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Pegasus® User's Guide

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This Pegasus® User's Guide is intended to familiarize potential space launch vehicle users with the Pegasus launch system, its capabilities and 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.

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LIST OF ACRONYMS

3DOF	Three Degrees of Freedom
6DOF	Six Degrees of Freedom
A, Amps	Amperes
AACS	Airborne Air Conditioning System
ac	Alternating Current
A/C	Air Conditioning
AFB	Air Force Base
AIT	Assembly and Integration Trailer
ARAR	Accident Risk Asessment Report
ARO	After Receipt of Order
ASE	Airborne Support Equipment
ATP	Authority to Proceed
AWG	American Wire Gauge
C/CAM	Collision/Contamination Avoidance Maneuver
C	Centigrade
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
DoD	Department of Defense
DoT	Department of Transportation
DPA	Dual Payload Adapter
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
FAS	Fin Actuation System
fps	Feet Per Second
FRR	Flight Readiness Review
ft	Feet
FTS	Flight Termination System
g	Gravity
GCL	Guidance and Control Lab
GN2	Gaseous Nitrogen
GN&C	Guidance, Navigation, and Control
GOP	Ground Operations Plan
GPS	Global Positioning System (NAVSTAR)
Grms	Gravity Root Mean Squared
GSE	Ground Support Equipment

H/W	Hardware
h	Height
HAPS	Hydrazine Auxiliary Propulsion System
HEPA	High Efficiency Particulate Air
HF	High Frequency
HVAC	Heating, Ventilating, and Air Conditioning
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/s	Meters Per Second
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
MPS	Mission Planning Schedule
MRR	Mission Readiness Review
ms	Millisecond
MSD	Mission Specification Document
MSPSP	Missile System Prelaunch Safety Package
MUX	Multiplexer
N2	Nitrogen
N/A	Not Applicable
N	Newtons

NASA	National Aeronautics and Space Administration	rpm	Revolutions Per Minute
NRTSim	Non-Real-Time Simulation	RTB	Return to Base
nm	Nautical Miles	RSS	Root Summed Squared
NTE	Not To Exceed	RTV	Room Temperature Vulcanizing
OASPL	Overall Sound Pressure Level	S&A	Safe & Arm
OCA	Orbital Carrier Aircraft	S/N	Serial Number
OD	Operations Directive	S/W	Software
OR	Operations Requirements Document	scfm	Standard Cubic Feet Per Minute
Orbital	Orbital Sciences Corporation	sec	Second(s)
P/L	Payload	SSPP	System Safety Program Plan
PA	Payload Adapter	SWC	Soft Wall Cleanroom
PDR	Preliminary Design Review	TLM	Telemetry
PDU	Pyrotechnic Driver Unit	T.O.	Take-Off
PLF	Payload Fairing	TPS	Thermal Protection System
POST	Program to Optimize Simulated Trajectories	TT&C	Telemetry, Tracking & Commanding
		TVC	Thrust Vector Control
PPWR	P Power	UDS	Universal Documentation System
PRD	Program Requirements Document	UFS	Ultimate Factory of Safety
psf	Pounds Per Square Foot	USAF	United States Air Force
psi	Pounds Per Square Inch	V	Volts
psig	Pounds per Square Inch Gauge	VAB	Vehicle Assembly Building
PSP	Program Support Plan	VAFB	Vandenberg Air Force Base
PSSTU	Pegasus Separation System Test Unit	VDC	Volts Direct Current
PTRN	P Turn	VHF	Very High Frequency
PTS	Power Transfer Switch	VSWR	Voltage Standing Wave Ratio
PWP	Pegasus Work Package	VT	Verification Test
QA	Quality Assurance	WFF	Wallops Flight Facility
RCS	Reaction Control System	WR	Western Range (USAF)
RF	Radio Frequency	XL	Extended Length (Pegasus)
		YFS	Yield Factor of Safety

1. 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 21 years, the "winged rocket" known as Pegasus has proven to be the most successful in its class, placing over 78 satellites in orbit with 40 launches as of April 2010.

Figure 1-1. Pegasus Rollout

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 launch system that has demonstrated 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 (VAB) at Vandenberg Air Force Base (VAFB), California;
- Horizontal payload integration;
- Shared payload launch accommodations for more cost-effective access to space as compared to Dual Launches;
- Portable air-launch capability from worldwide locations to satisfy unique mission requirements; and
- Fast, cost-effective, and reliable access to space.

The mobile nature of Pegasus allows Orbital to integrate the spacecraft to the Pegasus XL in our integration facility, the VAB, 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 demonstrated 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

Figure 1-2. Pegasus Launch Locations

vehicle approach is an example of the Pegasus way of providing customer oriented launch service.

In the interest of continued process improvement and customer satisfaction, the Pegasus Program successfully completed a 1-year effort of ISO 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 qualityproduct and service. Since that time, Orbital has achieved third party certification to ISO9001:2008 and AS9100B, providing even greater assurance of mission success. In addition to our AS9100B certification, NASA has granted the Pegasus XL Launch Vehicle a Category 3 certification that qualifies Pegasus to launch NASA's highest value spacecraft.

Pegasus is a customer oriented and responsive launch vehicle system. From Pegasus' com-

mercial 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 21-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.

2. PEGASUS DESCRIPTION

The Pegasus User's Guide is dedicated to the discussion of the Pegasus XL configuration, capabilities, and associated services.

2.1. Pegasus XL Vehicle Description

Pegasus XL is a winged, three-stage, solid rocket booster that 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 OCA to a level flight condition of about 11,900 m (39,000 ft) and Mach 0.82. 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 2-1. Pegasus XL on the Assembly and Integration Trailer (AIT)

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

- 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 and manufacturability. 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 a base frangible joint, 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 in the nose is released with a pyrotechnic separation nut. The base of the fairing is separated with
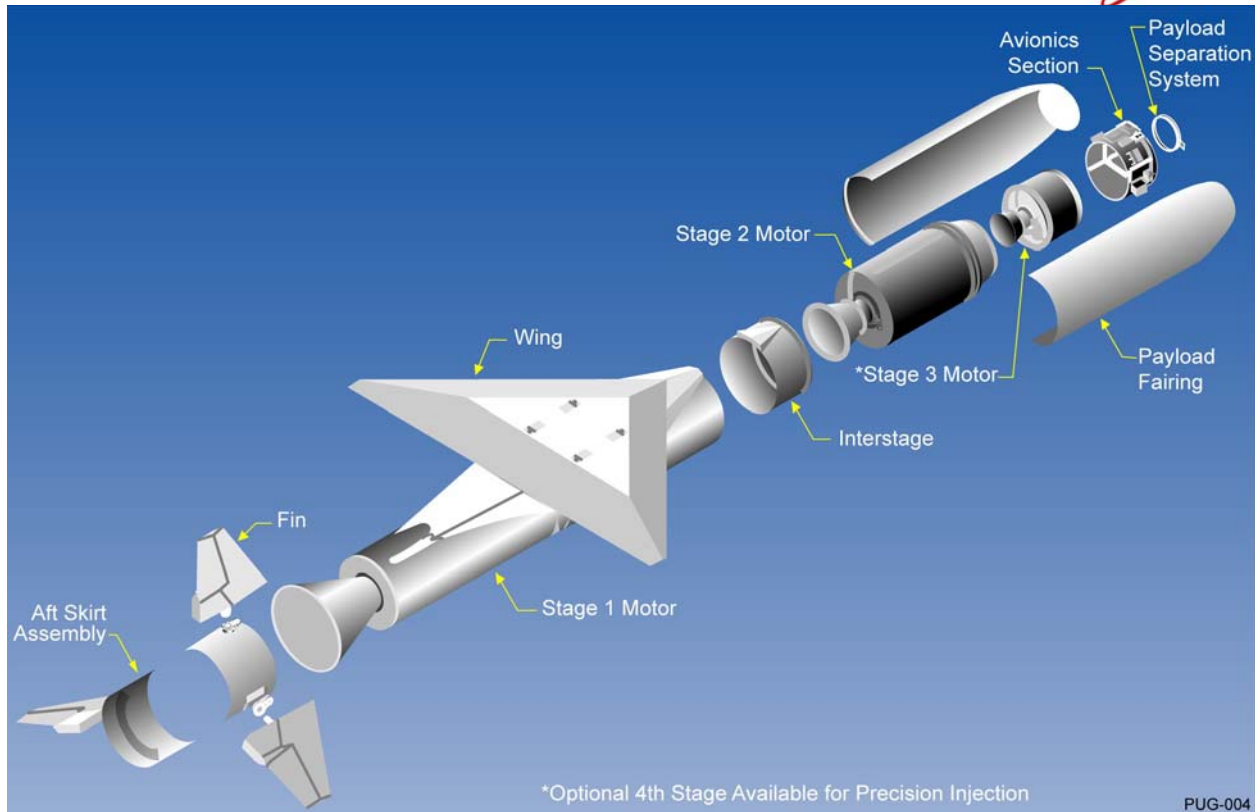
Figure 2-2. Expanded View of Pegasus XL Configuration

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 developments in hardware, software, communi-

cations, 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 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.
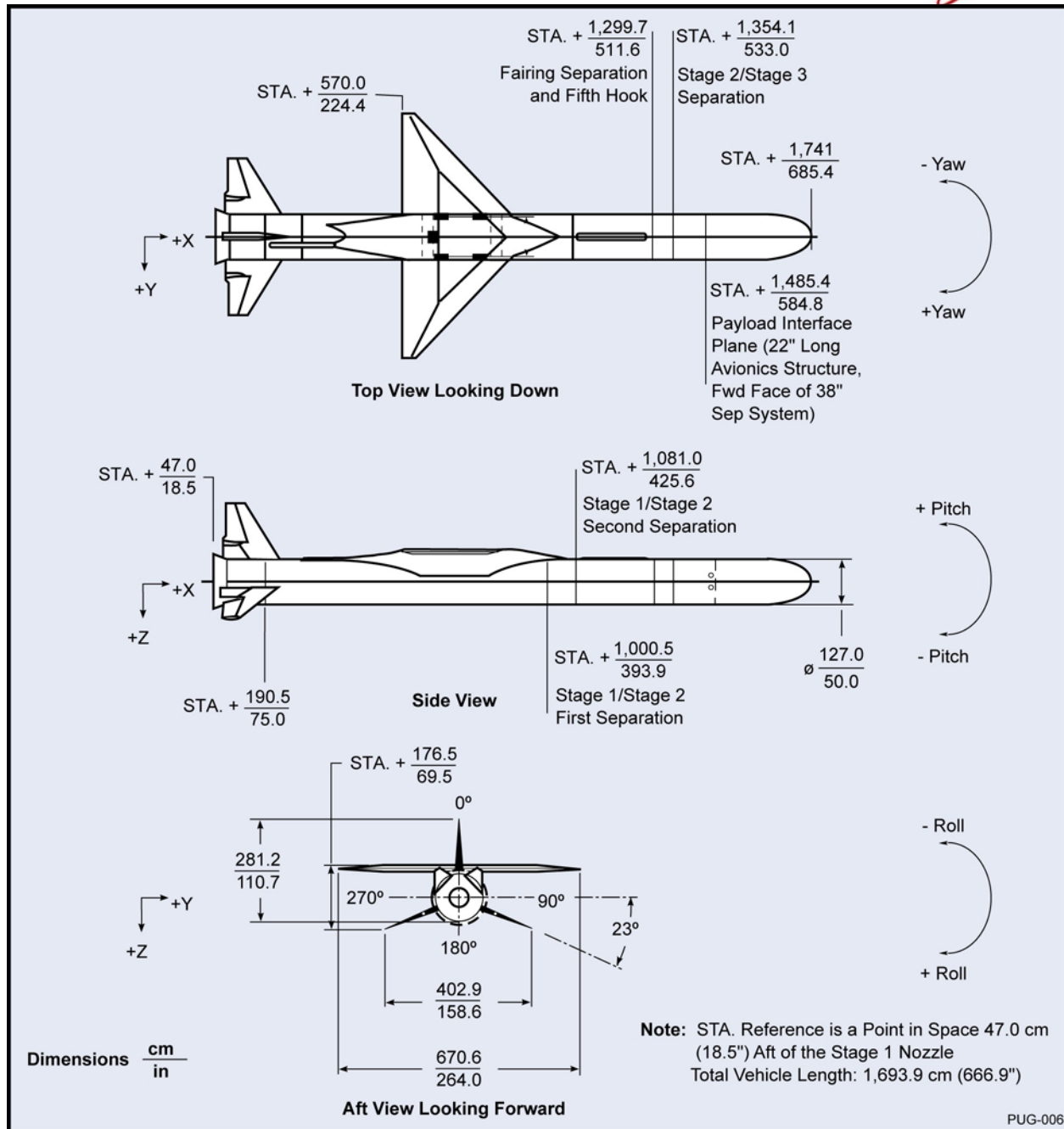
Figure 2-3. Principle Dimensions of Pegasus XL (Reference Only)

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. Stage 2 and Stage 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 (lbm)	1,369 (3,019)	416 (918)	126 (278)
Propellant Weight (2)	kg (lbm)	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	Degrees (^{0})	NA	3	3

Notes: (1) Including Wing Saddle, Truss, and Associated Fasteners
(2) Includes Igniter Propellants
(3) At 21C (70 F)
(4) To 207 kPa (30 psi)
(5) Delivered (Includes Expended Inerts)   NLS-074a

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

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 GN2 Reaction Control System (RCS) 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 is 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 nonstandard 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 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 that provide the structural interface between the Pegasus and the OCA.

Approximate Time (sec)	Event	Guidance Mode	Attitude Mode
0	Drop	Open-Loop	Inertial Euler Angles
5	S1 Ignition	Open-Loop	Inertial Euler Angles
16	Maximum Pitch Up	Open-Loop	Nz Limit
30	Pitch Down	Open-Loop	Inertial Euler Angles
65	Minimize Angle of Attack	Open-Loop	Gravity Turn
87	Begin S2 Powered Explicit Guidance (PEG)		Gravity Turn
90	Fins Zeroed		Gravity Turn
91	S2 Ignition	Closed-Loop PEG	Command Attitude
190	Begin S3 PEG Calculations		Attitude Hold
500 (variable)	S3 Ignition	Closed-Loop PEG	Command Attitude
575	Payload Events as Required		Command Attitude

PUG-008a

Figure 2-5. Typical Attitude and Guidance Modes Sequence

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 a 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 early in the processing flow.

2.2. Orbital Carrier Aircraft

Orbital furnishes and operates the 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 or from the Reagan Test Site from the Kwajalein Atoll, as well as equatorial missions from the Kwajalein Atoll. 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 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 across the United States or across the ocean (depending on landing site) to support ferry and campaign missions.

