
- Equipment to maintain standard payload environmental control requirements.
- General equipment to allow mating of the payload with the Pegasus vehicle (Orbital does not provide payload specific equipment).

7.2.1.2 Vehicle Integration and Test Activities

Figure 7-4 shows the Pegasus stages being integrated horizontally at the VAB prior to the arrival of the payload. Integration is performed at a convenient working height, which allows easy

Figure 7-4. *Pegasus Integration.*

access for component installation, test, and inspection. The integration and test process ensures that all vehicle components and subsystems are thoroughly tested before and after final flight connections are made.

Vehicle systems tests include a series of tests that verify operation of all subsystems prior to stage mate. The major tests are Vehicle Verification, Phasing Tests and Flight Simulations. For each of these a specialized test software load is installed into the Pegasus Flight Computer.

Vehicle Verification is a test that efficiently commands all subsystems (fin actuators, TVCs, FC discrete outputs, RCS, pyro commands, etc.) in an accelerated time line.

Phasing tests verify the sign of the control loop of the flight actuators and the dynamic operation of the IMU. In this test the IMU is moved manually while the motion of the flight actuators (fins, TVCs and RCS) is observed and recorded.

Flight simulation testing uses the actual flight code and simulates a “fly to orbit” scenario. All flight actuators, pyro commands and FC commands are exercised. The Flight Simulation is repeated after each major vehicle configuration change (i.e., Flight Simulation #1 after motor stages are built-up, Flight Simulation #2 after stage mate, Flight Simulation #3 after payload electrically mated/jumpered and Flight Simulation #4 after the payload is mechanically mated). After each test, the configuration of the vehicle is frozen until a full and complete data review of the test is complete, which usually takes one to two days. The payload nominally participates in Flight Simulation #3 and #4.

In addition to these major tests, several other tests are performed to verify the telemetry, flight termination, accelerometer and RF systems.

Pegasus integration activities are controlled by a comprehensive set of Pegasus Work Packages (PWPs), which describe and document in detail every aspect of integrating Pegasus and its payload. Pegasus Mission Specific Engineering Work Packages (EWPs) are created for mission unique or payload specific procedures.

7.2.2 Payload Processing

A typical Pegasus payload is delivered to the integration site at launch minus 30 calendar days. The payload completes its own independent verification and checkout prior to beginning integrated processing with Pegasus at the launch site. Initial payload preparation and checkout is performed by payload personnel prior to Flight Simulation #3.

Payload launch base processing procedures and payload hazardous procedures should be coordinated through Orbital to the launch range no later than 120 days prior to first use (draft) and 30 days prior to first use (final).

7.2.2.1 Ground Support Services

The payload processing area capabilities will depend on which mission option is chosen based on launch site – integrate and launch; integrate, ferry, and launch; or Pegasus campaign to launch site.

Vandenberg ground support services which would be used in the launch and ferry scenarios are outlined in **Appendix C**.

7.2.2.2 Payload to Pegasus Integration

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

7.2.2.2.1 Pre-Mate Interface Testing

The electrical interface is verified using a mission unique Interface Verification Test (IVT), in conjunction with any payload desired test procedures, to mutually verify that the interface meets specifications. The IVT and payload procedures include provisions for testing the LPO interfaces, if necessary.

If the payload provider has a payload simulator, this test can be repeated with this simulator prior to using the actual payload. These tests, customized for each mission, typically checkout the LPO controls, launch vehicle sequencing, and any off-nominal modes of the payload.

When the payload arrives at the launch site Pegasus can be made available for a preliminary mechanical interface verification before final payload preparations.

After "safe-to mate" tests, the payload is electrically jumpered, and further interface testing (e.g., data flow between the spacecraft and the Pegasus) is performed, if necessary. Flight Simulation #3 is then performed, using a flight MDL, IMU simulator, and other EGSE. For payloads with simplified interfaces to the Pegasus, it may be acceptable to proceed to payload mate and the final Flight Simulation, immediately after the IVT.

7.2.2.2.2 Payload Mating and Verification

Once the payload aft end closeouts are completed, the payload will be both mechanically and electrically mated to the Pegasus. Following mate, the flight vehicle is ready for the final integrated systems test, Flight Simulation #4, in flight configuration. One of the last two flight simulations is performed on the flight batteries. This test is in full flight configuration (internal power, firing RCS, etc.), but without ordnance connected, allowing a complete check of all interfaces after mating the payload, while minimizing the payload time on the vehicle before launch. The integrated test procedures are developed by the LOWG and reviewed by the appropriate payload, launch vehicle and safety personnel.

7.2.2.2.3 Final Processing and Fairing Close-Out

After successful completion of Flight Simulation #4, all consumables are topped-off and ordnance is connected. Similar payload operations may occur at this time. Once consumables are topped-off, final vehicle/payload closeout is performed and the payload fairing is mated. Integrated system tests are conducted to ensure that the Pegasus/payload system is ready for launch after payload mate.

7.2.2.2.4 Payload Propellant Loading

Payloads utilizing integral propulsion systems with propellants such as hydrazine can be loaded and secured through coordinated Orbital, Government and payload contractor arrangements for use of the propellant loading facilities in the VAB. All launch integration facilities will be configured to handle these sealed systems in the integration process with the launch vehicle. The propellant loading facility is maintained visibly clean.

7.2.3 Launch Operations

7.2.3.1 Orbital Carrier Aircraft Mating

The Pegasus is transported on the Assembly and Integration Trailer (AIT) to the OCA for mating. This activity typically takes place about three days prior to launch. Once Pegasus is mated to the OCA, Orbital monitors the Hot Pad 24 hours per day through launch.

The OCA/LPO/Pegasus interface is fully verified prior to mating the launch vehicle to the carrier aircraft by performing an OCA Pre-Mate Electrical Checkout. Mission unique/payload LPO Station interfaces are also verified using a mission specific EWP prior to Pegasus mate to the OCA. Using the AIT, the Pegasus ground crew then mates the vehicle to the OCA.

All OCA/LPO/Pegasus/payload interfaces are then verified again through a functional test, know as the combined systems Test (CST). The CST also verifies the interfaces with the range tracking, telemetry, video and communications resources. If the payload has an arming plug which inhibits a pyrotechnic event, and this plug was not installed in the VAB, it may be installed at this time through the fairing access door.

The payload can continue to maintain access to the payload through this door up to one hour prior to aircraft engine start (approximately take-off minus two hours). After engine #2 start, the ground air conditioning system is removed and the fairing environment is thermally controlled by the AACS from the aircraft, which flows into the fairing under the control of the LPO.

7.2.3.2 Pre-Flight Activities

The pre-departure activities and launch checklist flow is shown in **Figure 7-5**. The first procedure for the mission operations team begins after the range communications checks and setup at take-off (T.O.) minus 4.5 hrs. At T.O. minus 3.5 hrs, the LPO enters the carrier aircraft and powers up Pegasus upon direction from the Launch Conductor (LC). Concurrently, final closeout of Pegasus is accomplished and the range safety engineers verify that the FTS is functioning by sending arm and fire commands to the FTS antennas via actual range assets or a range test van.

Other Pegasus verification tests are then performed to exercise most aspects of the Pegasus, ensuring the vehicle will switch from carrier aircraft power to internal battery power and that the IMU, flight computer, and telemetry system are all working correctly. Payload operations are verified to ensure the payload can be controlled by the LPO control switches as required. End-to-end checks are made to verify Pegasus and payload (if applicable) telemetry transmissions are received in the telemetry room.

7.2.3.3 Launch Control Organization

The Launch Control Organization normally consists of three separate groups. The Management group includes the Mission Directors for the launch vehicle and the payload and a senior Range representative. The Orbital Mission Director provides the final Pegasus Program recommendation for launch decision based on inputs from the Vehicle Engineer and the Launch Conductor. Similarly, the Payload Mission Director polls the various payload personnel to determine the readiness of the payload for launch, and the Range representative provides the final Go/No-Go for the Range.