3. GENERAL PERFORMANCE CAPABILITY

This section describes the orbital performance capabilities of the Pegasus XL vehicle with and without the optional 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, the optional HAPS will provide additional performance at higher altitudes, as well as providing a more accurate insertion orbit capability.

From the 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), Reagan Test Site (RTS) Kwajalein, 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 the WR. These events will vary based on mission requirements.

The typical launch sequence begins with release of Pegasus from the carrier aircraft at an altitude of approximately 11,900 m (39,000 ft) and a speed of Mach 0.82. Approximately 5 seconds after drop, when 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 30 seconds after ignition. At approximately 15-20 seconds, a maneuver is initiated to depress the trajectory and the vehicle transitions to progressively lower angles of attack.

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 112,000 m (366,000 ft) and 121 seconds after drop. Stage 2 burnout is followed by a long coast, during which the payload and Stage 3 achieve orbital altitude. For a non-HAPS Pegasus configuration, 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.

An FAS, in conjunction with three aerodynamic fins, provides attitude control from drop through Stage 1 separation. Pitch and yaw attitude control during Stage 2 and Stage 3 powered flight is provided by the motor TVC system while roll attitude is controlled by the nitrogen cold gas RCS. The RCS also provides three-axis control during coast phases of the trajectory.
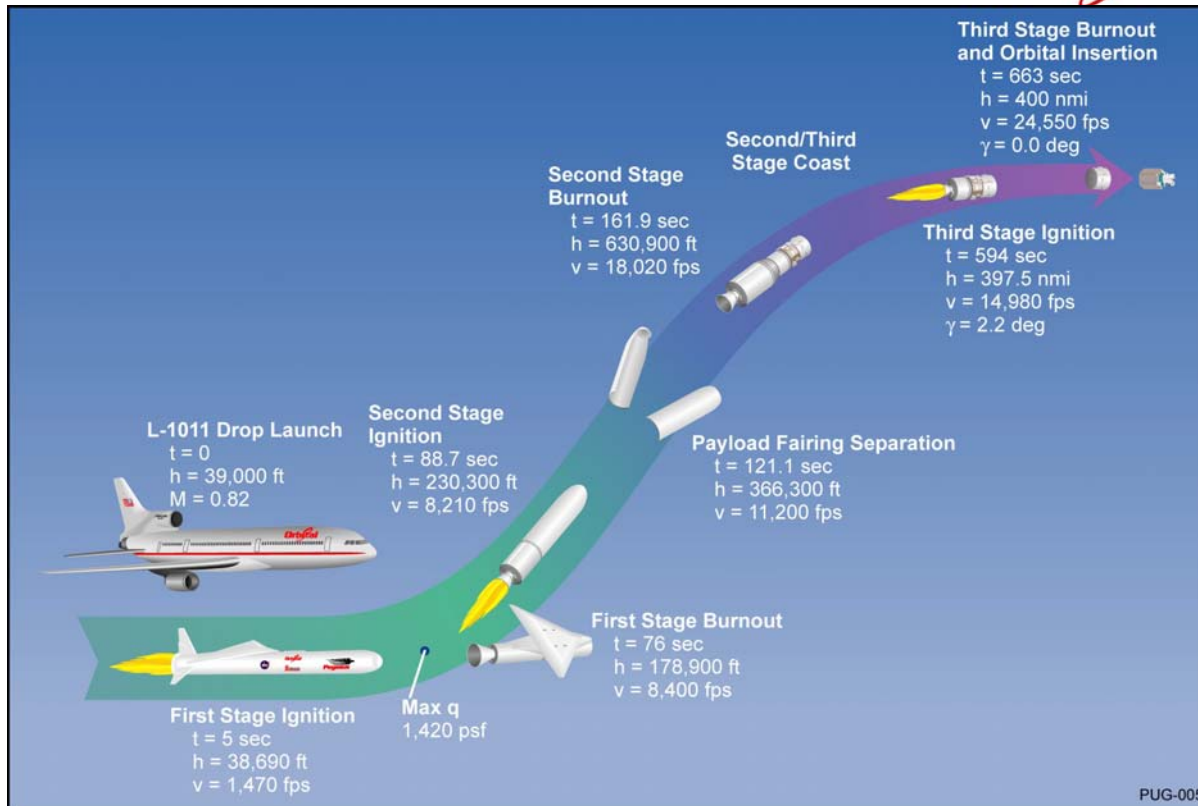
Figure 3-1. Pegasus XL Mission Profile to 741 km (400nmi) Circular, Polar Orbit with a 227 kg (501 lbm) Payload

3.2. Performance Capability

Performance capabilities to various orbits for the Pegasus XL are illustrated in Figure 3-3 and Figure 3-4 (HAPS configuration). These performance data were generated using the Program to Optimize Simulated Trajectories (POST), which is described below. Precise performance capabilities to specific orbits are typically provided per the documentation schedule shown in Section 8.0.

3.3. Trajectory Design Optimization

Orbital designs a unique mission trajectory for each Pegasus flight to maximize payload performance while complying with any applicable payload and launch vehicle constraints. In this process, a 3DOF simulation is developed using the current Pegasus mass properties, aerodynamic models, and motor ballistics data, and the desired target orbit and any applicable trajectory constraints are specified. POST then

uses a set of specified control parameters to iterate on the trajectory design until an optimal solution is identified which maximizes performance to the desired target orbit subject to the specified constraints. Typically, these constraints may include limitations on the angle of attack profile, dynamic loading constraints, payload environmental constraints such as heat rate, and Range-imposed constraints on the launch azimuth and spent stage impact locations. After POST has been used to determine the optimal trajectory design, a high-fidelity, Pegasus-specific, 6DOF simulation is then developed to conduct detailed trajectory analyses to verify the acceptability of the trajectory design and to verify robust control system stability margins.

3.4. Orbit Insertion Accuracy

The estimated orbit insertion errors for Pegasus vary from mission to mission and are influenced by a variety of factors including the target orbit,
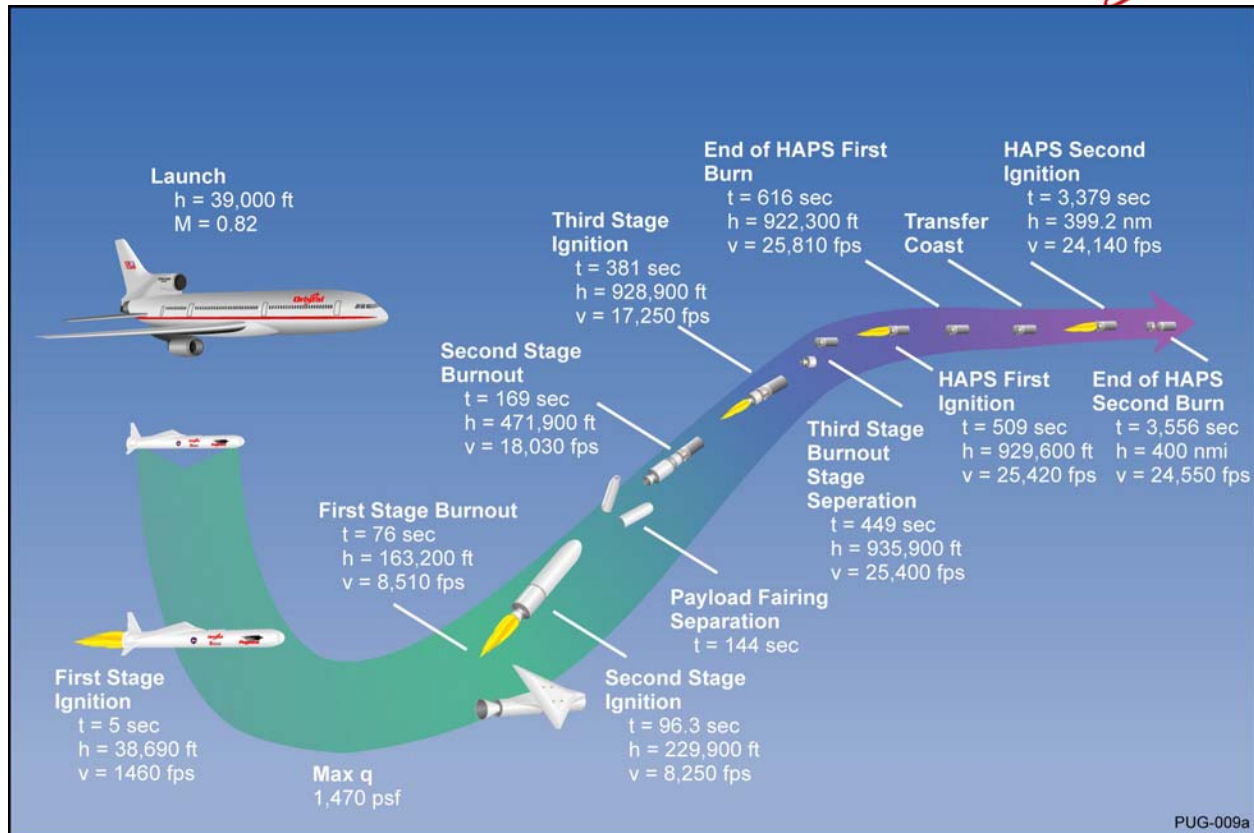
Figure 3-2. Pegasus XL with HAPS Mission Profile to 741 km (400nmi) Circular, Polar Orbit with a 227 kg (501 lbm) Payload

trajectory design, payload mass, and the guidance strategy requested by the payload. As a result, the specific Pegasus orbit accuracy capabilities for a particular mission are generally determined only after these mission-specific details are defined and detailed mission-specific analyses have been performed. However, Figure 3-5 provides estimates of 3-sigma orbit insertion errors for both Pegasus XL and Pegasus XL with HAPS vehicle configurations, which are representative of typical Pegasus missions. For non-HAPS configurations, these errors are generally dominated by the impulse variability associated with Stage 3. This variability is also responsible for the generally larger magnitude errors for the non-insertion apse relative to the insertion apse.

3.4.1. Actual Pegasus Insertion Accuracies

Figure 3-6 shows the actual Pegasus orbital insertion accuracies achieved for all missions since Flight 10. As this figure demonstrates, a

large majority of these missions resulted in perigee and apogee altitudes within 30 km of the desired target values and inclination errors of less than 0.05 degrees.

3.4.2. Error-Minimizing Guidance Strategies

Due to the large amount of actual flight experience Pegasus has accumulated to date, the Pegasus Program has been able to continually refine and improve the fidelity and accuracy of the Pegasus vehicle simulation. This process has allowed us to develop a high degree of confidence in the Pegasus simulation analysis results and to accurately predict mission performance in flight.

To ensure that even a 3-sigma low-performing Pegasus vehicle will achieve the required orbit, Pegasus trajectories include a 67 m/sec (220 ft/sec) guidance reserve. Pegasus flight software provides the capability to manage this reserve through the use of a variety of different
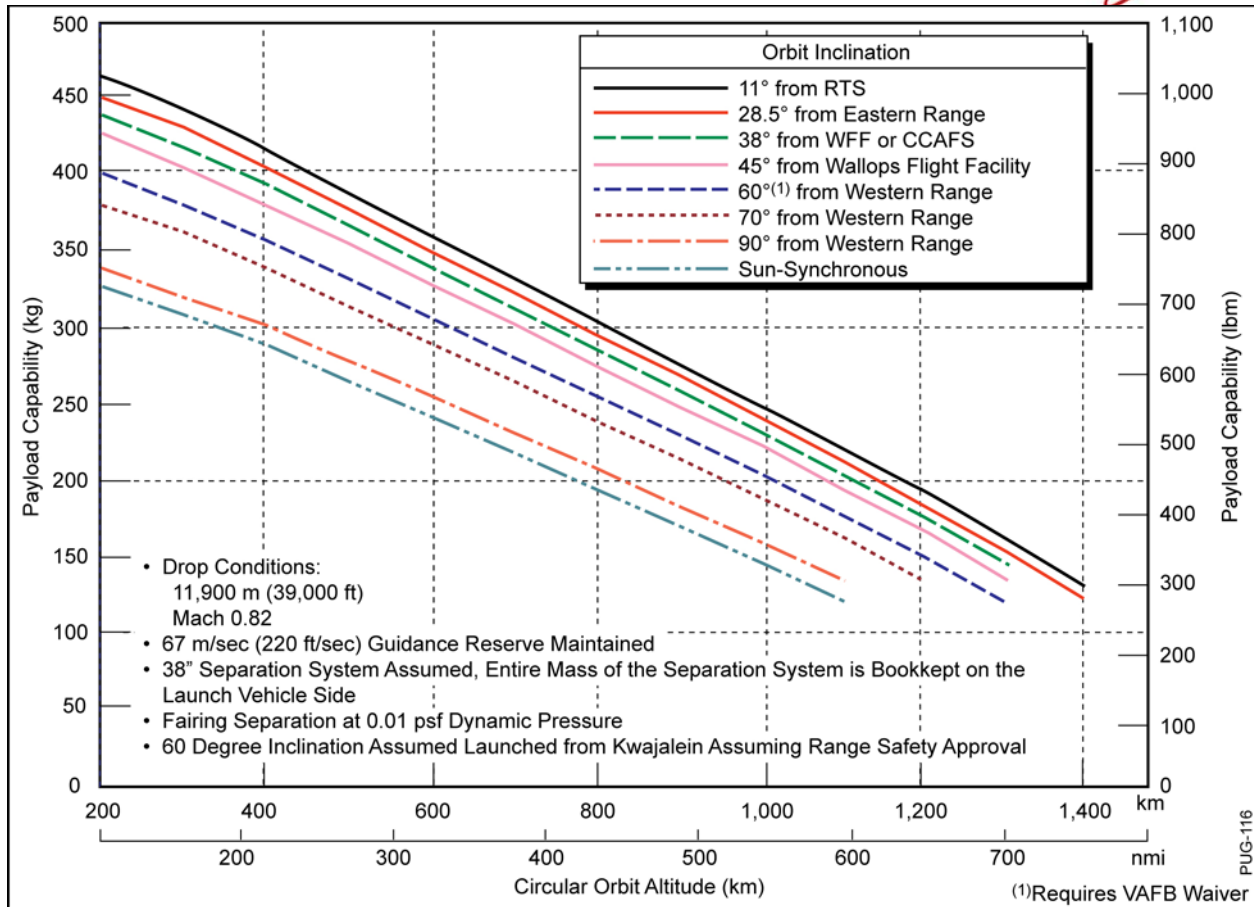
Figure 3-3. Pegasus XL Without HAPS Performance Capability

guidance strategies that are designed and tailored to meet specific mission objectives. These strategies fall into several basic categories:

(1) Minimize Insertion Errors. Using this strategy, the guidance system manages the excess vehicle energy by implementing out-of-plane turning during Stage 2 and Stage 3 burns as required, and by adjusting the timing of Stage 3 ignition. This "energy-scrubbing" strategy results in the smallest possible insertion errors for both apogee and perigee altitudes.