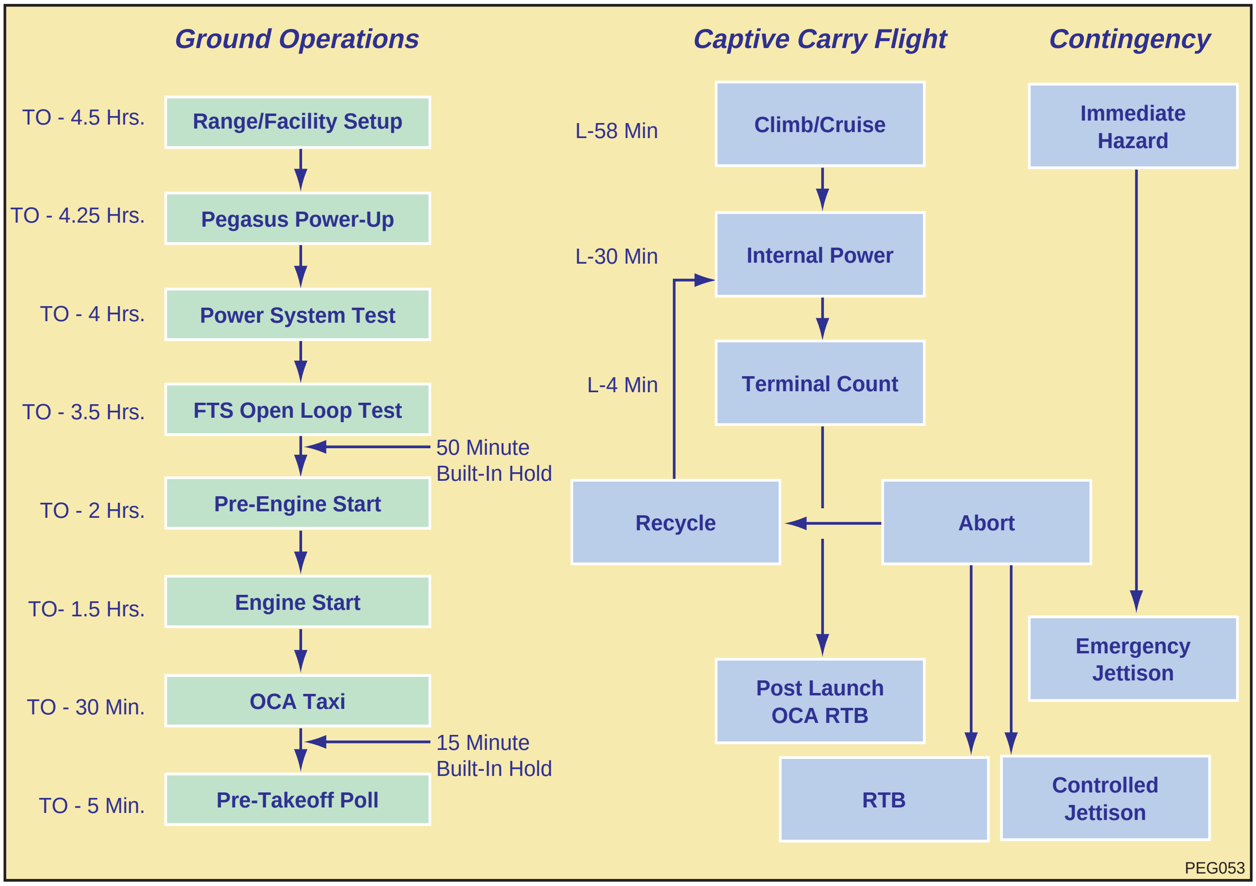


Figure 7-5. *Typical Pegasus Launch Checklist Flow.*

The second group is the Operations/Engineering Group, including the Launch Conductor, the Vehicle Engineer and the Range Control Officers. The Orbital Launch Conductor is responsible for running the countdown procedure. The Orbital Vehicle Engineer has the overall responsibility for the Pegasus launch vehicle. A team of engineers, which reviews the telemetry to verify the system is ready for launch, support the Vehicle Engineer. The range status is coordinated by the Range Control Officer who provides a Go/No-Go status to the Launch Conductor.

The third group is the Airborne Operations Group which includes the Launch Panel Operator (LPO) and the aircraft crew. The LPO monitors on-board systems from the launch panel station onboard the carrier aircraft and executes on-board countdown procedures. The aircraft crew operates the aircraft, achieves proper pre-release flight conditions and activates the actual physical release of the Pegasus vehicle.

7.2.3.4 Flight Activities

The launch checklist begins prior to engine start and continues until after Pegasus is released. All members of the launch team and the aircraft crew work from this procedure. Abort procedures and emergency procedures are also contained in the launch notebooks.

At the hotpad about one hour before take-off, the FTS power is turned on and all inhibits are verified, the S&A safing pins are removed, and the vehicle is placed in a ready state. At this time the aircraft and the Pegasus are ready for take-off.

Orbital arranges for Pegasus telemetry and tracking services during captive carry and Pegasus powered flight. Data will be passed to the payload mission control console as determined by the LOWG and MIWG process.

Once airborne, Pegasus is configured into a launch condition by switching the FTS to internal battery power at L-15 min, the avionics bus to internal power at L-6 min, and the transient power bus to internal power at L-4 min. If the LPO station is supplying external power to the spacecraft, the spacecraft will be transitioned to internal power no later than L-6 minutes. At L-45 sec, the fin thermal batteries are activated and a sinusoidal fin sweep is commanded by the flight computer to all fins to verify that they are working correctly. The fin sweep telemetry, fin position and command current, are monitored and, if they are nominal, the Pegasus is “Go For Launch.” The Orbital Launch Conductor relays this "Go" from the Pegasus control center to the pilot commander. After confirmation from the pilot commander of a go for launch, the Launch Conductor performs the drop countdown. The pilot releases Pegasus on the Launch Conductor's command. After release, the Pegasus flight is autonomous with the exception of the positive command capability for flight termination in the event of an anomalous flight.

7.2.3.5 Abort/Recycle/Return-to-Base Operations

The approximate time to recycle in the air is 30 minutes. The minimum stand-down time after an abort/return-to-base is 24 hours. Orbital plans and schedules all required contingency landing areas and support services prior to each launch attempt. In general, only minimal support services are available to the payload at contingency landing sites. Available recycle time is dependent on payload constraints as well. For example, the payload must determine battery margins to verify recycle capabilities. Payload providers must specify the maximum time they can withstand the absence of GSE support.

Section 8.0—Documentation

8.1 Interface Products and Schedules

Orbital divides external interfaces into two areas: interfaces with the Pegasus production team (i.e., our subcontractors and vendors), typically for hardware products, and interfaces with external organizations, which are typically documentation products and data exchanges.

External organizations with which Orbital will have information exchanges include the launch vehicle customer, the payload provider, the range, and the U.S. Department of Transportation. The products associated with these organizations are included within the 24 to 30-month baseline Pegasus mission cycle. As such, Orbital references required dates in a "launch minus" timeframe. The major products and submittal times associated with these organizations are divided into two areas — those products that Orbital produces, detailed in **Figure 8-1**, and those products that are required by Orbital, detailed in **Figure 8-2**.

Delivered to	Product	Delivered (L-Weeks)
Customer	Preliminary ICD	ATP+90 Days*
	Preliminary Mission Analysis/ Mission Profile	L-74
	Preliminary Trajectory Analysis	L-52
	Final ICD	Customer Sign +30 Days**
	Final Mission Analysis /Mission Profile	L-12
	Post-Flight Report	L+7
Range	Program Requirements Document	L-52
	PRD Mission Annex	L-52
	Pegasus Flight Termination System Report	As Required
	Pegasus Accident Risk Assessment Report	As Required
	Preliminary Mission Constraints Document	L-26
	Preliminary Launch Checklist	L-26
	Operations Requirements Document	L-22 (Ops -60 Days)
	Preliminary Trajectory	L-9
	Final Trajectory	L-6
	Final Launch Checklist	L-6
	Mission Constraints Document	L-6
Department of Transportation	Launch Specific Flight Plan	L-9
	Payload Description	L-9
	Vehicle Information Message	L-2

* Or Prior to Payload PDR ** Or Prior to Payload CDR

PEG056

Figure 8-1. *Documentation Produced by Orbital for Commercial Pegasus Launch Services.*

8.2 Mission Planning Documentation

The available Pegasus documentation includes a collection of formal and informal documents developed and produced by Orbital. The number of separate formal documents required for a successful mission has been minimized by consolidation of documents and maximizing the informal exchange of information (e.g., working groups) before inclusion on formal, controlled configuration documents such as the payload Interface Control Document (ICD).

8.3 Mission-Unique Analyses

Mission analysis, which includes trajectory/ GN&C analyses and environment analyses, begins shortly after mission authorization is received. Orbital will generate the optimal trajectory to the desired orbit, determine the guidance parameters, and evaluate the autopilot stability. From these analyses, the Mission Data Load (MDL) will be generated and then tested in real-time simulations.

8.3.1 Trajectory Analysis

Orbital will perform a Preliminary and Final Mission Analysis using POST and the Orbital-developed Non-Real Time Simulation (NRTSim) analysis tool, which performs six degree-of-freedom simulations. The primary objective is to determine the compatibility of the payload with

Delivered by	Product	Due Date (L-Weeks)
Customer	Mission Unique Services Definition	ATP
	Mission Requirements Summary	L-92
	Preliminary Payload Drawing/Mass Properties	L-76
	Payload PRD Input	L-56
	Final Payload Drawing	L-48
	Payload Accident Risk Assessment Report	L-45
	Checklist/Launch Constraint Inputs	L-28
	Integration Procedures	L-24
	Final Payload Mass Properties	L-8
Range	Program Support Plan	L-48
	Operations Directive	L-15
	Flight Plan Approval	L-1

PEG057

Figure 8-2. *Documentation Required by Orbital for Commercial Pegasus Launch Services.*

Pegasus and to provide succinct, detailed mission requirements, such as payload environments, performance capability, accuracy estimates and preliminary mission sequencing. Much of the data derived from the Preliminary Mission Analysis is used to establish the ICD and perform initial range coordination.

Orbital will perform recontact analysis for post-separation events to determine if a C/CAM is required. The analysis will verify that sufficient separation distance exists between the payload and final stage following payload separation and will include effects of separation system operation and residual final stage thrust.

8.3.2 Guidance, Navigation and Control Analyses

Consists of several separate detailed analyses to thoroughly evaluate the planned mission and its effects throughout powered flight. The trajectory design, guidance, stability, and control analyses result in a verified mission-unique flight software MDL.

Guidance Analysis — Pegasus dispersions and injection accuracies are determined using predicted vehicle motor performance, mass uncertainties, and aerodynamic and INS errors. Uncertainties are combined to obtain estimated dispersions in perigee, apogee, inclination and argument of perigee. This data is incorporated in the payload ICD.

Stability and Control Analysis — Using the optimum trajectory from POST, Orbital selects a set of points throughout Stage 1 burn for investigating the stability characteristics of the autopilot. For the exo-atmospheric portions of flight, the autopilot margins are similarly evaluated at discrete points to account for the changing mass properties of the vehicle. The control system gains are chosen to provide adequate stability margins at each operating point. Orbital validates these gains through perturbed flight simulations designed to stress the functionality of the autopilot and excite any possible instabilities. Due to the proprietary nature of Orbital's control algorithms, this analysis is not a deliverable to the payload vendor.

8.3.3 Coupled Loads Analysis

Orbital has developed finite element structural models of the Pegasus vehicle. Orbital will perform a coupled loads analysis to determine maximum responses of the entire stack. A single load cycle is run after a payload modal survey has taken place and a test verified payload model has been supplied. The coupled loads analysis will also contain a "rattlespace analysis." This analysis verifies the payload does not violate the payload fairing dynamic envelope.

8.3.4 Payload Separation Analysis

Orbital will use the Pegasus STEP simulation to ensure that the payload is in the desired orientation for successful separation at the end of boost. Orbital will perform a separation tip-off analysis to verify the three axis accelerations that the payload will experience during the separation event from the final stage. This analysis will only be conducted on an Orbital-supplied separation system.

8.3.5 RF Link and Compatibility Analyses

RF link analyses will be updated for each trajectory to ensure sufficient RF link margins exist for both the telemetry and flight termination systems.

8.3.6 Mass Properties Analysis and Mass Data Maintenance

Orbital will track and maintain all mass properties, including inertias, relating to the Pegasus vehicle. Payload-specific mass properties provided to Orbital by the customer will be included. All flight components are weighed prior to flight and actual weights are employed in final GN&C analyses. Orbital will require estimates of the payload mass to facilitate preliminary mission planning and analyses. Final payload mass properties are required at least 75 days prior to launch within the tolerances specified.

8.3.7 Power System Analysis

Orbital develops and maintains a power budget for each mission. A mission power budget will verify that sufficient energy and peak load margin exist. Battery usage is strictly controlled on the vehicle and batteries are charged prior to vehicle close-out.

8.3.8 Fairing Analyses

Two payload-specific analyses performed by Orbital relate to the payload fairing. These are a critical clearance analysis (contained in the coupled loads analysis) based on the dimensions and payload characteristics provided by the customer and a separation point analysis to select the timing for this event. Payload fairing maximum deflection occurs at pull-up.

The fairing separation point is nominally timed to coincide with dynamic pressure falling below 0.01 psf which usually occurs during the Stage 2 burn. Payload requirements specifying lower dynamic pressures or aerodynamic heating environments at fairing deployment may be accommodated by delaying this separation event. In general, this separation delay will lead to some degradation in Pegasus payload performance, which will need to be evaluated on a case by case basis.

8.3.9 Mission-Unique Software

Mission-unique flight software consists of the flight MDL, which contains parameters and sequencing necessary to guide Pegasus through the desired trajectory.

Prior to each flight, Orbital evaluates the interaction of the flight MDL with the mission-independent guidance and control software in the Guidance and Control Lab (GCL). Orbital personnel conduct a formalized series of perturbed trajectories, representing extreme disturbances, to ensure that both the flight MDL and the G&C software are functioning properly. MDL performance is judged by the ability of the simulation to satisfy final stage burnout requirements. The final flight MDL verification is obtained by conducting a closed-loop real-time simulation.

8.3.10 Post-Launch Analysis

Orbital will provide a detailed mission report to the customer normally within six weeks of launch. Included in the mission report will be the actual trajectory, event times, environments and other pertinent data as reduced from telemetry from onboard sensors and range tracking. Orbital also analyzes telemetry data from each launch to validate Pegasus's performance.

8.4 Interface Design and Configuration Control

Orbital will develop a mission-unique payload ICD to succinctly define the interface requirements for the payload. This document will detail mechanical, electrical and environmental interfaces between the payload and Pegasus as well as all payload integration specifics, including ground support equipment, interface testing and any unique payload requirements. The customer and Orbital jointly approve the ICD.

Section 9.0—Shared Launch Accommodations

Orbital has extensive experience in integrating and launching multiple payloads. Multiple spacecraft configurations have been flown on over half of the Pegasus missions to date.

Two technical approaches are available for accommodating multiple payloads. These design approaches are:

Load-Bearing Spacecraft — aft spacecraft designed to provide the structural load path between the forward payload and the launch vehicle, maximizing utilization of available mass performance and payload fairing volume

Non Load-Bearing Spacecraft — aft spacecraft whose design cannot provide the necessary structural load path for the forward payload

9.1 Load-Bearing Spacecraft

Providing a load-bearing aft payload maximizes use of available volume and mass. The available mass for the aft payload is determined by the Pegasus performance capability to orbit less the forward payload and attach hardware mass. All remaining mission performance, excluding a stack margin, is available to the aft payload. The load-bearing spacecraft interfaces directly to Pegasus and the forward payload via pre-determined interfaces. These interfaces include standard Orbital separation systems and pass-through electrical connectors to service the forward payload. **Figure 9-1** illustrates this approach.

Two approaches may be taken for load-bearing spacecraft. The first approach involves the use of an Orbital design using the MicroStar bus, successfully developed and flown for ORBCOMM spacecraft. The MicroStar bus features a circular design with an innovative, low-shock separation system. The spacecraft bus is designed to allow stacking of co-manifested payloads in "slices" within the fairing. The bus design is compact and provides exceptional lateral stiffness.

The second approach is to use a design developed by other spacecraft suppliers, which must satisfy Pegasus and forward payload structural design criteria. The principal requirements levied upon load-bearing spacecraft are those involving mechanical and electrical compatibility with the forward payload. Structural loads from the forward payload during all flight events must be transmitted through the aft payload to the Pegasus. Orbital will provide minimum structural interface design criteria for shear, bending moment, axial and lateral loads, and stiffness.

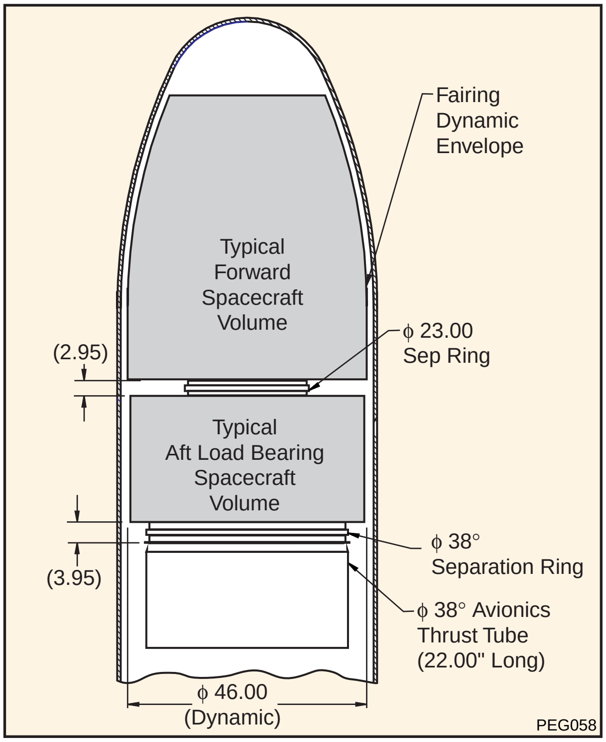


Figure 9-1. *Load-Bearing Spacecraft Configuration.*

For preliminary design purposes, coupled effects with the forward payload can be considered as a rigid body design case with Orbital provided mass and center of gravity parameters. Integrated coupled loads analyses will be performed with test verified math models provided by the payload contractors. These analyses are required to verify the fundamental frequency and deflections of the stack for compliance with the Pegasus requirement of 20 Hz minimum. Design criteria provided by Orbital will include “stack” margins to minimize interactive effects associated with potential design changes of each payload. Orbital will provide the necessary engineering coordination between the spacecraft and launch vehicle.

Electrical pass-through harnesses will also need to be provided by the aft payload along with provisions for connectors and interface verification. The spacecraft supplier will need to provide details of the appropriate analyses and test to Orbital to verify adequacy of margins and show that there is no impact to the forward spacecraft or the launch vehicle.