(2) Maximize Insertion Altitude. Using this strategy, excess vehicle performance is conserved to maximize the altitude at insertion. This allows the customer to achieve the highest possible circular orbit altitude

based on the actual vehicle performance while minimizing the eccentricity of the final orbit.

(3) Maximize Insertion Velocity. Using this strategy, excess vehicle performance is conserved to maximize velocity at insertion. This allows the customer to use the excess guidance reserve to increase the expected apogee (non-insertion apse) altitude while continuing to maintain a precise perigee (insertion apse) altitude.

(4) Some Combination of (2) and (3). Options 2 and 3 represent the two endpoints of a spectrum of potential guidance strategies that can be combined and tailored to achieve mission-specific guidance objectives. Both insertion altitude and velocity may be maximized to achieve the highest possible
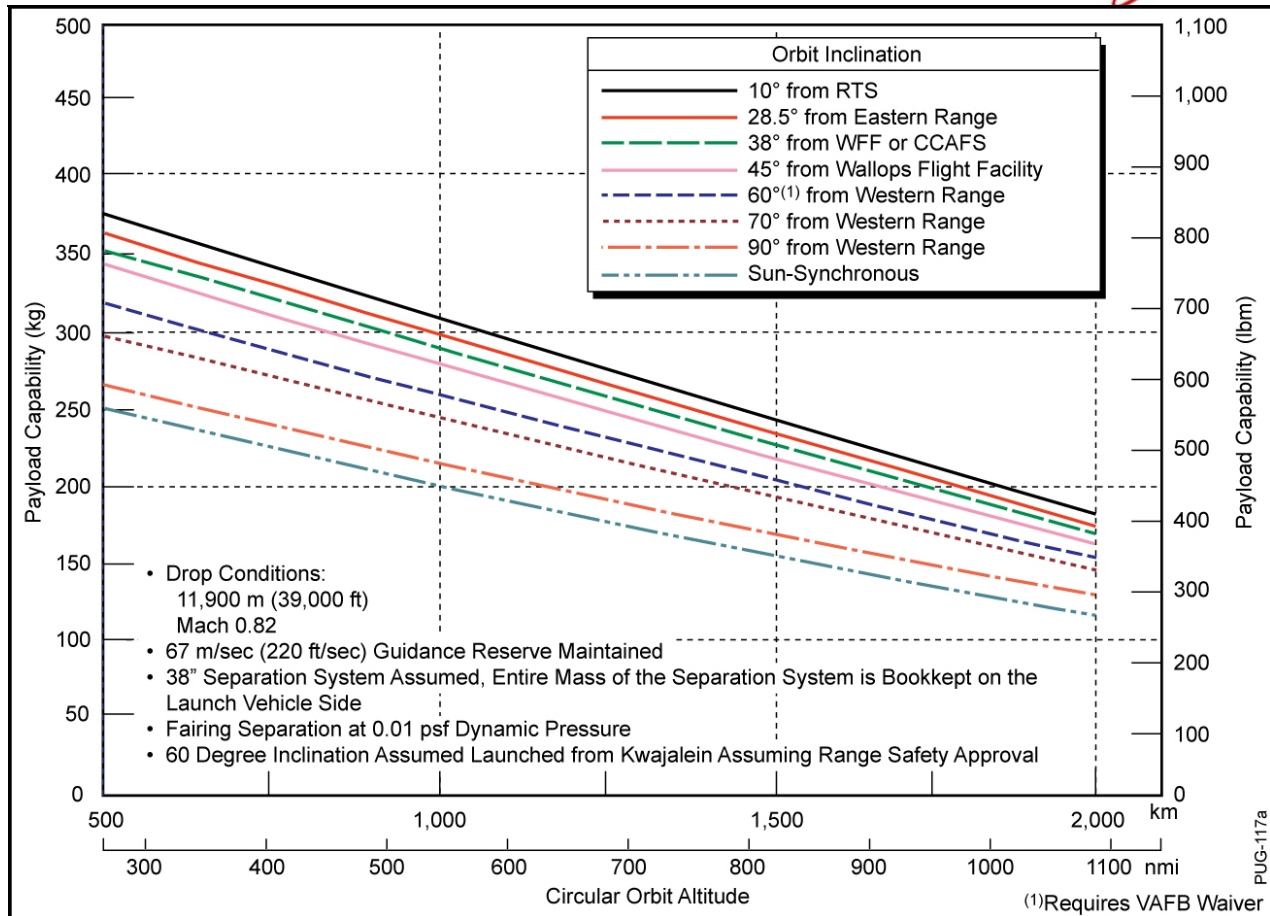
Figure 3-4. Pegasus XL With HAPS Performance Capability

orbit energy, or specific altitude and velocity thresholds may be defined, which trigger energy-scrubbing only in the event that the thresholds are exceeded. The optimal strategy for a particular mission will therefore depend on the specific guidance objectives.

Configuration	Insertion Apse Altitude	Non-Insertion Apse Altitude	Semi-Major Axis	Inclination
Pegasus XL	±10 km	±80 km	±45 km	±0.15°
Pegasus XL with HAPS	±15 km	±15 km	±15 km	±0.08°

Figure 3-5. 3-sigma Injection Accuracies Typical of Pegasus XL Missions

3.5. Collision/Contamination Avoidance Maneuver

Following orbit insertion, the Pegasus Stage 3 RCS or HAPS will perform a Collision/Contam-ination Avoidance Maneuver (C/CAM). The C/CAM consists of a series of maneuvers designed to both minimize payload contamination and the potential for recontact between Pegasus hardware and the separated payload.

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 (for a non-HAPS configuration) consists of the following steps:

(1) At payload separation +3 seconds, the launch vehicle performs a 90° yaw maneuver designed to direct any remaining Stage 3 motor impulse in a direction that will increase
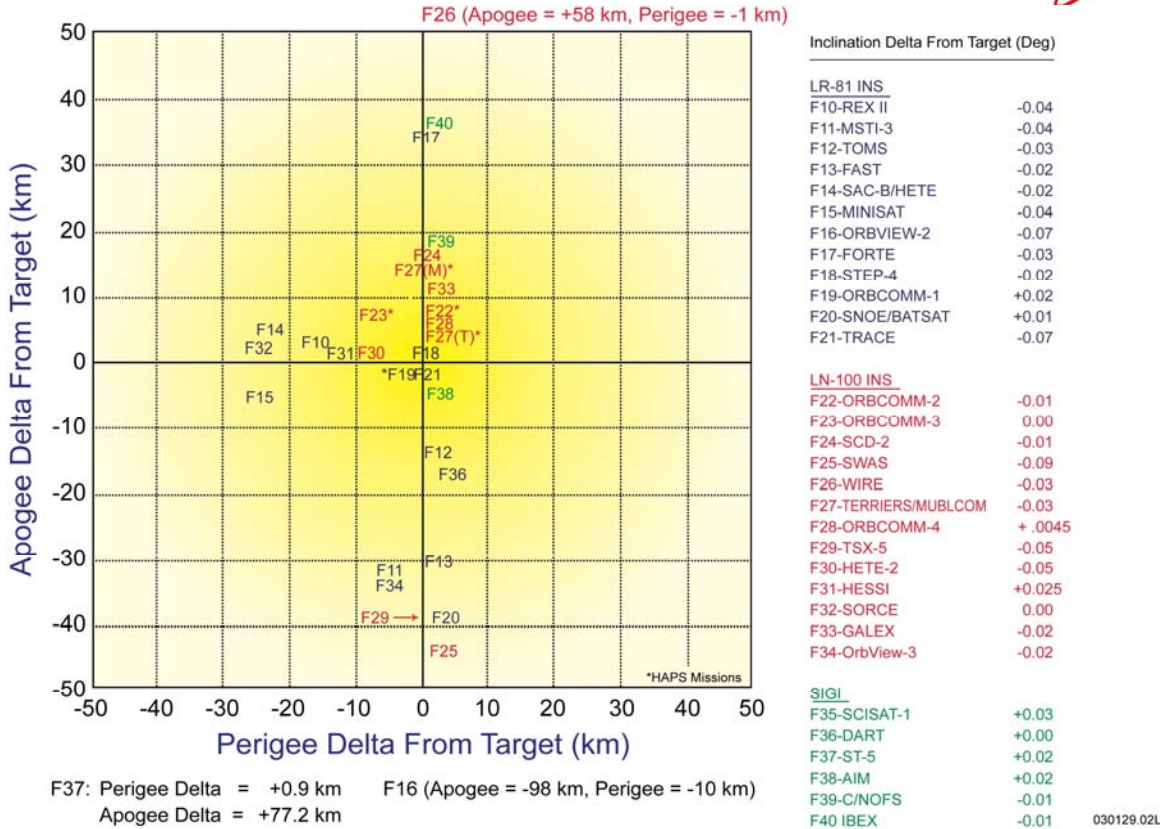
Figure 3-6. Typical and Recent Pegasus Orbital Accuracy

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 a direction designed to increase the separation distance between Pegasus and the payload. The maneuver is terminated approximately 600 seconds after separation.

At the completion of the C/CAM, all remaining nitrogen and/or hydrazine is depleted.

4. PAYLOAD ENVIRONMENTS

The following subsections present the maximum payload environment levels during Pegasus captive carry and powered flight. The acoustic,

vibration, shock, and acceleration environments presented below apply to the launch vehicle with a single payload using either the 38" or 23" payload adapter. The payload environments associated with the use of alternative separation systems, a nonseparating payload interface, or multiple payload attach fittings will differ from those presented below.

The electromagnetic radiation and thermal environments presented below apply to all launch vehicle and payload configurations.

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 ensures 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 the CFR14 document, FAR Part 25. UFS 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 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

Maximum expected loads during captive carry and launch are shown in Figures 4-3, 4-4, and 4-5.

The Pegasus air-launch operation results in a launch vehicle/OCA separation transient at drop. The drop transient acceleration limits presented here are based on two assumptions:

(1) Pegasus Standard 23" or 38" payload separation system is used.

(2) The first fundamental lateral frequency of the spacecraft cantilevered at the payload interface (excluding the payload separation system) is greater than 20 Hz.

If either assumption is violated, mission-specific analyses are required. For all missions, 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 transient environment (see Section 8.3.3 for details).

Transient loading also exists due to motor ignition. Stage 1 provides the worst-case loading due to motor ignition. The Stage 1 ignition acceleration limits at the payload interface are listed in Figure 4-3. The Stage 1 shock response spectrum (SRS) at the payload interface is shown in Figure 4-6. As is the case with the drop transient, accurate estimation of loading requires a CLA. The Stage 1 ignition transient CLA requires finite element models of the Pegasus avionics structure, payload separation system, and the payload.

4.4. Payload Random Vibration Environment

The maximum expected random vibration levels at the payload interface are shown in Figure 4-7. Random vibration data recorded during multiple Pegasus missions was used to create this overall

Safety Factors to be Used with Rigorous Flight Loads Methodology

Metalic Flight Structures [5]	Yield SF (Min)	Ultimate SF (Min)	Buckling SF (Min)
Non-Tested Structures	1.6	2.0	2.3
Tested Structures	1.1	1.25 [2]	1.44
Composite and Plastic Flight Structures [1,4]	Yield SF (Min)	Ultimate SF (Min)	Buckling SF (Min)
Non-Tested Structures	N/A	2.0	2.3
Tested Structures [3]	N/A	1.25	1.44
Safety Factors for Seismic Loads [6]			
All Structures (Including Support Equipment)	The Factor of Safety for seismic loads shall be 1.0 or greater. The analyst must consider all possible failure modes (yield, ultimate, buckling, etc.) and the corresponding response of the structure. For example, if a launch stool yields significantly, the vehicle CG may pass over-center and result in instability. For this case, yield might be the governing criteria. Similarly, if an aft skirt buckles before reaching yield or ultimate, buckling would be the governing criteria.		

NOTES:
1. A composite material is defined as a combination of two or more distinct, structurally complementary substances that are inseparably joined to produce structural or functional properties not present in any individual component. For example, two metallic face sheets separated by, and bonded to, a core shall be considered a composite material.
2. Qualification articles must pass a test load level of 1.25. Acceptance articles must pass a test load level of 1.1.
3. All composite flight structures using the "Tested structures" category shall be acceptance tested unless a proven non-destructive evaluation (NDE) method or proven coupon test method with well established accept/reject criteria is employed. The NDE or coupon test plan must be developed and presented to the Mechanical Engineering Director for approval prior to bypassing acceptance testing.
4. Any composite materials that are to be reused shall be evaluated and/or acceptance tested before each use.
5. Due to the inherent variability involved with the casting process, an additional knock down factor of 1.25 shall be applied when determining the structural capability of cast parts.
6. Use these safety factors if no other governing document exists or if governing document contains less stringent requirements. The safety factors required for analysis of flight structures will be determined by the fidelity of the loads derivation and whether or not the structures have been adequately tested.

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

envelope that encompasses all phases of a Pegasus launch operation including OCA takeoff, captive carry, and powered flight.

A +3 dB factor should be added to this spectrum for 75 seconds in each axis for payload standard vibration testing to account for fatigue duration effects to encompass at least two launch attempts and powered flight.

4.5. Sinusoidal Vibration
The Pegasus launch vehicle has no significant sustained sinusoidal vibration environments during captive carry or powered flight.

4.6. Payload Shock Environment
The maximum expected shock response spectrum at the base of the payload from all launch vehicle

events is shown in Figure 4-8. The flight limit levels are derived from ground stage and payload separation test data assuming a 38" Orbital-supplied separation system.

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

Figure 4-2. Payload Testing Requirements

4.7. Payload Acoustic Environment
The maximum expected acoustic levels within the payload fairing are shown in Figure 4-9. Acoustic data recorded during previous Pegasus missions

was used to create this overall envelope that encompasses all phases of Pegasus launch operation including OCA takeoff, captive carry, and powered flight.

A +6 dB factor should be added to this spectrum for 75 seconds for payload standard acoustic testing to account for fatigue duration effects to encompass at least two launch attempts and powered flight.

4.8. Pressure Profile

Due to the low pressure decay rate associated with OCA ascent and low initial static pressure at drop, the depressurization rates for the Pegasus payload fairing are less than 0.3 psi/sec. The internal pressure at fairing jettison is well below 0.1 psia. Representative pressure profiles for captive carry and powered flight are provided in Figures 4-10 and 4-11.