9.2 Non Load-Bearing Spacecraft

For aft spacecraft that are not designed for withstanding and transmitting structural loads from the forward payload, the flight-proven Dual Payload Attach Fitting (DPAF) is available on an optional basis.

The DPAF structure (**Figure 9-2**) is an all graphite structure which provides independent load paths for each satellite. The worst-case "design payload" for the DPAF is a 193 kg (425 lbs) spacecraft with 51 cm (20 in) center of mass offset and first lateral frequency of 20 Hz. The DPAF is designed to accommodate this "design payload" at both the forward and aft locations, although the combined mass of the two payloads cannot exceed Pegasus capabilities. The upper spacecraft loads are transmitted around the lower spacecraft via the DPAF structure, thus avoiding any structural interface between the two payloads.

The DPAF uses an Orbital standard 58 cm (23 in) Marmon clamp band interface for the upper payload mounted on a separable adapter cone which provides the transition to the 97 cm (38 in) cylinder. The aft satellite support structure consists of a 43 cm (17 in) separation system and a 43 cm (17 in) adapter cone which transitions to the 97 cm (38 in) diameter Pegasus third stage.

The separation systems are aluminum Marmon clamp designs. Each satellite is provided an independent electrical interface to the launch vehicle including zero-force connectors to minimize tip-off at deployment.

The separation sequence for the stack begins with initiation of the forward payload separation system followed by the separation of the conical adapter. The aft payload is then separated and ejected from within the cylinder which remains with the third stage.

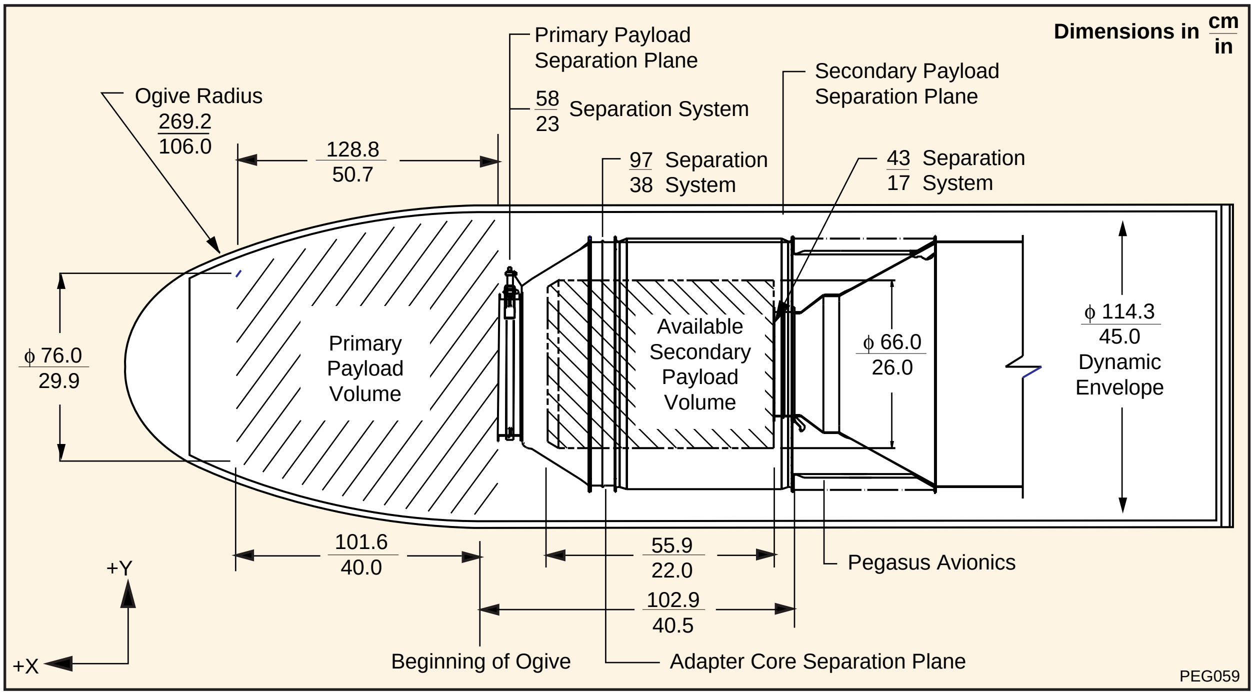


Figure 9.2. *Dual Payload Attach Fitting Configuration.*

Section 10.0—Non-Standard Services

This section describes optional non-standard services available. The earlier non-standard service requirements are identified, the better, preferably at Orbital ATP. Many of these non-standard services have flight heritage on one or more Pegasus flights.

10.1 Additional Fairing Access Doors

Additional access doors are available. Standard sizes are 8.5” x 13” and 4.5” circular. Certain restrictions apply to door location.

10.2 Alternative Integration Sites

As a non-standard service, Pegasus can use the following sites for payload integration:

- Eastern Range;
- Wallops Flight Facility; and
- Other sites are possible and will be investigated on a case-by-case basis and may require inter-governmental coordination.

Pegasus will be integrated at Vandenberg and flown to the alternate integration site. The Pegasus will be demated from the OCA, transported to the integration facility, the fairing will be removed, payload integration activities will be conducted, the fairing will be reinstalled, and the Pegasus will be transported back to the OCA and prepared for launch.

10.3 Alternative Range Services

As a non-standard service, specifically to support trajectories not attainable without significant trajectory dog-leg from Vandenberg, the Pegasus can be launched from the following ranges:

- Eastern Range;
- Wallops Flight Facility; and
- Other ranges are possible and will be investigated on a case-by-case basis and may require inter-governmental coordination.

This assumes that the rocket and payload integration takes place at Vandenberg and the integrated launch vehicle/satellite is ferried to the launch site on the OCA and launched without demating from the OCA.

10.4 Class 10,000 Fairing Environment

Orbital can provide payload fairing purge with air meeting FED-STD-209E Class 10,000 (M5.5), in accordance with TD-0289, “Pegasus Contamination Control Plan, NASA Class M5.5 Missions.” This task includes installing, operating, monitoring, and cleaning special HEPA-and carbon-filtered conditioned-air supply systems during four phases of integrated operations:

- Inside the integration facility (Vehicle Assembly Building);
- During transport to Hot Pad;
- During Hot Pad ground operations; and
- During Orbital Carrier Aircraft mated operations.

10.5 Class 10,000 Payload/Vehicle Integration Environment

Orbital can provide a payload/vehicle integration environment that is clean, certified, and maintained at FED-STD-209E Class 10,000 (M5.5) to support payload mate through fairing closeout operations. This includes assembly of the payload separation system in a Class 10,000 cleanroom, final assembly of the payload fairings and other components in Class 10,000 cleanrooms, preparation and verification of the Class 10,000 softwall cleanroom, and integration of the Pegasus and payload in the cleanroom. All these tasks include cleaning operations, monitoring, verifying, and recording cleanliness levels frequently.

10.6 Fairing Internal Surface Cleaning

Orbital can clean, certify, and maintain internal surfaces of the Pegasus payload fairing to MIL-STD-1246C, Level 750A, 600A or 500A. This involves increased levels of precision cleaning of the internal fairing surfaces prior to payload encapsulation; additional surface cleanliness measurements to verify surface cleanliness; and additional handling controls to maintain cleanliness.

10.7 40-Pin Pass-Through Harness

As a non-standard service, Pegasus can incorporate 20 twisted shielded pairs of wires from the payload interface plane to the OCA. This wiring matches the specifications of the standard 5 pass-through pairs: 22 gauge wire, 90% shielding, 2.5 ohms resistance, and a maximum carrying capability of 3.0A per wire pair.

10.8 Hydrazine Auxiliary Propulsion System

The Hydrazine Auxiliary Propulsion System (HAPS) improves injection accuracy (*Table 3.1*) and increases payload capability above 600 km by 25 to 120 kg. Contact Orbital to obtain the exact performance capability associated with the HAPS. HAPS is more effective at higher altitude and also permits injection of shared payloads into different orbits. HAPS is available as an optional enhancement to Pegasus.

HAPS, which is mounted inside the Avionics Structure, consists of a hydrazine propulsion subsystem and a Stage 3 separation subsystem. After burnout and separation from the Stage 3 motor, the HAPS hydrazine thrusters provide additional velocity and both improved performance and precise orbit injection.

The HAPS propulsion subsystem (**Figure 10-1**) consists of a centrally mounted tank containing approximately 59 kg (130 lbm) of hydrazine, helium pressurization gas, and three fixed, axially pointed thrusters. The hydrazine tank contains an integral bladder which will support multiple restarts.

10.9 Hydrocarbon Monitoring

Orbital can provide continuous monitoring of hydrocarbon levels during all integrated payload/Pegasus operations. This requires the installation, calibration and frequent round-the-clock monitoring of fixed and portable hydrocarbon (VOC) detectors in the Vehicle Assembly Building, during rollout to Hot Pad, and during Hot Pad operations through fairing closeout. Also required are computer-controlled contamination data recorders and alarming systems, for continuous capture of hydrocarbon level data and remote warning of excessive levels.

10.10 Instrument Purge System

Orbital can provide an instrument purge system capable of delivering GN2 or GHe to a payload. Orbital's quick disconnect system exerts less than 50 lbf on the payload fitting. Orbital also offers the ability to cycle the system up to a flowrate of 40 SCFM with a pressure drop downstream of the Pegasus/OCA interface of less than 75 psi. After fairing closeout on the Hot Pad the payload is limited to a maximum of 703 kg (1550 lbm) of GN2 or 50 kg (110 lbm) of GHe throughout captive carry.

10.11 Load Isolation System

Orbital can provide a Load Isolation System that will lower the fundamental frequencies of the payload to avoid dynamic coupling with the Pegasus fundamental frequencies at drop. This Load Isolation System will decrease volume and mass available to the payload, to be quantified by the frequency modification requirements of the payload.

10.12 Low Tip-Off Rate Payload Attach Fittings

Clamp band separation impulse is one of the primary causes of tip-off on the Pegasus separation system. Reduced Marmon clamp tension is possible for some payloads that are significantly below the structural capabilities of the separation system.

10.13 Downrange Telemetry Support

Orbital has established relationships with a number of government organizations to provide telemetry coverage beyond the capability of the launch-range fixed telemetry assets. These mobile assets can be deployed in advance to an appropriate down range location or in near real-time (airborne systems) to support the acquisition of telemetry from either Pegasus or spacecraft (spacecraft telemetry downlink dependent)

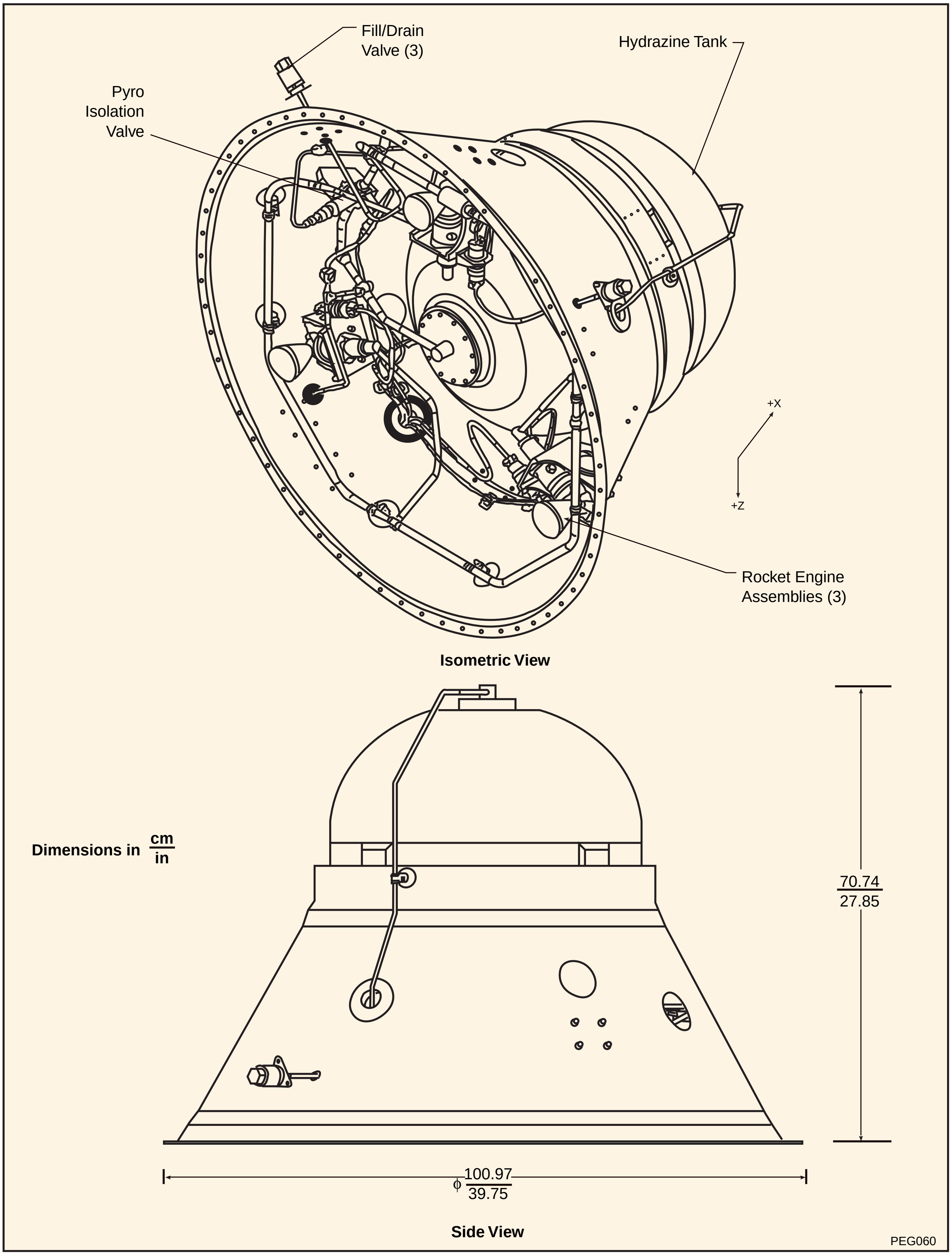


Figure 10-1. *Hydrazine Auxiliary Propulsion System (HAPS).*

telemetry. These systems have been used successfully on a number of Pegasus missions and prove to be a cost-effective means of collecting telemetry for real-time re-transmission or for post-flight data review. Orbital will coordinate spacecraft requirements with the mobile range provider to ensure appropriate operational support and data products are provided to the payload customer.

10.14 Payload Connector Covers

Flight-proven connector covers are available for the payload side of the separation system to cover the 42-pin and 18-pin interface connectors. The connector covers are spring loaded and attach to the standard umbilical support brackets. At payload separation, the spring-loaded aluminum cover snaps closed covering the connector.

10.15 Payload Fit Check Support

Pegasus can send flight and non-flight hardware and test support personnel to the payload contractor site for a fit check. Support hardware (flight fairing, flight or universal frangible joint depending on when fit check is to be performed and payload contractor’s ability to support ordnance operations, mock Stage 2/3 interstage, inert Stage 3, mock avionics section) and technical and engineering support will be sent to the payload contractor’s designated site to support a fairing fit check with flight hardware.

10.16 Payload Propellant Loading

Orbital can provide for full hydrazine or bi-propellant loading services. This service can be performed in the Pegasus Vehicle Assembly Building at Vandenberg AFB, CA.

10.17 Pegasus Separation System Test Unit

Orbital can provide a Pegasus Separation System Test Unit (PSSTU) and Avionics Structure to the payload contractor. The PSSTU is a non-flight separation system that is provided to payload contractors to perform pyroshock characterization testing. The pyroshock test plan should be submitted to Orbital 30 days prior to testing for Orbital concurrence on the use of the PSSTU and Avionics Structure. The PSSTU and Avionics Structure will be delivered to the spacecraft contractor two weeks prior to the required need date for pyroshock testing and returned to Orbital no later than two working days after the conclusion of pyroshock testing. Orbital will review and check the test set up prior to firing the bolt cutters for pyroshock testing. Orbital must witness the test.

The PSSTU may not be used by the payload contractor to perform any testing other than pyroshock characterization and may not be used as a spacecraft build/transportation fixture. Electrical harnessing and connectors for the PSSTU are the responsibility of the payload contractor and will not be supplied by Orbital. Contractor must identify need date of PSSTU at least six months prior to need date.

10.18 Round-the-Clock Payload Support

Pegasus supports a nominal eight-hour per day, five day per week work schedule prior to payload fairing mate. During certain launch vehicle operations, hours will be briefly exceeded. Facility safety requirements dictate that Orbital employees must be present during payload processing. As a non-standard service, payload support requirements prior to payload fairing mate outside these hours can be satisfied.

10.19 Serial Telemetry Interface

Orbital offers a polled payload Serial Telemetry Interface to incorporate payload telemetry data into the Pegasus launch vehicle telemetry downlink. The RS-422/485 interface employs a serial link between the payload and the Pegasus flight computer. The flight computer interrogates the payload at a predetermined rate and receives payload data to be interleaved into the downlinked telemetry stream. The serial stream is radiated to the ground via the Pegasus S-Band network. The telemetry data volume cannot exceed 125 bytes/sec.

10.20 Spin Stabilization Above 60 RPM

As a non-standard service, Orbital can provide the necessary supplies and services to separate payloads into a spin stabilization mode above 60 rpm, the nominal limit.

10.21 Stage 2 Onboard Camera

Pegasus can fly a real-time second stage video system. This self-contained system has a dedicated battery, RF signal transmission system, and two cameras for forward and aft views of the rocket. The cameras switch views as commanded by the flight computer to capture critical staging events and fairing separation. It can also be switched from the LPO control station while in captive carry.

10.22 State Vector Transmission From Pegasus

As a non-standard service, Pegasus can utilize the serial telemetry link with the payload to transmit a state vector from the flight computer directly to the satellite. This state vector will be in a format specified in the Pegasus Serial Telemetry Specification. State vector accuracy will be that of the Pegasus inertial navigation system.