4.9. Payload Thermal Environment

The payload thermal environment is maintained during all phases of integrated operations including payload processing, fairing encapsulation, transportation of the launch vehicle, ground operations at the flight line and launch operations.

4.9.1. Payload Processing

During payload processing, the temperature and humidity of the spacecraft processing areas within Building 1555 are maintained within a range of 18 to 29 ºC (64.4 to 84.2 ºF) and ≤55%, respectively. Following encapsulation of the payload, but prior to transportation of the Pegasus vehicle to the Hot Pad, the fairing is continuously purged with filtered air. The temperature and humidity limits are the same as listed above. The flowrate of air through the fairing is maintained between 50 and 200 cfm. The air flow enters the fairing forward of the payload and exits aft of the payload. There are baffles on the inlet that minimize the impingement velocity of the air on the payload.

4.9.2. Transportation

During transportation of the Pegasus vehicle to the Hot Pad, the fairing is continuously purged with filtered and dried ambient air. The air temperature is not actively controlled; however, transportation operations are performed only when the ambient temperature ensures that the air supplied to the fairing will be between 2 to 29 ºC (35.6 to 84.2 ºF). The relative humidity of the air supplied to the

Environment	Ax (g's)		Ay (g's)		Az (g's)	
	Steady-State	Quasi-Static[1]	Steady-State	Quasi-Static[1]	Steady-State	Quasi-Static[1]
Taxi, Abort, and Captive Flight[2]	±1.0	N/A	±0.7	N/A	+1.0	+2.6/-2.0
Drop Transient	N/A	±0.5	N/A	±0.5	N/A	±3.85[3]
Aerodynamic Pull-Up	+3.7	±1.0	±0.3	±0.9	-2.33	±1.0
Stage 1 Ignition	N/A	Note 4	N/A	Note 4	N/A	Note 4
Stage Burn Out	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

Note 1: Static equivalent of mixed dynamic environments.
Note 2: Dominated by abort and ferry landing environments.
Note 3: Use Figure E1A-31 to estimate payload CG loads.
Note 4: Axial response and cross-coupling of the Stage 1 ignition transient at the interface is highly dependent on payload mass and structural properties; therefore a Coupled Loads Analysis (CLA) is required to determine the axial and lateral loads at the payload interface as well as the loads at the payload CG associated with the Stage 1 ignition transient. If required, a load isolation system can be provided as a non-standard service to ensure that loads associated with Stage 1 ignition are within payload design limits.

Figure 4-3. Pegasus Design Limit Load Factors

Does Not Include Random Vibe

TM21845_088
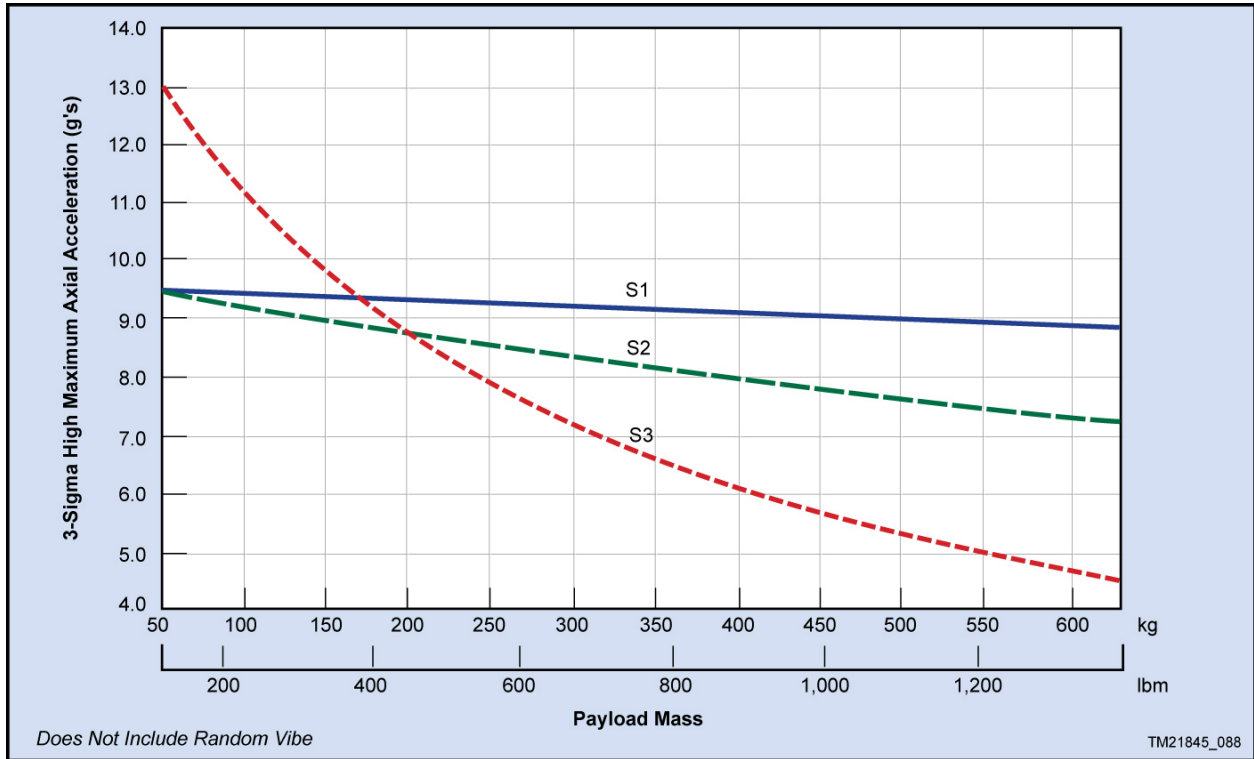
Figure 4-4. Pegasus XL Maximum Quasi Steady Acceleration as a Function of Payload Weight