10.23 Thermal Coated Forward Separation Ring

Prior to separation system assembly, Orbital can provide the customer a forward payload separation system ring for application of thermal coating or thermal blankets. All work procedures and added materials must be approved by Orbital in advance of ring shipment.

Appendices

A Payload Questionnaire (PQ) is required from the payload organization for use in preliminary mission analysis. The PQ is the initial documentation of the mission cycle and is needed at least 22 months before the desired launch date. It is not necessary to fill out this PQ in its entirety to begin mission analysis. Simply provide any available information.

Spacecraft Information		
Spacecraft Name		
Spacecraft Owner		
Spacecraft Manufacturer		
Spacecraft Purpose		
Point of Contact		
Mission Information		
Nominal Launch Date		
Launch Window Description		
Mission Timeline		
Trajectory Requirements		
Parameter	**SI Units**	**English Units**
Final Orbit Apogee	km	nmi
Final Orbit Perigee	km	nmi
Final Orbit Inclination	deg	deg
Maximum Apogee Allowable	km	nmi
Minimum Perigee Allowable	km	nmi
Argument of Perigee	deg	deg
Right Ascension of Ascending Node	deg	deg
Apogee Accuracy	km	nmi
Perigee Accuracy	km	nmi
Inclination Accuracy	deg	deg
Argument of Perigee Accuracy	deg	deg
Right Ascension of Ascending Node Accuracy	deg	deg

Propulsion		
Parameter	**SI Units**	**English Units**
Propellant Type, Orbit Insertion		
Propellant Type, Station Keeping		
Multiple Burn Capability?	Y/N	Y/N
Propellant Mass	kg	lbm
Specific Impulse	sec	sec
Mass Properties		
Spacecraft Mass (Maximum or Nominal)	kg	lbm
Spacecraft Coordinate System		
C.M. - Thrust Axis (Origin at Interface Plane)	mm	in
C.M. - Y Axis	mm	in
C.M. - X Axis	mm	in
C.M. - Z Axis	mm	in
C.M. Tolerance - Thrust Axis	± mm	± in
C.M. Tolerance - Y Axis	± mm	± in
C.M. Tolerance - Z Axis	± mm	±
The Coefficients of Inertia Below Are About the Center of Mass		
Coefficients of Inertial - Ixx	kg m^2	slug ft^2
Coefficients of Inertial - Ixx Tolerance	± kg m^2	± slug ft^2
Coefficients of Inertial - Iyy	kg m^2	slug ft^2
Coefficients of Inertial - Iyy Tolerance	± kg m^2	± slug ft^2
Coefficients of Inertial - Izz	kg m^2	slug ft^2
Coefficients of Inertial - Izz Tolerance	± kg m^2	± slug ft^2
Coefficients of Inertial - Ixy	kg m^2	slug ft^2
Coefficients of Inertial - Ixy Tolerance	± kg m^2	± slug ft^2
Coefficients of Inertial - Iyz	kg m^2	slug ft^2
Coefficients of Inertial - Iyz Tolerance	± kg m^2	± slug ft^2
Coefficients of Inertial - Ixz	kg m^2	slug ft^2
Coefficients of Inertial - Ixz Tolerance	± kg m^2	± slug ft^2

Mechanical Interface		
Parameter	SI Units	English Units
Spacecraft Height	mm	in
Spacecraft Diameter	mm	in
Dimensional Drawing/CAD Model		
Payload Separation System Supplier		
Payload Adapter Supplier		
Fairing Access Door Locations		
Mission Specific Hardware		
Electrical Interface		
Pegasus Provided Pryo Commands		
Pegasus Provided Discrete Commands		
Electromagnetic Compatibility		
Payload EMI/RFI Susceptibility	dbµ V/m	MHz
Payload RF Emitters and Receivers		
Source		
Function		
Role		
Band		
Frequency		
Bandwidth		
Power Output		
Sensitivity		
Thermal Environment		
Prelaunch Temperature Range	°C	°F
Prelaunch Relative Humidity Range	%	%
Maximum Prelaunch Gas Impingement Velocity	m/sec	ft/sec
Maximum Ascent Heat Flux	W/m^2	BTU/hr ft^2
Maximum Free-Molecular Heat Flux	W/m^2	BTU/hr ft^2
Maximum Fairing Ascent Depressurization Rate	mbar/sec	psi/sec

Dynamic Environment		
Parameter	**SI Units**	**English Units**
Maximum Allowable Flight Accuracies	dB OA	dB OA
Allowable Acoustics Curve		
Maximum Allowable Sine Vibration	Grms	Grms
Allowable Sine Vibration Curve		
Maximum Allowable Shock	g	g
Allowable Shock Curve		
Maximum Lateral Acceleration	g	g
Maximum Longitudinal Acceleration	g	g
Fundamental Frequency - Lateral	Hz	Hz
Fundamental Frequency - Longitudinal	Hz	Hz
Contamination Control		
Fairing Air Cleanliness	Class	Class
Maximum Deposition on Spacecraft Surfaces	mg/m^2	$grains/ft^2$
Outgassing - Total Weight Loss	%	%
Outgassing - Volatile Condensable Material Weight Loss	%	%
Orbital Injection Conditions		
Maximum Allowable Tip-Off Rate	deg/sec	deg/sec
Spin-Up Required at Separation?	Y/N	Y/N
Desired Spin-Up Rate	rpm	rpm
Pointing Requirement		
Maximum Allowable Pointing Error	± deg	± deg

The following questions pertain to Pegasus Launch Operations and should be provided to Orbital as soon as possible after contract start:

Flightline Operations

1. Provide a brief description of any testing to be performed at the flightline on the day of launch operations:

2. What is the maximum expected duration of the testing?
   - ☐ <30 minutes
   - ☐ <60 minutes
   - ☐ >60 minutes (provide further detail)

3. Will the testing involve GSE or ASE?
   - ☐ GSE
   - ☐ ASE

4. Provide a brief description of types of closeouts expected at the flightline on the day of launch operations
   - ☐ Mechanical:
   - ☐ Electrical:
   - ☐ Software:

5. What is the total maximum expected duration of these closeouts?
   - ☐ <30 minutes
   - ☐ <60 minutes
   - ☐ >60 minutes (provide further detail)

6. Specify any transition of spacecraft control/monitor functions from GSE or ASE?

7. Provide a brief description of any timers or restrictions associated with flightline closeouts (e.g., battery plugs, solar array deployment, etc.)

8. Specify payload LPO readback actions required during captive carry:
   - ☐ Telemetry:
   - ☐ Power Supply:
   - ☐ Heaters:
   - ☐ Other (specify):

9. Is telemetry available to ground or LPO or both?
   - ☐ LPO
   - ☐ Ground

10. Describe any final configuration functions the payload LPO must perform during captive carry (e.g., keyboard input commands, power down payload trickle charge, etc.):

Safety Operations

11. Are there any unique LPO safety monitor systems?
    - ☐ Yes (provide description)
    - ☐ No

Power Down/Power Up

12. Provide a brief description of Spacecraft configuration steps in the event Pegasus cycles power during ground operations:

Abort Operations

13. In the event of an abort, describe any payload LPO re-configuration operations (e.g., battery trickle charge power up, etc.):

14. In the event of an abort, is there any GSE required immediately upon landing?

15. In the event of a return to remote landing site, are there any unique GSE transportation issues?

1.0 Wiring

Orbital provides one 42-pin umbilical harness dedicated for payload use. The standard interface connects the payload to the Pegasus flight computer as well as to the Launch Panel Operator Station located in the carrier aircraft. All wiring shall be 22 AWG. Twisted Shielded Pair (TSP) passthroughs shall not exceed 3 A current per wire pair.

The standard connector is configured as shown in **Figure B-1**.

Connector Function Allocation	Number of Wires
5 Payload Passthrough Pairs	10
1 RS-422 Bi-Directional Serial Interface	4
4 Discrete Talkback Inputs (Breakwire-Type) to Pegasus Flight Computer	8
8 Discrete Commands from Pegasus Flight Computer to Payload	16
1 Payload Separation Sense to Pegasus Flight Computer	2
1 Spare Wire Pair	2

PEG061

Figure B-1. *Standard Payload Electrical Connections.*

2.0 Connectors

Figure B-2 defines the pin assignments for the standard payload interface connector at the separation plane. The connectors are as follows:

Launch vehicle side: 42 pin plug with pin contacts:

MS-27484T-16F-42P

Payload side: 42 pin receptacle with socket contacts:

MS-27474T-16F-42S

Orbital will provide the payload contractor with the payload half of the electrical separation connectors for integration into the payload harness.

3.0 Non-Standard Interfaces

Depending on the mission, non-standard interfaces may still be accommodated on the interface connectors by taking advantage of unused functions.

Pin	Name	Function	Standard Destination
1	PPT1 +	Payload Passthrough 1 +	LPO Station
2	PPT1 -	Payload Passthrough 1 -	
3	PPT2 +	Payload Passthrough 2 +	LPO Station
4	PPT2 -	Payload Passthrough 2 -	
5	PPT3 +	Payload Passthrough 3 +	LPO Station
6	PPT3 -	Payload Passthrough 3 -	
7	PPT4 +	Payload Passthrough 4 +	LPO Station
8	PPT4 -	Payload Passthrough 4 -	
9	PPT5 +	Payload Passthrough 5 +	LPO Station
10	PPT5 -	Payload Passthrough 5 -	
11	CMD1 +	Discrete Command 1 +	FC Discrete Output 9
12	CMD1 -	Discrete Command 1 -	
13	CMD2 +	Discrete Command 2 +	FC Discrete Output 10
14	CMD2 -	Discrete Command 2 -	
15	CMD3 +	Discrete Command 3 +	FC Discrete Output 11
16	CMD3 -	Discrete Command 3 -	
17	CMD4 +	Discrete Command 4 +	FC Discrete Output 12
18	CMD4 -	Discrete Command 4 -	
19	CMD5 +	Discrete Command 5 +	FC Discrete Output 13

Figure B-2. *Payload Interface Connector Pin Assignments for P-65/J-2 Connector.*

PEG062A

Pin	Name	Function	Standard Destination
20	CMD5 -	Discrete Command 5 -	
21	CMD6 +	Discrete Command 6 +	FC Discrete Output 14
22	CMD6 -	Discrete Command 6 -	
23	CMD7 +	Discrete Command 7 +	FC Discrete Output 15
24	CMD7 -	Discrete Command 7 -	
25	CMD8 +	Discrete Command 8 +	FC Discrete Output 16
26	CMD8 -	Discrete Command 8 -	
27	P/L SEP +	Payload Separation Sense +	FC Discrete Input 10
28	P/L SEP -	Payload Separation Sense -	
29	TB1 +	Discrete Talkback 1 +	FC Discrete Input 5
30	TB1 -	Discrete Talkback 1-	
31	TB2 +	Discrete Talkback 2 +	FC Discrete Input 6
32	TB2 -	Discrete Talkback 2 -	
33	TB3 +	Discrete Talkback 3 +	FC Discrete Input 7
34	TB3 -	Discrete Talkback 3 -	
35	TB4 +	Discrete Talkback 4 +	FC Discrete Input 8
36	TB4 -	Discrete Talkback 4 -	
37	TLM TXD +	RS-422/485 TXD +	FC Serial Channel 12
38	TLM TXD -	RS-422/485 TXD -	
39	TLM RXD +	RS-422/485 RXD +	
40	TLM RXD -	RS-422/485 RXD -	
41	Spare	Spare	N/A
42	Spare	Spare	

Figure B-2. *Payload Interface Connector Pin Assignments for P-65/J-2 Connector (continued).* PEG062B

1.0 Ground Support Services

The payload processing area within the VAB will be made available to the payload 30 calendar days prior to launch for independent payload check-out. This area is intended to allow payload preparations prior to mate.

All work performed within the VAB is scheduled through the Orbital Site Manager. Orbital will support and schedule all payload hazardous or RF test operations conducted within the VAB which require Range notification or approval.

2.0 Payload Servicing Areas

The VAB includes a payload preparation area accessible via motorized roll-up doors and double doors. Personnel access is via separate doors. Separate areas in the facility are designated for payload servicing, test, and integration with sufficient space for payload-specific checkout equipment.

The VAB is temperature and humidity controlled and kept "visibly clean." A soft-walled clean room is available if required for cleanliness levels greater than visibly clean for payload preparation and mating. The cleanroom will enclose Pegasus Stage 3 during processing as shown in **Figure C-1**. Floor loading is consistent with a fully loaded Pegasus on its AIT.

3.0 Available Ground Support Equipment

The VAB is equipped with 552 Kpa (80 psi) compressed air and 115 VAC/220 VAC 3 phase power. Overhead sodium lamps provide a minimum of 824 lux (75 ft-candles) of illumination in the payload and vehicle processing areas. Full lightning protection and dedicated extended building grounding comply with the standards for ordnance processing. Conductive floor surface and continuous grounding strips support the full building and personnel antistatic disciplines.

All personnel are required to wear leg stats when working near the rocket in the high bay areas of the VAB. Access to the integration facility is strictly controlled with a badging system. The number of payload personnel allowed in the entire facility is limited to no more than 10 at any time whenever Pegasus motors are in the facility. This requirement will vary depending on total facility activities and is driven by operational safety constraints.

Orbital will provide a forklift, hydraulic lift table, 5-ton bridge crane, and 1-ton cleanroom crane for payload handling, as needed. Any payload specific handling hardware required for interfacing with the lift table or crane (e.g. handling crane, rotation fixture, attachments, test equipment, etc.) should be supplied by the payload unless other arrangements have been made.

4.0 Payload Work Areas

Orbital will provide approximately 37 m^2 (400 ft^2) of work space in the west coast VAB for payload use starting 30 calendar days prior to a planned launch operation and extending to one week after launch. Approximately 9 m^2 (100 ft^2) of administrative office space will be provided at a site close to the VAB.

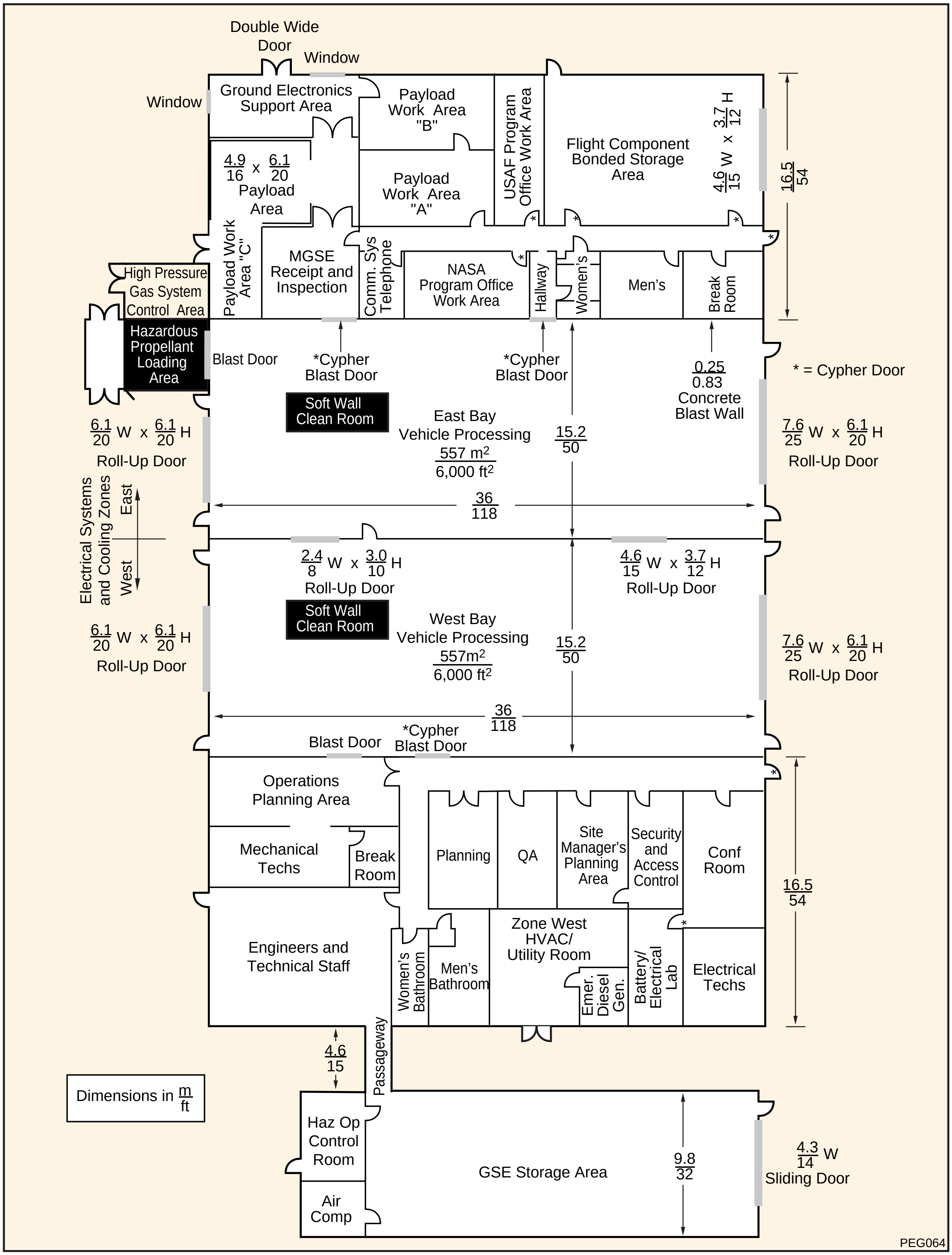


Figure C-1. *The Vandenberg Vehicle Assembly Building General Layout.*

1.0 Introduction

Pegasus's air-launched design vastly increases launch point flexibility. Some ground support is required to insure the safety of the people and property, to communicate with the carrier aircraft and to provide data collection and display. This support is usually provided by a federal Major Range and Test Facility Base (MRTFB) such as the Eastern Range, Patrick AFB, FL; Western Range, Vandenberg AFB, CA; and Wallops Flight Facility, VA.