TM21845_089
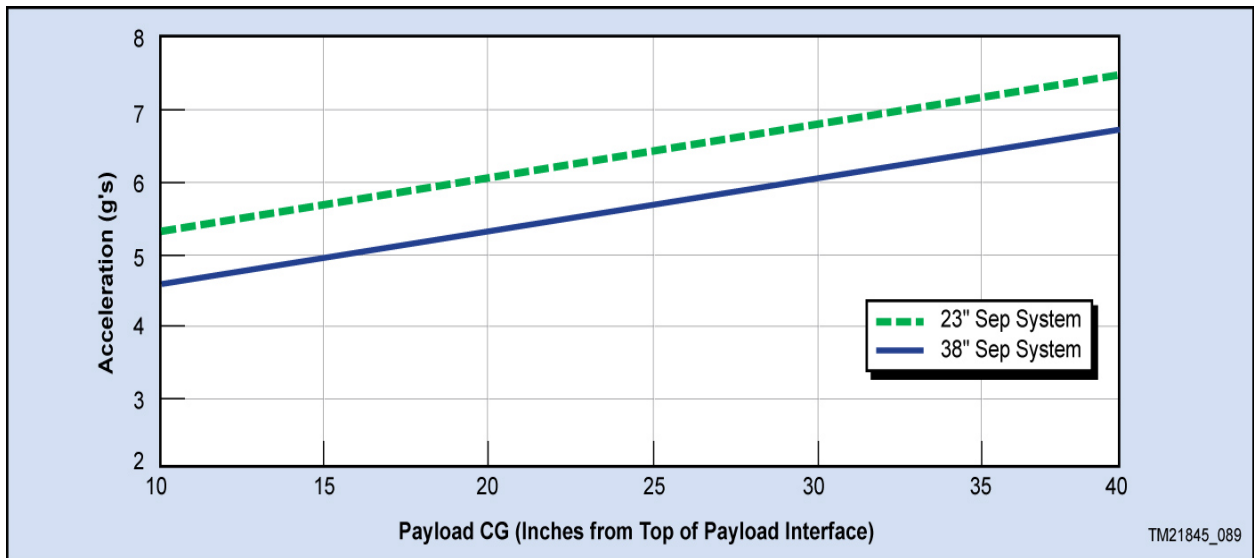
Figure 4-5. Pegasus Net CG Load Factor Predictions
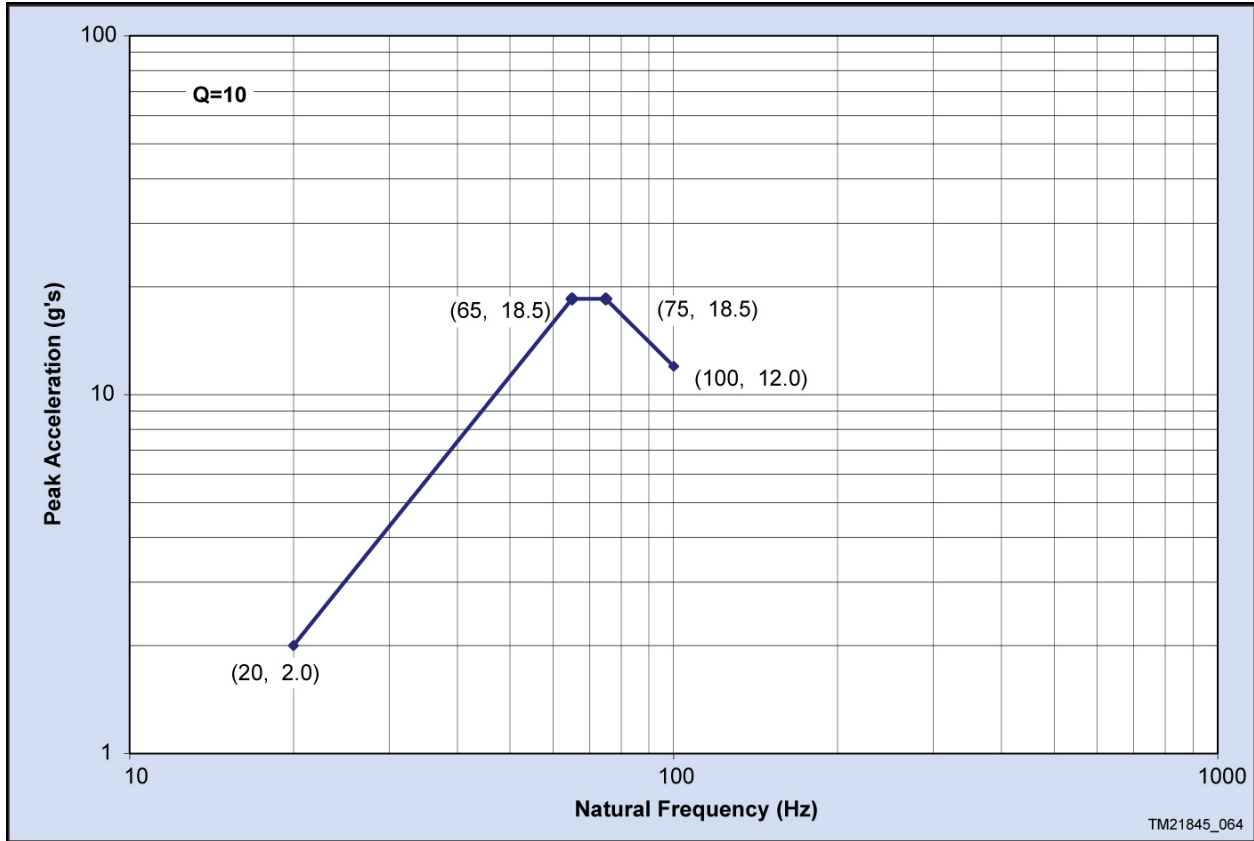
Figure 4-6. Motor Ignition Transient Shock Response Spectrum Specification
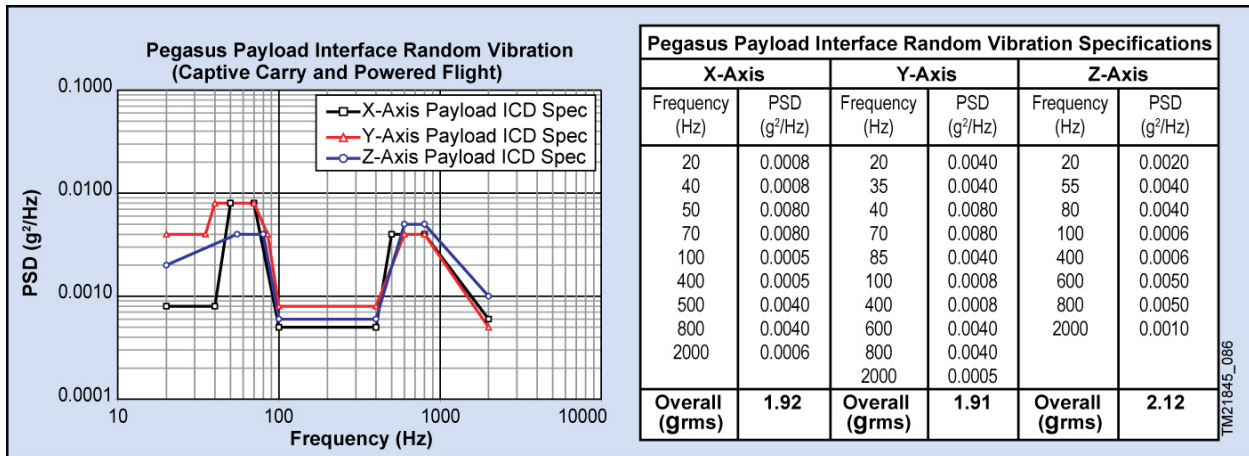
Figure 4-7. Payload Interface Random Vibration Specification
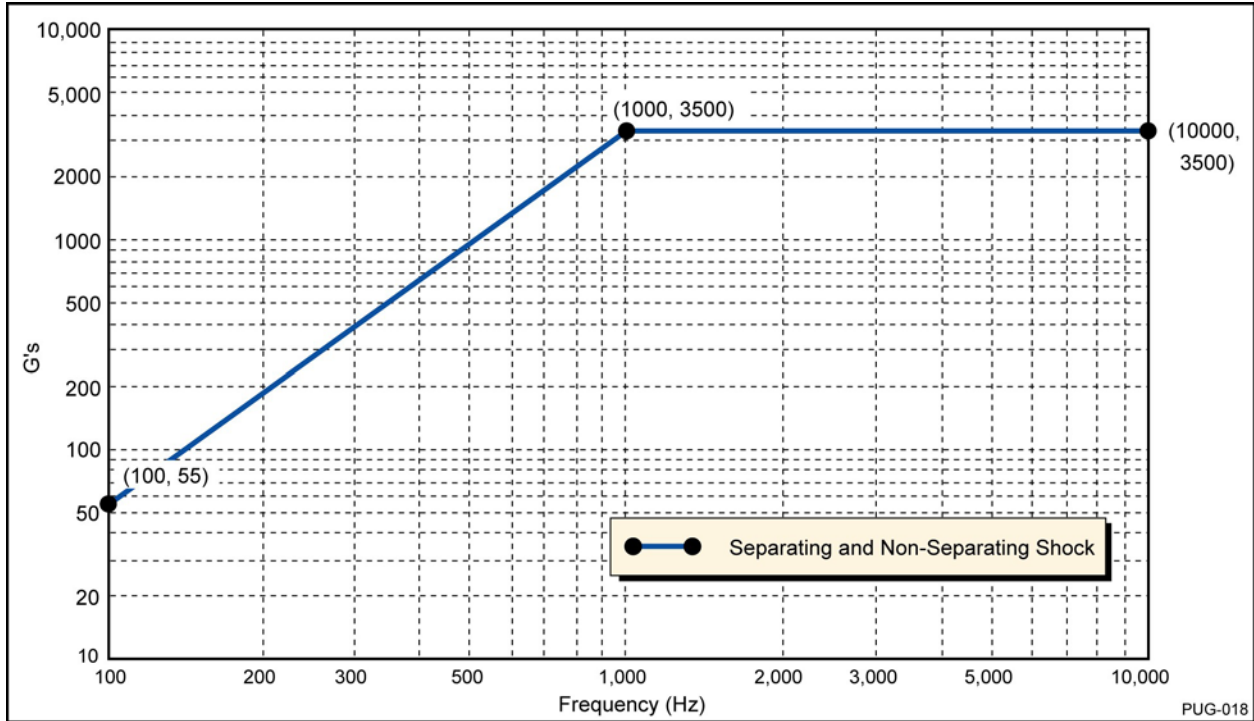
Figure 4-8. Shock Environment at Base of the Payload
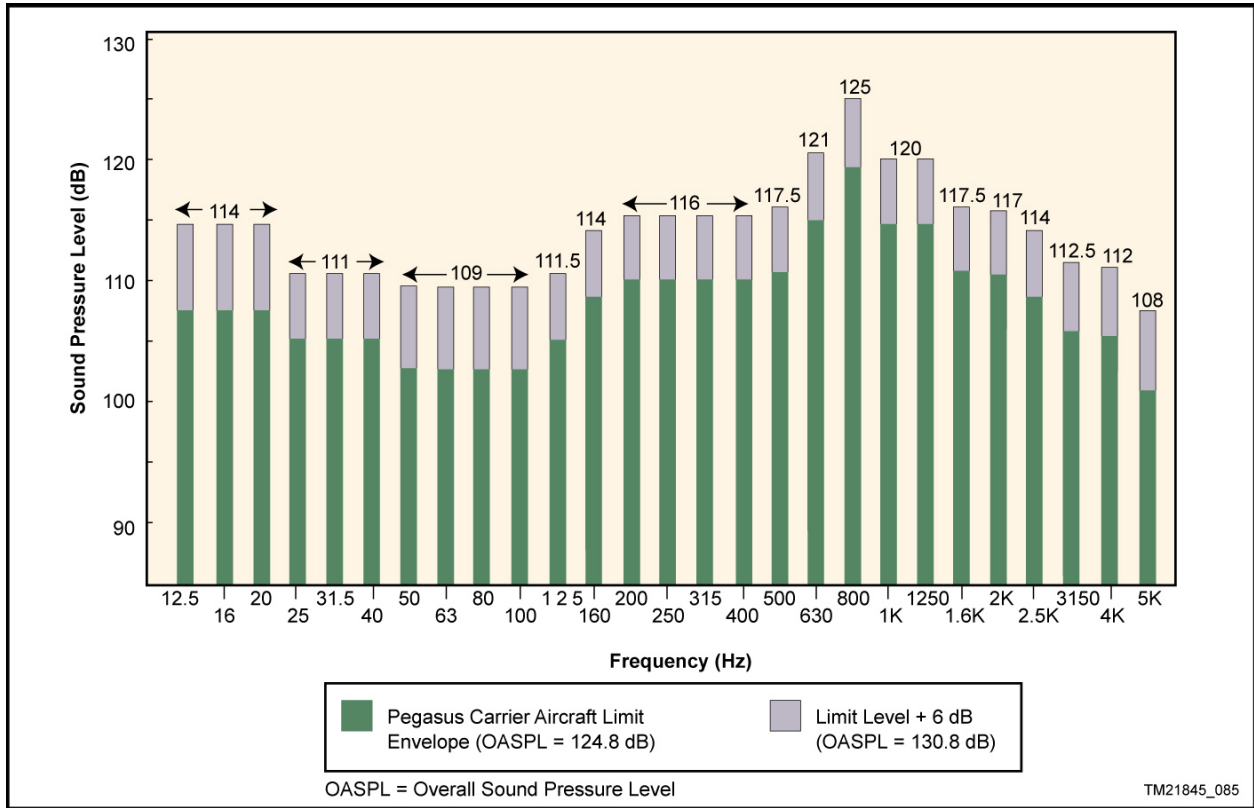
Figure 4-9. Payload Acoustic Environment
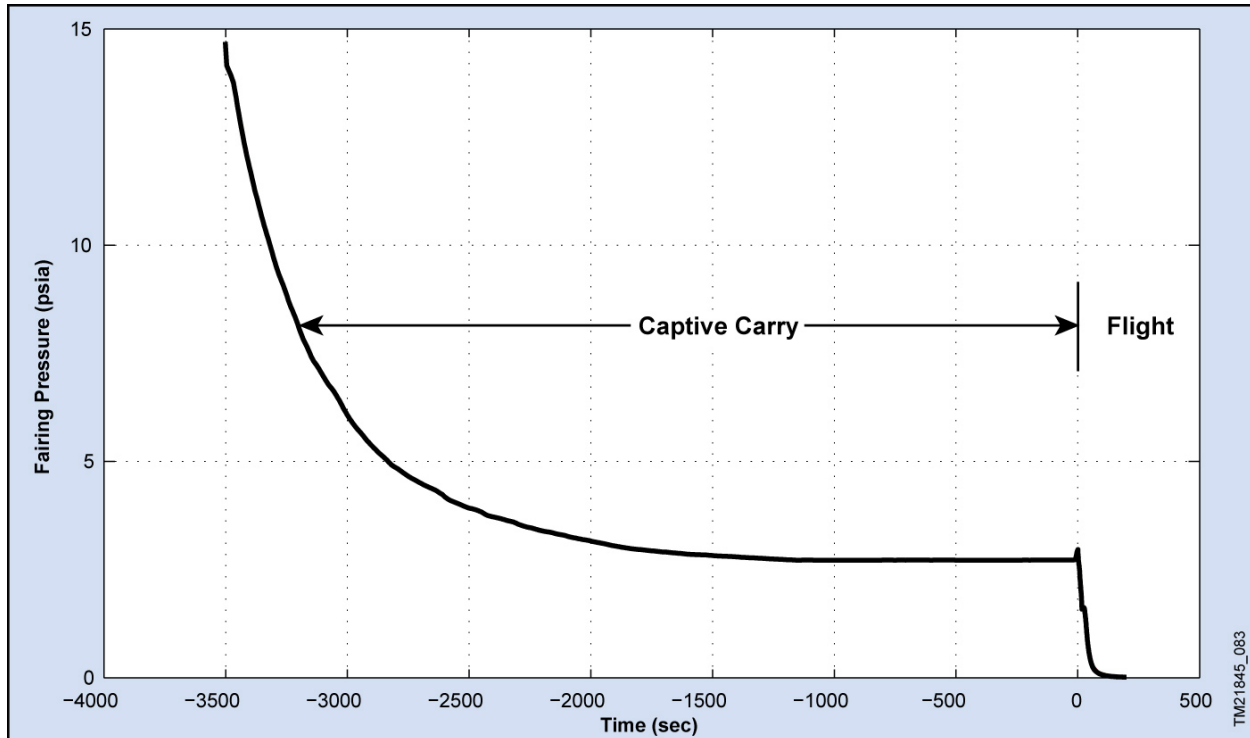
Figure 4-10. Representative Fairing Internal Pressure Profile During Captive Carry
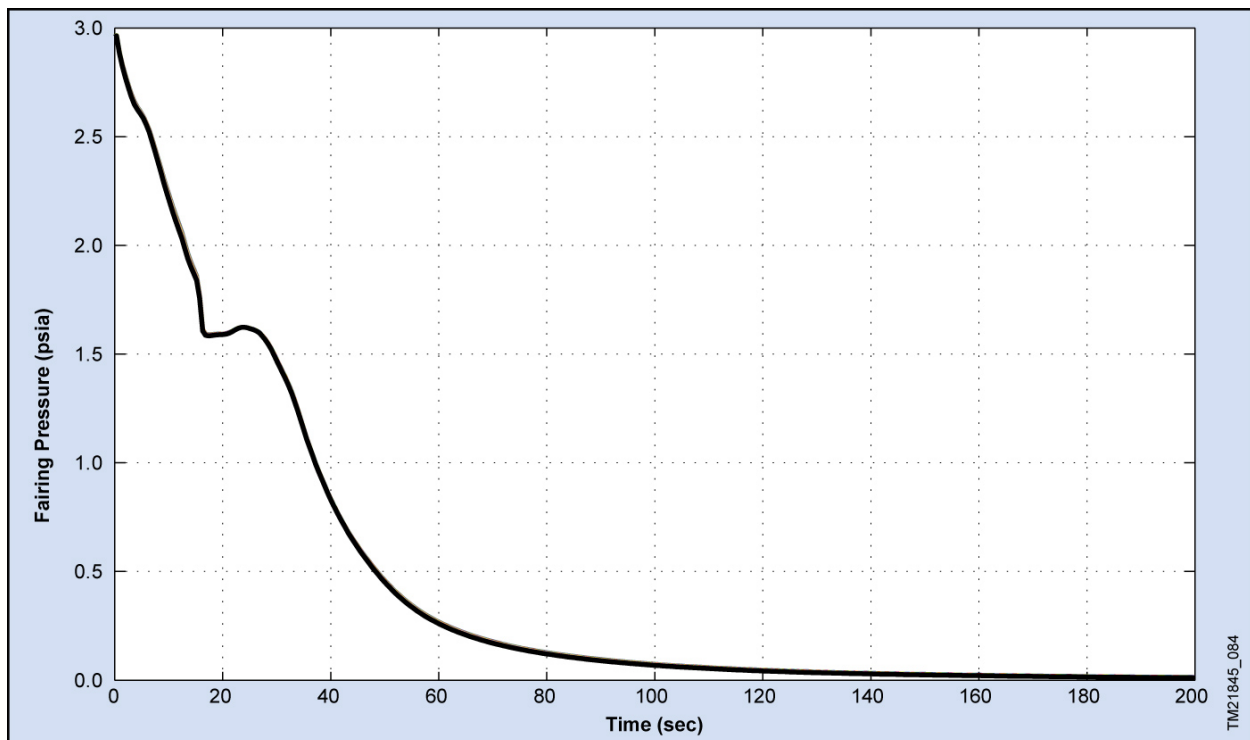
Figure 4-11. Representative Fairing Internal Pressure Profile During Powered Flight

fairing is maintained to < 60%. The flowrate of air through the fairing is maintained between 120 and 200 cfm.

4.9.3. Ground Operations at the Flightline and Launch Operations

Following transportation of the Pegasus vehicle to the Hot Pad, the fairing is continuously purged with conditioned filtered air. During ground operations, the temperature of the conditioned air, as measured at the fairing inlet, is maintained between 13 to 29 ºC (55.4 to 84.2 ºF). The relative humidity of the conditioned air is maintained to ≤55%. During ground operations, the flowrate of air through the fairing is maintained between 120 and 200 cfm. During launch operations, which includes captive carry, the flowrate of air through the fairing is maintained between 120 and 240 cfm. During captive carry, the air temperature within the fairing is significantly colder than the measured inlet air temperature due to the cold ambient conditions at altitude. The bulk air temperature within the fairing during the approximately 1-hour long captive carry will typically be between 0 and 10 ºC.

4.9.4. Powered Flight

The inside fairing wall is the component with the highest temperature that has a view factor to the payload during powered flight. Flight data shows that the fairing structure does not exceed 60 ºC prior to jettison from the vehicle during Stage 2 burn. As a standard service, a low emissivity aluminum liner is applied to the inside wall of the fairing. The emissivity of the fairing liner is less than 0.1.

The forward dome of the third stage motor does not have a significant view factor to the payload due to the RCS tank, bulkhead and avionics components located within the avionics section.

4.9.5. Nitrogen Purge

There are two standard nitrogen systems that provide nitrogen to the fairing during various phases of a launch. All nitrogen meets MIL-PRF-27401C, Grade B specifications.

Avionics Cooling purge use is used to maintain launch vehicle avionics in their operational temperature range. This system is controlled solely at the discretion of the launch vehicle and provides 725 slpm (26 scfm) directed to various high dissipating launch vehicle avionics components. Flow is ground adjustable in 33% increments to maintain temperatures and post-landing humidity within limits.

Fairing Purge is used to prevent condensation within the payload fairing as the aircraft descends in altitude following an abort and return to base. This system is controlled solely at the discretion of the launch vehicle and provides 535 slpm (19.2 scfm) to the forward part of the fairing through two tubes and exit through nozzles that are nominally mounted on the fairing forward bulkhead. Flow is ground adjustable in 33% increments to maintain temperatures and post-landing humidity within limits. One nozzle can be relocated at payload discretion, however, the purge system will be turned on/off to meet launch vehicle needs. The location of these nozzles is documented in the payload mechanical ICD.

4.10. Payload Electromagnetic Environment

The electromagnetic environment to which the payload will be exposed during ground processing, launch operations and powered flight is due to a combination of RF emitters. These emitters fall into three categories: 1) RF systems onboard the Pegasus launch vehicle and the L1011 carrier aircraft; 2) Range emitters such as tracking radars and the FTS command uplink; and 3) uncontrolled emitters not associated with the Range such as military, air traffic control and weather radars as well as satellite control ground stations.