Pegasus has also been supported by the Wallops Mobile Range for launch from foreign soil such as from the Canary Islands, Spain. The use of a certified mobile range satisfies requirements of the Department of Transportation to enable a licensed commercial launch.

To assist customers who may wish to launch from a specific geographic location, this Appendix D summarizes the capabilities needed. This support could be provided by any facility meeting the following requirements:

2.0 Range Safety

2.1 Trajectory Analysis

The planned trajectory must be analyzed to determine if any populated areas will be overflown and if the risk is acceptable. Impact limit lines must be developed to insure that the instantaneous impact point (IIP) of any stage or debris does not impact inhabited land. Reference the Eastern and Western Range, Range Safety Requirements Document (EWR 127-1) for detailed requirements and risk limitations.

2.2 Area Clearance and Control

The airspace surrounding the launch area must be cleared and controlled during the mission. Notices to airmen and mariners must be sent to clear the airspace and the predicted impact points of the spent stages and known debris.

2.3 Range Safety Displays

Visual display of the present position and IIPs must be available to the safety personnel to verify that no safety criteria are violated. This requires redundant tracking sources such as radar or telemetry guidance data. Pegasus is equipped with a C-Band tracking transponder and provides position data in the telemetry downlink.

2.4 Flight Termination System

Pegasus is equipped with command receivers that operate at either 416.5 or 425.0 MHz. They are capable of receiving commands utilizing the standard four tone alphabet. The command transmitter system must meet federal standards as described in EWR 127-1.

2.5 FTS Controllers

Certified FTS Controllers must meet the federal standards described in EWR 127-1.

3.0 Telemetry

Pegasus downlinks telemetry data in the S-band and upper S-band frequency range (2,200-2,300 and 2,300-2,400 Mhz). A telemetry system must be capable of tracking, receiving and recording this data. The OCA has onboard video cameras and this data is transmitted via a telemetry system that operates in the upper S-band range. A chase aircraft is normally used and it also downlinks telemetry. A separate telemetry system is required to track, receive and record this data.

4.0 Communications

4.1 Air to Ground

Air to ground communications are required to communicate with the carrier aircraft during the launch operations. This can be in the HF, VHF or UHF frequency range.

4.2 Voice Nets

Voice nets are required for communications between the various controllers involved in the operation. Four to eight nets are required.

5.0 Control Center

The launch team requires a control center to conduct the launch countdown. This center requires a minimum of twenty consoles with voice nets and video displays. The consoles must have the capability to remote key the radios for communications with the carrier and chase aircraft.

6.0 Data Requirements

6.1 Realtime Data

Realtime telemetry data must be provided to Orbital computers for logging and conversion to video displays. This data is used to monitor the health and status of the rocket and payload.

6.2 Video Distribution System

A video distribution system is required capable of displaying a minimum of twelve video screens.

6.3 Recording

Recording of all the telemetry downlinks is required.

6.4 IRIG Timing

IRIG timing is required.

6.5 Weather Forecasts

Weather forecasts are required.

7.0 Optional Launch Ranges

Figure D-1 summarizes the additional launch ranges available for Pegasus use, along with the inclinations that are achievable from each range. In addition, Orbital can as an optional service, launch Pegasus XL to low inclination easterly orbits from alternative launch sites.

Range		Achievable Inclinations(1) (Direct)
Established Launch Sites	Western Range (Baseline)	70° to 130°
	Eastern Range (Option)	28° to 51°
	Wallops Flight Facility (Option)	38° to 55°
Alternative Launch Sites	Alcantara (Future)	Equatorial
	Kwajalein (Future)	Equatorial
	Mission Unique Location (Requires Mobile Range)	To Be Determined

Note: (1)A broader range of inclinations may be achievable from each point, subject to additional analyses and coordination with range authorities. Additionally, lower inclinations than those indicated for each range can be achieved through dog-leg trajectories, with a commensurate reduction in performance. Some specific inclinations within these ranges may be limited by stage impact point or other restrictions.

PEG065

Figure D-1. *Optional Launch Ranges and Achievable Inclinations.*

Flight Number	Launch Date	Vehicle Type	Customer(s)	Payload	Payload Mission	Target Orbit
XF1	4/5/90	Standard	DoD/NASA DoD	PegaSat SECS	• Flight Test Instrumentation • Atmospheric Research • Communications Experiment	320.0 x 360.0 nm @ 94.00° i
XF2	7/19/91	Standard w/HAPS	DoD	7 MicroSats	• Tactical Communications Network	389.0 x 389.0 nm @ 82.00° i
F3	2/9/93	Standard	INPE Brazil Orbital	SCD-1 OXP-1	• Data Communications • Communications Experiment	405.0 x 405.0 nm @ 25.00° i
F4	4/25/93	Standard	DoD/DoE Orbital	ALEXIS OXP-2	• Technology Validation • Communications Experiment	400.0 x 400.0 nm @ 70.00° i
F5	5/19/94	Standard w/HAPS	DoD	STEP-2	• Technology Validation	450.0 x 450.0 nm @ 82.00° i
F6	6/27/94	XL	DoD	STEP-1	• Technology Validation	400.0 x 400.0 nm @ 70.00° i
F7	8/3/94	Standard	DoD	APEX (PegaStar)	• Technology Validation	195.0 x >1000 nm @ 70.02° i
F8	4/3/95	Standard (Hybrid)	ORBCOMM NASA	FM1 &FM2 MicroLab	• Communications • Atmospheric Research	398.0 x 404.0 nm @ 70.00° i
F9	6/22/95	XL	DoD	STEP-3	• Technology Validation	195.0 x >1000 nm @ 70.02° i
F10	3/8/96	XL	DoD	REX-2	• Technology Validation	450.0 x 443.0 nm @ 90.00° i
F11	5/16/96	Standard (Hybrid)	BMDO	MSTI-3	• Technology Validation	298.0 x 394.0 km @ 97.13° i
F12	7/2/96	XL	NASA	TOMS	• Atmospheric Research	340.0 x 955.0 km @ 97.40° i
F13	8/21/96	XL	NASA	FAST	• Space Physics Research	350.0 x 4200.0 km @ 83.00° i
F14	11/4/96	XL	NASA	SAC-B HETE	• Space Physics Research	510.0 x 550.0 km @ 38.00° i
F15	4/21/97	XL	INTA Spain	MINISAT 01	• Space Physics Research	587.0 x 587.0 km @ 151.01° i
F16	8/1/97	XL	Orbital/ NASA	OrbView-2	• Ocean Color Imaging	310.0 x 400.0 km @ 98.21° i
F17	8/29/97	XL	DoD	FORTE	• Technology Validation	800.0 x 800.0 km @ 70.00° i
F18	10/22/97	XL	DoD	STEP-4	• Technology Validation	430.0 x 510.0 km @ 45.00° i
F19	12/23/97	XL w/HAPS	ORBCOMM-1	8 ORBCOMM Satellites	• LEO Communications	825.0 x 825.0 km @ 45.00° i
F20	2/25/98	XL	NASA Teledesic	SNOE BATSAT (T-1)	• University Science Payload • Commercial Telecommunications Test Payload	580.0 x 580.0 km @ 97.75° i
F21	4/1/98	XL	DoD/NASA	TRACE	• Space Physics Research	600.0 x 650.0 km @ 97.88° i

Flight Number	Launch Date	Vehicle Type	Customer(s)	Payload	Payload Mission	Target Orbit
F22	8/2/98	XL w/HAPS	ORBCOMM-2	8 ORBCOMM Satellites	• LEO Communications	818.5 x 818.5 km @ 45.02° i
F23	9/23/98	XL w/HAPS	ORBCOMM-3	8 ORBCOMM Satellites	• LEO Communications	818.5 x 818.5 km @ 45.02° i
F24	10/22/98	Standard (Hybrid)	INPE Brazil NASA	SCD-2 Wing Glove	• Data Communications • Atmospheric Experiment	750.0 x 750.0 km @ 25.00° i
F25	12/5/98	XL	NASA	SWAS	• Space Physics Research	635.0 x 700.0 km @ 70.00° i
F26	3/4/99	XL	NASA	WIRE	• Space Physics Research	540.0 x 540.0 km @ 97.56° i
F27	5/17/99	XL w/HAPS	NASA Orbital SSG	TERRIERS MUBLCOM	• University Science Payload • Technology Validation	550.0 x 550.0 km @ 97.75° i 775.0 x 775.0 km @ 97.75° i
F28	12/4/99	XL w/HAPS	ORBCOMM-4	7 ORBCOMM Satellites	• LEO Communications	825.0 x 825.0 km @ 45.02° i
F29	6/7/00	XL w/HAPS	Orbital SSG/DoD	TSX-5	• Military Technology Demonstration	405.0 x 1,750.0 km @ 69.00° i