Figure 4-12 lists the frequencies and maximum field strength associated with RF emitters on the Pegasus launch vehicle. The worst-case field

Source	1	2	3	4	5	6
Function	Command Destruct	Tracking Transponder	Tracking Transponder	Instrument Telemetry	Booster Telemetry	GPS
Role	Receive	Transmit	Receive	Transmit	Transmit	Receive
Band	UHF	C-Band	C-Band	S-Band	S-Band	L-Band
Frequency (MHz)	425.0	5,765	5,690	2,269.5	2,288.5	1,575.42±10.23 1,227.60±10.23
Bandwidth	180 kHz at 60 dB	N/A	14 MHz at 3 dB	750 kHz at 3 dB	315 kHz at 3 dB	20.46 MHz
Power Output	N/A	400 W Peak	N/A	5 W	5 W	N/A
Sensitivity	-107 dBm	N/A	-70 dBm	N/A	N/A	N/A
Modulation	FM	Pulse Code	Pulse Code	FM/FM	PCM/FM	PRN Code

Figure 4-12. Pegasus XL RF Emitters and Receivers

strength values in the table occur during powered flight after the payload fairing has been jettisoned and the Pegasus Stage 3 S-band antenna is active.

Figure 4-13 lists the frequencies and maximum field strength associated with RF emitters on the L1011 carrier aircraft. The worst-case field strength values in the table only exist while Pegasus is mated to the carrier aircraft and all L1011 emitters are active during captive carry or ferry operations.

During captive carry and powered flight, uncontrolled RF emitters not associated with the Range may cause the electric field at the payload to exceed the levels caused by Range emitters. Potential sources of significant RF fields will vary depending on launch site.

Spacecraft radiated susceptibility testing limits should be tailored to include the worst-case composite of the electrical field strength during all phases of integrated operations with the launch vehicle and spacecraft on-orbit operations.

Source	1	2	3	4	5	6	7	8	9
Function	Long Range Comm	Comm	Comm	ATC Transponder	GPS/ LORAN	GNSS Nav	GPS Relay	Video Telemetry	Weather Radar
Role	Receive Transmit	Receive/ Transmit	Receive/ Transmit	Receive/ Transmit	Receive	Receive	Receive/ Transmit	Transmit	Receive/ Transmit
Band	HF	VHF	UHF	L-Band	L-Band	L-Band	L-Band	S-Band	X-Band
Frequency (MHz)	2-29.999	118-151	225-400	R: 1030 ± 0.2 T: 1090 ± 3	1,575.42	1,575.42	1,575.42	2210.50 or 2383.5	9,345±30
Bandwidth	SSB:3 KHz AM: 6 KHz	90 KHz @ -100dB		25 MHz @ -60 dB	20.46 MHz	20.46 MHz	20.46 MHz	12 MHz	700 kHz
Power Output	SSB: 400W AM: 125W	25 W	10 W	631W	N/A	N/A	< 1W	10 Watts	65 kW
Sensitivity	SSB: 1 µV AM: 3 µV	3 µV	4 µV	-76 dBm	N/A	N/A	N/A	N/A	N/A
Modulation	SSB AM	AM	AM	Pulsed 1% duty cycle	PRN Code	PRN Code	PRN Code	N/A	5.74 µS Pulse, 200 pps

Figure 4-13. Carrier Aircraft RF Emitters and Receivers

The maximum average electric field to which the payload will be exposed due to Range emitters is controlled to 20 V/m from 10 kHz to 40 GHz with the exception of C-band frequencies used for radar tracking. Between 5.4 and 5.9 GHz, the maximum average electric field is 40 V/m.

4.11. Payload Contamination Control

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. For each mission, Orbital prepares a payload contamination control plan that documents the provisions and

practices that are followed to ensure payload contamination requirements are met.

The VAB is maintained at all times as a visibly clean, air-conditioned, humidity-controlled work area. As a standard service, the payload can be provided with a soft-walled cleanroom that is certified and operated at Class 8 (Class 100,000) level per ISO 14644-1. This vertical down flow cleanroom is 12'(W) x 24'(L) x 14'(H). As an optional nonstandard service, the cleanroom can be certified and operated at ISO 14644-1 Class 7 (Class 10,000). Overhead crane lifts must occur outside of the cleanroom. If crane lifts are required for payload handling, it may be necessary to bag or otherwise protect the payload while it is outside of the cleanroom.

After encapsulation of the payload, the fairing is purged with conditioned air that is certified to ISO 14644-1 Class 8. Within the VAB, this air flow is provided by an air conditioning system. The output of the facility air conditioner is routed through an activated charcoal and high-efficiency particulate air (HEPA) filters prior to being directed into the nose of the fairing. Particulate levels within the airflow are measured prior to and continuously after the system is connected to the fairing. The activated charcoal filter removes better than 95% of volatile hydrocarbons with a molecular weight of 70 or higher. During transportation of the Pegasus launch vehicle to the Hot Pad, the fairing purge air is provided using a mobile blower. The output from the blower is routed through a desiccant bank to control humidity and a similar activated charcoal and HEPA filter system. While at the Hot Pad, the fairing purge air is supplied using a specially designed ground air conditioning system (GACS) that includes a desiccant dryer wheel and heater to allow control of humidity and temperature. During launch operations and captive carry, the fairing air flow is provided using the airborne air conditioning system (AACS) on the L1011 carrier aircraft. For both air conditioning systems, the

output air flow is routed through an activated charcoal and HEPA filter system prior to entering the fairing. The air flow to the fairing is constantly monitored for temperature, humidity, flow rate, and particulate levels.

The inner surface of the Pegasus payload fairing is a low emissivity aluminum liner. As a standard service, this liner is cleaned and maintained to Level 750A cleanliness requirements of IEST-STD-CC1246D. As an optional nonstandard service, the fairing liner can be cleaned and maintained to Level 600A or 500A.

All materials within the fairing that are in close proximity to the payload are selected based on NASA RP-1124. To the extent possible, all materials meet NASA outgassing standards of total mass loss (TML) <1.0% and collected volatile condensable material (CVCM) <0.1%. For those materials that do not meet these requirements, an accounting of material quantity, location and contamination mitigation measures is provided to the customer.

5. SPACECRAFT INTERFACES

5.1. Payload Fairing

This section describes the fairing, fairing separation sequence, payload static and dynamic envelopes, 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 noncontaminating 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 noncontaminating 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 Design Envelopes

The payload static envelope for a rigid payload hard mounted to the 97 cm (38 in.) PA is shown in Figure 5-1. The payload static envelope for the 59 cm (23 in.) PA is shown in Figure 5-3. No portion of the payload shall extend aft of the payload/launch vehicle interface plane, unless otherwise approved in the ICD. The static envelopes account for fairing and payload structural deflections assuming a minimum lateral bending frequency of 20 Hz for the payload. The static envelope accounts for PAF interface plane deflection and rotation. The static envelope does not account for payload non-rigid body deflections, payload dimensional errors due to manufacturing/design and tolerance stack-up shall be accounted for within the static envelope. Extensions of the static envelope are common but must be assessed on a mission-specific basis.

Pegasus payload dynamic envelopes are provided in Figure 5-2 and Figure 5-4.

5.1.3. Payload Access Door

Unless otherwise specified in the contract, Orbital provides one 21.6 cm x 33.0 cm (8.5 in. x 13.0 in.) graphite payload fairing access door. The long dimension of the load-bearing rectangular door

shall be oriented along the vehicle x-axis, and can be positioned according to user requirements within the zones defined in Figure 5-5. The position of the payload fairing access door must be defined no later than L-18 months.

5.2. Payload Mechanical Interface and Separation System

Orbital will provide all hardware and integration services necessary to attach nonseparating 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 nonseparating mechanical interfaces.

5.2.1. Standard Nonseparating Mechanical Interface

Figure 5-6 illustrates the standard, nonseparating 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 #10 fasteners as shown in Figure 5-6. Orbital will supply a detailed drawing of the bolt circle to allow accurate machining of the fastener holes and will supply all necessary attachment hardware per the payload specifications.

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.

Two different separation systems are available, depending on payload interface and size. They are the 97 cm (38 in.) and 59 cm (23 in.) separation systems. The 97 cm (38 in.) separable payload interface is shown in Figure 5-7 and the 59 cm (23 in.) separable payload interface is shown in Figure 5-8.

Harness
Pigtails
to Payload

0

Pyrotechnic Event Connector

Stayout Zone
Clamp/Separation
System Components

Legend:

Payload
Stayout Zones

$\phi \dfrac{77.7}{30.6}$

90

270

Forward View
Looking Aft

Payload Interface Connector

180

38"Payload Separation System
Stayout Zone

Notes:

(1) The location of harnesses, access doors, purge lines, and fairing reinforcements result in several incursions into the payload envelope. These incursions are defined below. Fairing harnessing and purge line locations within Incursion Zones #1- #4 can be adjusted to provide additional payload clearance on a case by case basis.

Incursion Zone #1:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 350° and 10° azimuths, beginning at the Payload Interface Plane (PIP) and terminating 111.4 cm (43.86 inches) forward.
Incursion Zone #2:	Extends 0.64 cm (0.25 inches) radially into the payload envelope between the 345° and 15° azimuths, beginning at 111.4 cm (43.86 inches) forward of the PIP and terminating at the forward end of the payload envelope.
Incursion Zone #3:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 10° and the 90° azimuths, beginning at 104.4 cm (41.11 inches) forward of the PIP and terminating 108.9 cm (42.61 inches) forward of the PIP.
Incursion Zone #4:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 197° and 350° azimuths, beginning at 107.4 cm (42.27 inches) forward of the PIP and terminating 108.9 cm (42.87 inches) forward of the PIP.
Incursion Zone #5:	Consists of a 10.2 cm (4.0 inch) diameter, radially oriented cylinder that extends 2.54 cm (1.0 inch) into the payload envelope, located 106.3 cm (41.86 inches) forward of the PIP at the 90° azimuth.
Incursion Zone #6:	Exists wherever a Payload access door is located. Extends 1.02 cm (0.4 inches) radially into the payload envelope over a region 44.2 cm (17.4 inches) along the vehicle axis, by an arc length of 30.7 cm (12.1 inches).
Incursion Zone #7:	If the payload requires nitrogen cooling, then the payload envelope will be reduced by 2.54 cm (1.0 inch) radially and circumferentially along the cooling tube routing.

0.6°

See
Note 1

$\dfrac{70.9}{27.9}$

Payload
Static
Envelope

Fairing

$R \dfrac{268.5}{105.7}$

Ogive Mate

$\dfrac{213.8}{84.2}$

$\phi \dfrac{115.3}{45.4}$

$\dfrac{111.0}{43.7}$

$\dfrac{50.8}{20.0}$

$\dfrac{10.0}{3.95}$

$\dfrac{2.5}{1.0}$

RCS Stayout
Zone

Payload Interface Plane for
Payload Separation System

Payload Interface Plane
for Non-Separating Payloads

38" Avionics Thrust Tube 56 cm
(22") Long

+X

+Z

Dimensions in $\dfrac{cm}{in}$

$\phi \dfrac{100.3}{39.5}$

Side View

TM21845_069

Figure 5-1. Payload Fairing Static Envelope with 97 cm (38 in.) Diameter Payload

Notes:
(1) The location of harnesses, access doors, purge lines, and fairing reinforcements result in several incursions into the payload envelope. These incursions are defined below. Fairing harnessing and purge line locations within Incursion Zones #1- #4 can be adjusted to provide additional payload clearance on a case by case basis.

Incursion Zone #1:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 350° and 10° azimuths, beginning at the Payload Interface Plane (PIP) and terminating 111.4 cm (43.86 inches) forward.
Incursion Zone #2:	Extends 0.64 cm (0.25 inches) radially into the payload envelope between the 345° and 15° azimuths, beginning at 111.4 cm (43.86 inches) forward of the PIP and terminating at the forward end of the payload envelope.
Incursion Zone #3:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 10° and the 90° azimuths, beginning at 104.4 cm (41.11 inches) forward of the PIP and terminating 108.9 cm (42.61 inches) forward of the PIP.
Incursion Zone #4:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 197° and 350° azimuths, beginning at 107.4 cm (42.27 inches) forward of the PIP and terminating 108.9 cm (42.87 inches) forward of the PIP.
Incursion Zone #5:	Consists of a 10.2 cm (4.0 inch) diameter, radially oriented cylinder that extends 2.54 cm (1.0 inch) into the payload envelope, located 106.3 cm (41.86 inches) forward of the PIP at the 90° azimuth.
Incursion Zone #6:	Exists wherever a Payload access door is located. Extends 1.02 cm (0.4 inches) radially into the payload envelope over a region 44.2 cm (17.4 inches) along the vehicle axis, by an arc length of 30.7 cm (12.1 inches).
Incursion Zone #7:	If the payload requires nitrogen cooling, then the payload envelope will be reduced by 2.54 cm (1.0 inch) radially and circumferentially along the cooling tube routing.

Figure 5-2. Payload Fairing Dynamic Envelope with 97 cm (38 in.) Diameter Payload

Notes:
(1) The location of harnesses, access doors, purge lines, and fairing reinforcements result in several incursions into the payload envelope. These incursions are defined below. Fairing harnessing and purge line locations within Incursion Zones #1- #4 can be adjusted to provide additional payload clearance on a case by case basis.

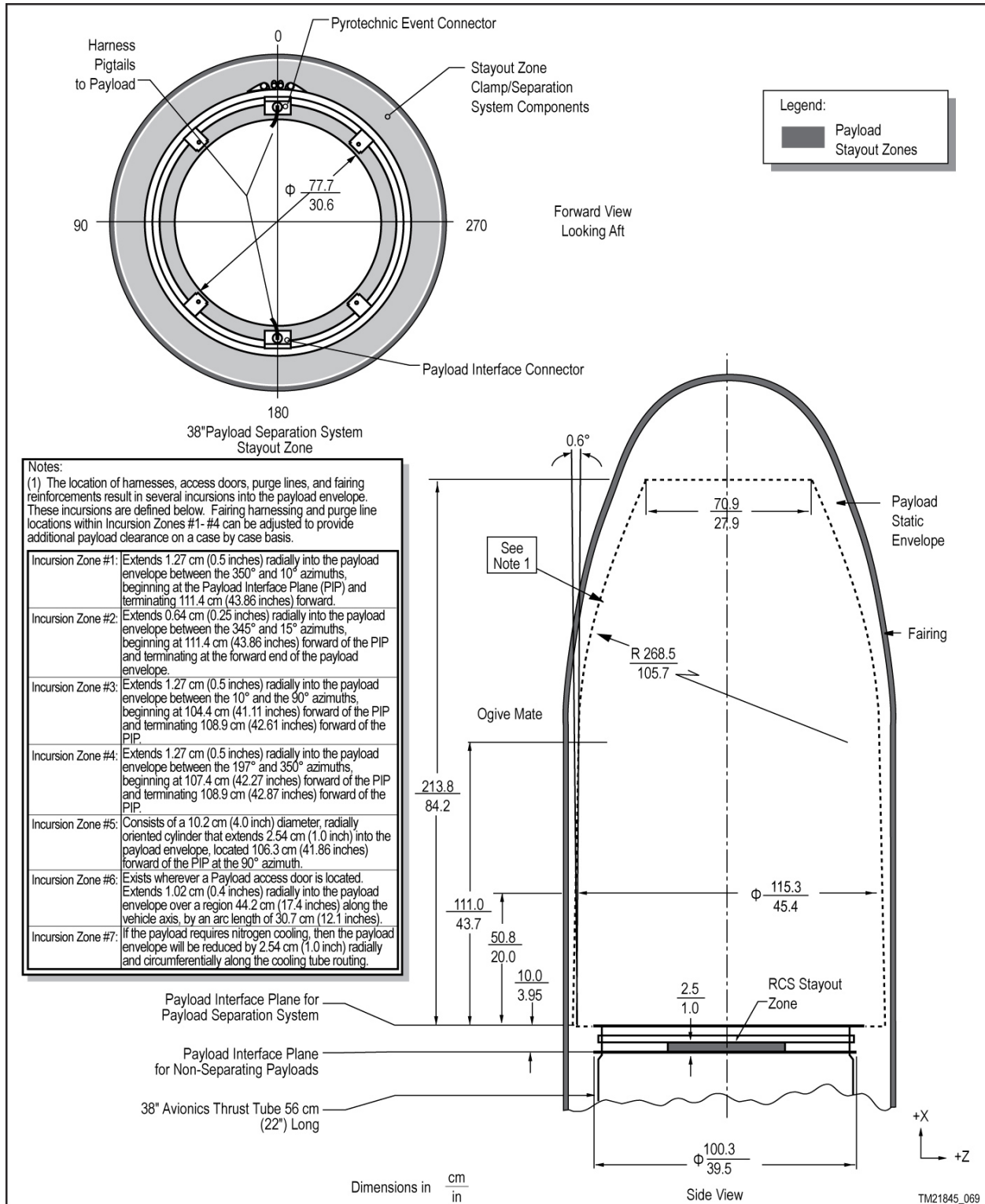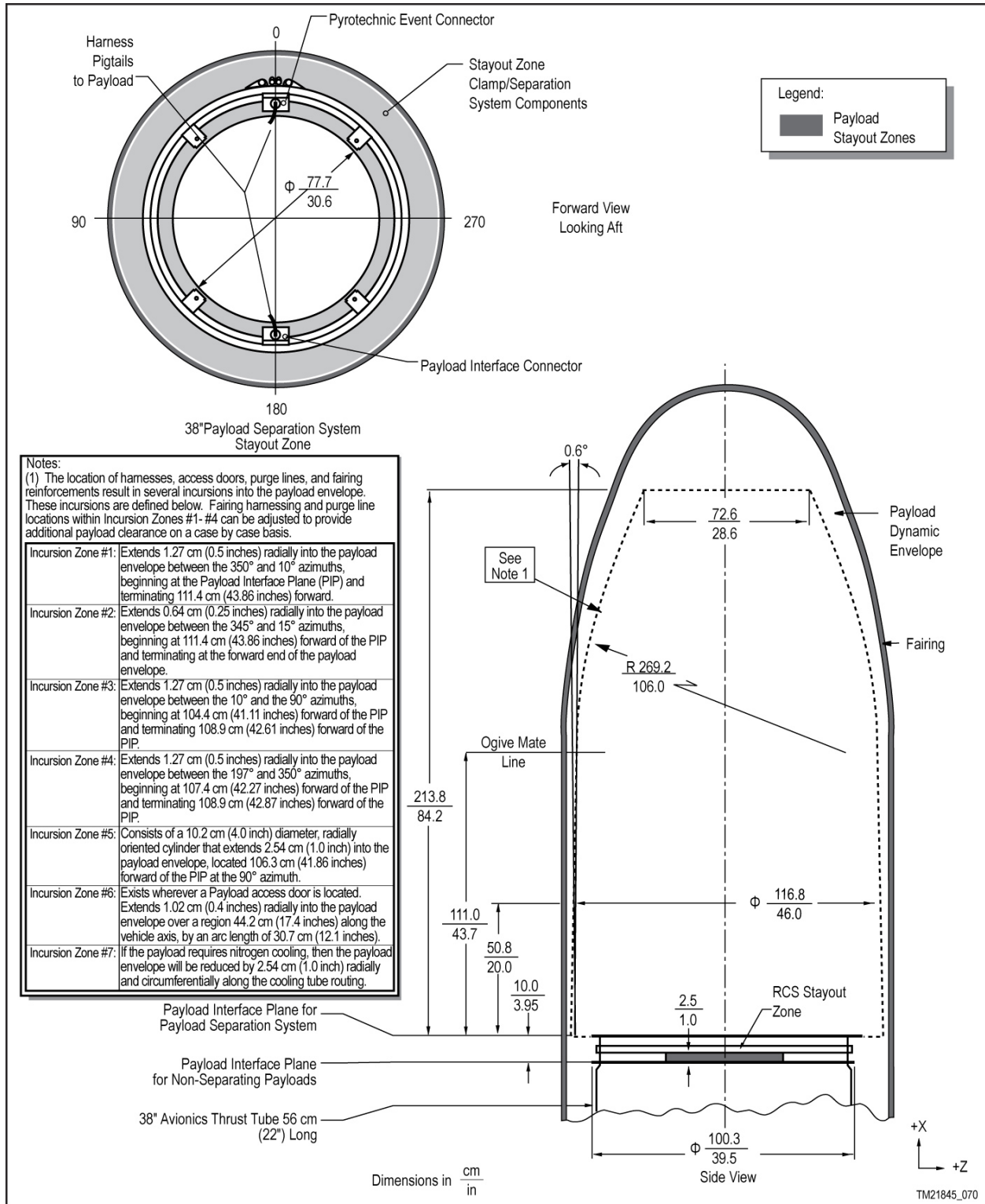|	
Incursion Zone #1:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 350° and 10° azimuths, beginning at the Payload Interface Plane (PIP) and terminating 92.1 cm (36.26 inches) forward (based on mission using Pegasus standard P/L separation system).
Incursion Zone #2:	Extends 0.64 cm (0.25 inches) radially into the payload envelope between the 345° and 15° azimuths, beginning at 92.1 cm (36.26 inches) forward of the PIP and terminating at the forward end of the payload envelope.
Incursion Zone #3:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 10° and the 90° azimuths, beginning at 85.1 cm (33.51 inches) forward of the PIP and terminating 88.9 cm (35.27 inches) forward of the PIP.
Incursion Zone #4:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 197° and 350° azimuths, beginning at 88.1 cm (34.67 inches) forward of the PIP and terminating 89.6 cm (35.27 inches) forward of the PIP.
Incursion Zone #5:	Consists of a 10.2 cm (4.0 inch) diameter, radially oriented cylinder that extends 2.54 cm (1.0 inch) into the payload envelope, located 87.0 cm (34.26 inches) forward of the PIP at the 90° azimuth.
Incursion Zone #6:	Exists wherever a Payload access door is located. Extends 1.02 cm (0.4 inches) radially into the payload envelope over a region 44.2 cm (17.4 inches) along the vehicle axis, by an arc length of 30.7 cm (12.1 inches).
Incursion Zone #7:	If the payload requires nitrogen cooling, then the payload envelope will be reduced by 2.54 cm (1.0 inch) radially and circumferentially along the cooling tube routing.

Figure 5-3. Payload Fairing Static Envelope with 59 cm (23 in.) Diameter Payload

Notes:
(1) The location of harnesses, access doors, purge lines, and fairing reinforcements result in several incursions into the payload envelope. These incursions are defined below. Fairing harnessing and purge line locations within Incursion Zones #1- #4 can be adjusted to provide additional payload clearance on a case by case basis.

Incursion Zone #1:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 350° and 10° azimuths, beginning at the Payload Interface Plane (PIP) and terminating 92.1 cm (36.26 inches) forward.
Incursion Zone #2:	Extends 0.64 cm (0.25 inches) radially into the payload envelope between the 345° and 15° azimuths, beginning at 92.1 cm (36.26 inches) forward of the PIP and terminating at the forward end of the payload envelope.
Incursion Zone #3:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 10° and the 90° azimuths, beginning at 85.1 cm (33.51 inches) forward of the PIP and terminating 88.9 cm (35.01 inches) forward of the PIP.
Incursion Zone #4:	Extends 1.27 cm (0.5 inches) radially into the payload envelope between the 197° and 350° azimuths, beginning at 88.1 cm (34.67 inches) forward of the PIP and terminating 89.6 cm (35.27 inches) forward of the PIP.
Incursion Zone #5:	Consists of a 10.2 cm (4.0 inch) diameter, radially oriented cylinder that extends 2.54 cm (1.0 inch) into the payload envelope, located 87.0 cm (34.26 inches) forward of the PIP at the 90° azimuth.
Incursion Zone #6:	Exists wherever a Payload access door is located. Extends 1.02 cm (0.4 inch) radially into the payload envelope over a region 44.2 cm (17.4 inches) along the vehicle axis, by an arc length of 30.7 cm (12.1 inches).
Incursion Zone #7:	If the payload requires nitrogen cooling, then the payload envelope will be reduced by 2.54 cm (1.0 inch) radially and circumferentially along the cooling tube routing.

0.6°

See Note 1

72.6 / 28.6

Payload Dynamic Envelope

R 269.2 / 106.00

Fairing

194.5 / 76.6

Ogive Mate Line

91.7 / 36.1

83.8 / ø 33.00

116.8 / ø 46.0

Payload Interface Plane for Payload Separation System

31.5 / 12.4

61.0 / ø 24.00

17.3 / 6.79

26.4 / 10.40

Payload Interface Plane for Non-Separating Payloads

7.5 / 2.95

38" Avionics Thrust Tube (22" Long)

+X

+Z

Dimensions in cm / in

Side View

TM21845_072

Figure 5-4. Payload Fairing Dynamic Envelope with 59 cm (23 in.) Diameter Payload
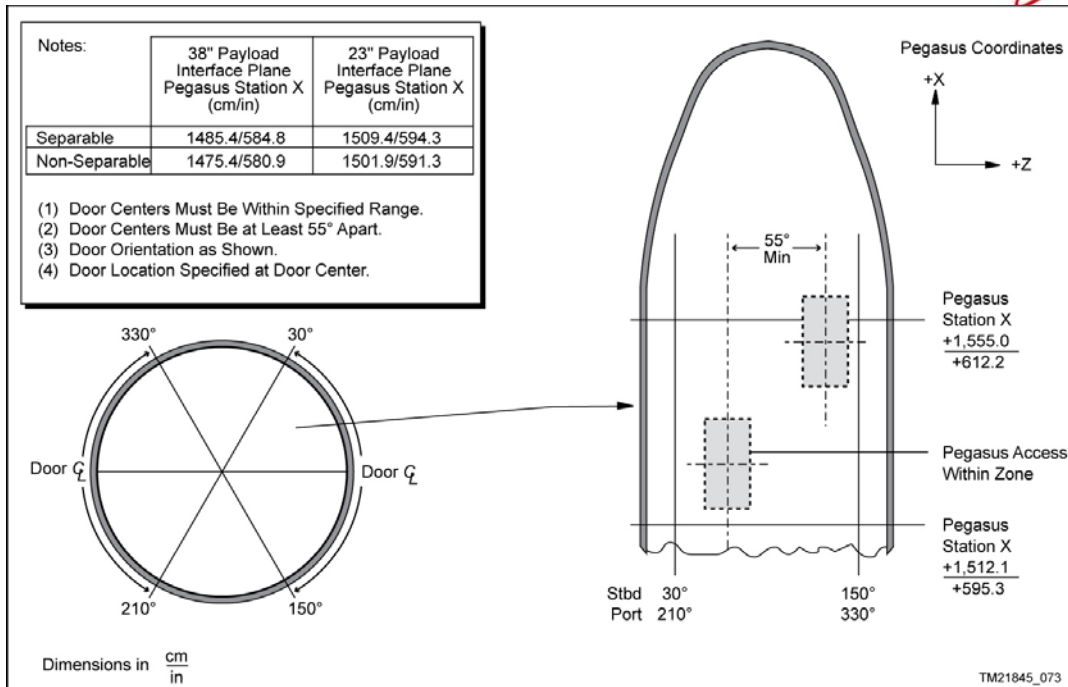
Figure 5-5. Payload Fairing Access Door Placement Zones (shown with optional second door shown)

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 and 2.7 kg (6.0 lbm) for the 59 cm (23 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 supply a detailed drawing of the bolt circle to allow accurate machining of the fastener holes and will supply all necessary attachment hardware to payload specifications. 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 to activate the redundant bolt cutters, which allows the titanium clamp band and its aluminum shoes to release. The clamp band and 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 5-9. If nonstandard separation velocities are needed, different springs may be substituted on a mission-specific basis.

5.3. Payload Electrical Interfaces
As a standard service, Orbital provides a basic electrical interface between the payload, the launch vehicle and any electronic support equipment located in the L1011 carrier aircraft. As a mission-unique service, Orbital can provide a wide variety of electrical services to the payload and a significantly increased number of pass through circuits between the payload and support equipment located in the carrier aircraft.
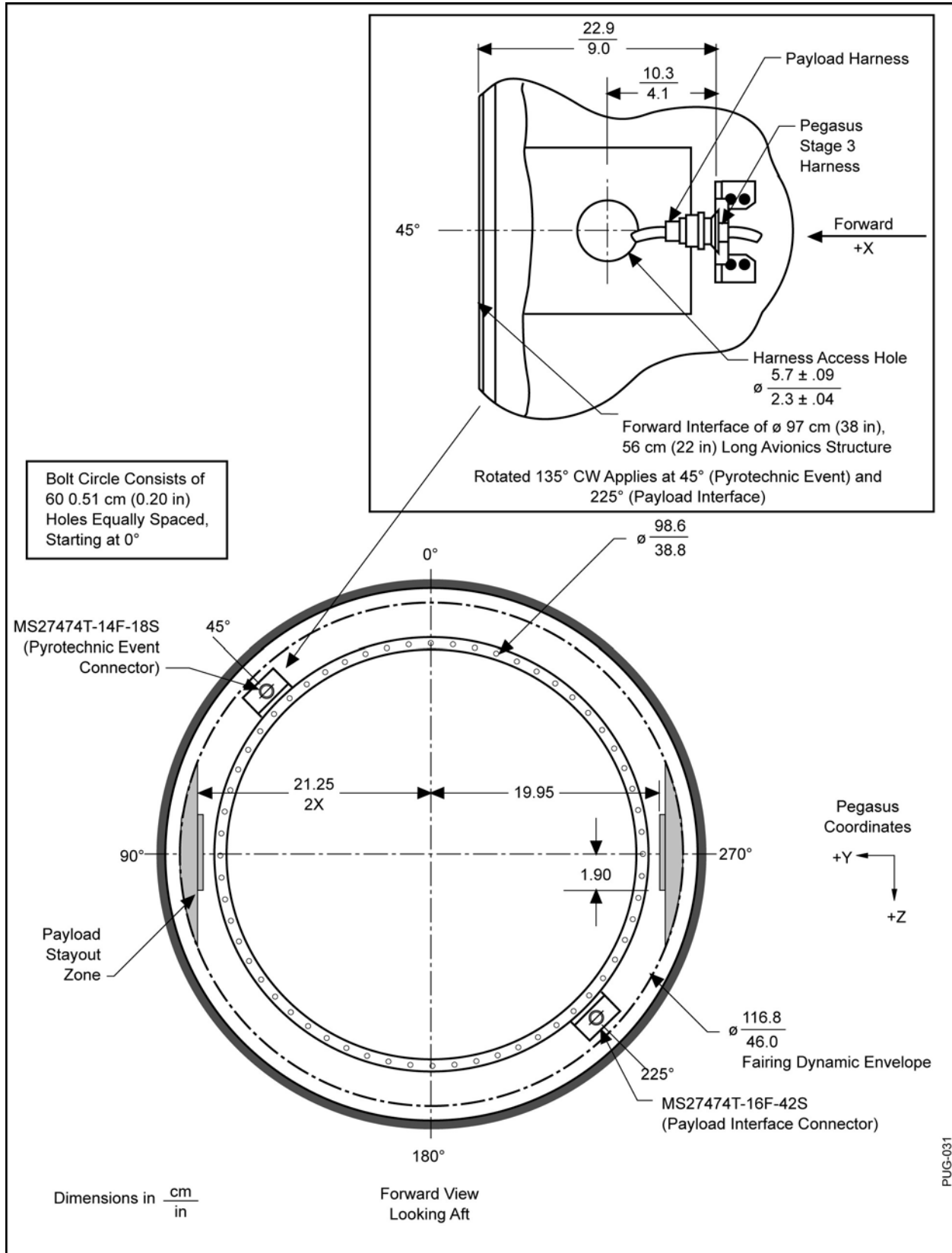
Figure 5-6. Nonseparable Payload Mechanical Interface

Pegasus
Coordinates

+Y

+Z

42 Pin Payload
Connector

0º

Bolt Cutters (2) (Redundant)

Payload Interface

90º

270º

Bolt Circle Consists of 60 0.51 cm
(0.201") Holes Equally Spaced,
Starting at 0º

Payload
Push-Off
Springs (4 Places)

Clamp Band
Retention Springs (8)

42 Pin Payload
Connector

180º

Forward View Looking Aft

4.0 kg (8.7 lbm) Remains with
Payload (Includes Harness)

$\frac{5.0}{2.0}$

$\frac{10.0}{4.0}$

ø $\frac{98.58}{38.81}$ Bolt Circle

Payload Interface
Plane

Separation
Plane

Payload Separation
Clamp Band

+X

Avionics Structure

+Y

Dimensions in $\frac{cm}{in}$

Side View

TM21845_074

Figure 5-7. 97 cm (38 in.) Separable Payload Interface
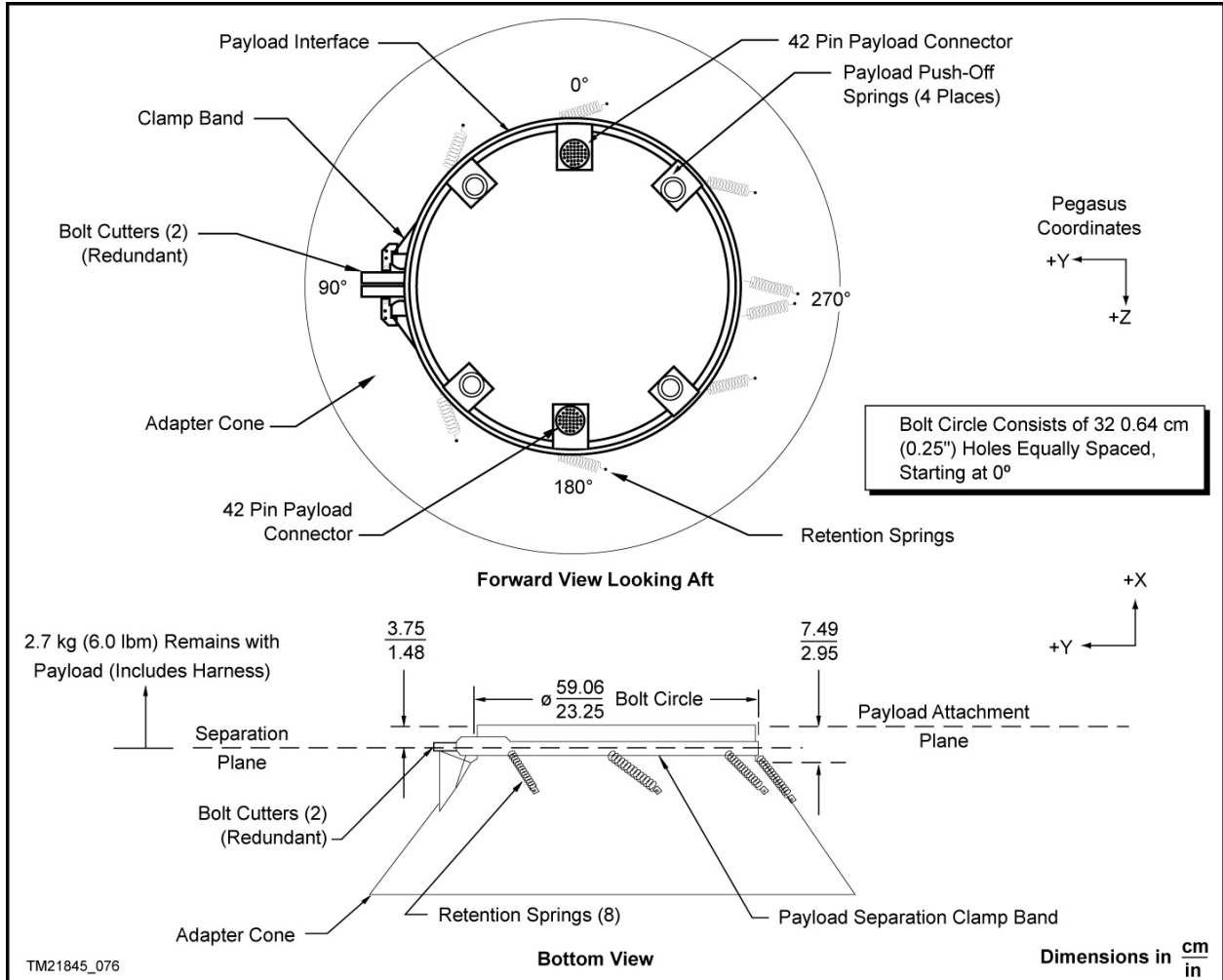
Figure 5-8. 59 cm (23 in.) Separable Payload Interface
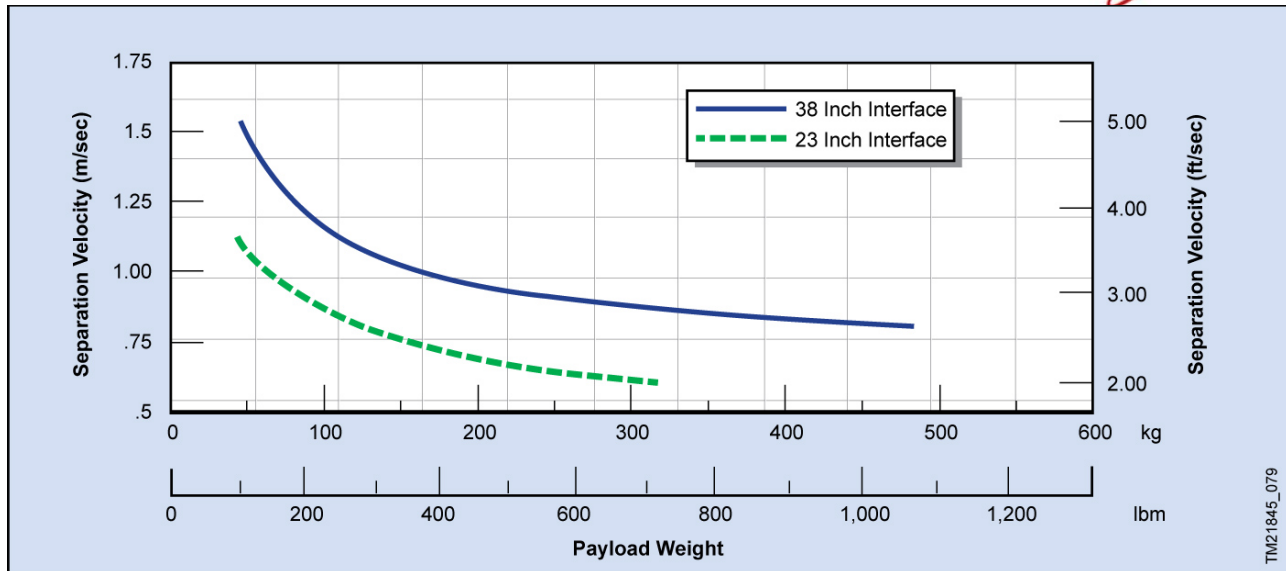
Figure 5-9. Payload Separation Velocities Using the Standard Separation System

5.3.1. Standard Electrical Interface

The standard electrical interface between the Pegasus launch vehicle and a payload using a nominal 38" separation system is shown in Figure 5-10. In this case standard electrical interface between the Pegasus launch vehicle and payload is two 42-pin MIL-C-38999 Series II electrical connectors located at the separation plane. These connectors are located at launch vehicle clocking angles of 0º and 180º. This provides symmetric connector pull forces during separation to minimize payload tip-off rates. The circuits that cross this interface will be documented in a mission-specific Electrical Interface Control Document (EICD).

As shown in the figure, the standard electrical interface provides:

- Ten pass-through wires (five twisted shielded wire pairs) between the payload interface plane and electrical support equipment installed in the Orbital Carrier Aircraft,
- Up to six breakwire circuits to be used by the payload to sense separation from the launch vehicle, and
- Two breakwire circuits to be used by the launch vehicle to sense separation of the payload.

The ten pass-through wires may be used for payload direct power, battery charging, command and telemetry transmission, safety inhibits, battery relay control and/or analog instrumentation. The current on each circuit is limited to 2.25 A. The six breakwire circuits are typically split evenly between the two connectors at the interface plane but may be configured as required by the payload. The payload shall provide one launch vehicle breakwire in each connector on the payload side of the electrical interface. This provides a redundant means of sensing payload separation and allows positive confirmation that both electrical connectors at the interface plane separated properly.

Figure 5-10. Standard Payload Electrical Interface

Orbital will provide limited space within the Launch Panel Operator (LPO) Station on the carrier aircraft for the payload's electrical support equipment. As a standard service, Orbital will provide personnel to operate the payload electrical support equipment during launch operations. This Payload LPO will monitor critical payload data, send commands, and adjust Airborne Support Equipment (ASE) settings as required per payload-provided procedures.

5.3.2. Mission-Unique Electrical Interface
As a nonstandard service, Orbital can provide a wide range of electrical interface options to meet the mission-specific requirements of the payload. These services include increased umbilical pass-through circuits, payload ordnance initiation, discrete commanding of the payload, processing of payload analog instrumentation, and a serial telemetry interface used to incorporate payload data into launch vehicle telemetry.

As described in detail in Section 10.7, Orbital can provide 40 additional umbilical pass-through wires from the payload separation interface to payload-supplied electronic support equipment installed on the carrier aircraft. This nonstandard service brings the total pass-through circuits to 50 wires (25 twisted shielded wire pairs).

The Pegasus launch vehicle can provide up to 6 high-current pulsed circuits that can be used to initiate payload ordnance or deployment devices such as propulsion system isolation valves, deployment system pin pullers or payload-provided separation systems. The nominal electrical output of these circuits is 6 A into a 1 Ohm load for 75 ms. If the payload uses an Orbital-supplied separation system, only four of the six circuits are available for payload use.

As described in detail in Section 10.14, payload status and state of health data can be

incorporated into launch vehicle telemetry using a serial telemetry interface. This interface is either a 4-wire RS-422, or a 2-wire RS-485 serial communication link between the Pegasus flight computer and the spacecraft. Up to 250 bytes/sec of payload data can be incorporated into Pegasus telemetry. The payload data is available in the launch control room during ground operations, captive carry and powered flight. The serial interface can also be used to send timed commands from the Pegasus launch vehicle to the payload during flight as required.

Pegasus avionics can be used to read and process data from payload analog instrumentation such as temperature sensors, strain gauges and pressure transducers. Data from up to eight separate sensors can be incorporated into launch vehicle telemetry and displayed in the launch control room during ground operations, captive carry and powered flight. Pegasus can provide 10 V excitation for payload instrumentation if required.

The Pegasus flight computer can generate discrete commands on eight separate channels as required by the payload. These opto-isolated circuits can be configured as voltage switching or switch closure. Each command circuit is capable of producing multiple pulses of programmable length. Minimum pulse duration is 40 ms. Maximum current for voltage switching circuits is 500 mA. The commands may be manually initiated during ground operations and captive carry or automatically sequenced during powered flight of the Pegasus vehicle.

All nonstandard services required by the payload will be documented in a mission-specific EICD.

5.3.2.1. 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 that is initiated on 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 of Pegasus from the 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 required 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.

5.3.2.2. Electrical Isolation

All power carrying circuits are isolated from the Pegasus XL and payload structures by at least 1 MΩ. 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.

5.3.2.3. Pre-Drop Electrical Safing

Prior to drop, all electrical power interfaces on the umbilical interface circuits between the carrier aircraft and the Pegasus vehicle shall be shut off to the extent possible to minimize current flow across the umbilical interface. Payload interface circuits that cannot be turned off and will have a current flow greater than 100 mA prior at drop must be evaluated by Orbital on a mission-specific basis.

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 5-11. 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 5-12). Payloads whose c.g. extend 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 5-13 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 5-12. The payload center of mass (c.m.) 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 c.g. to an accuracy to 6.4 mm in each axis, and the products of inertia to 0.7 kg-m2. 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. During the mission integration process, Orbital will provide specific notches that the payload should incorporate into radiated emission testing per MIL-STD-461 RE02. These notches are intended to ensure that the payload does not interfere with the S-band, C-band and GPS
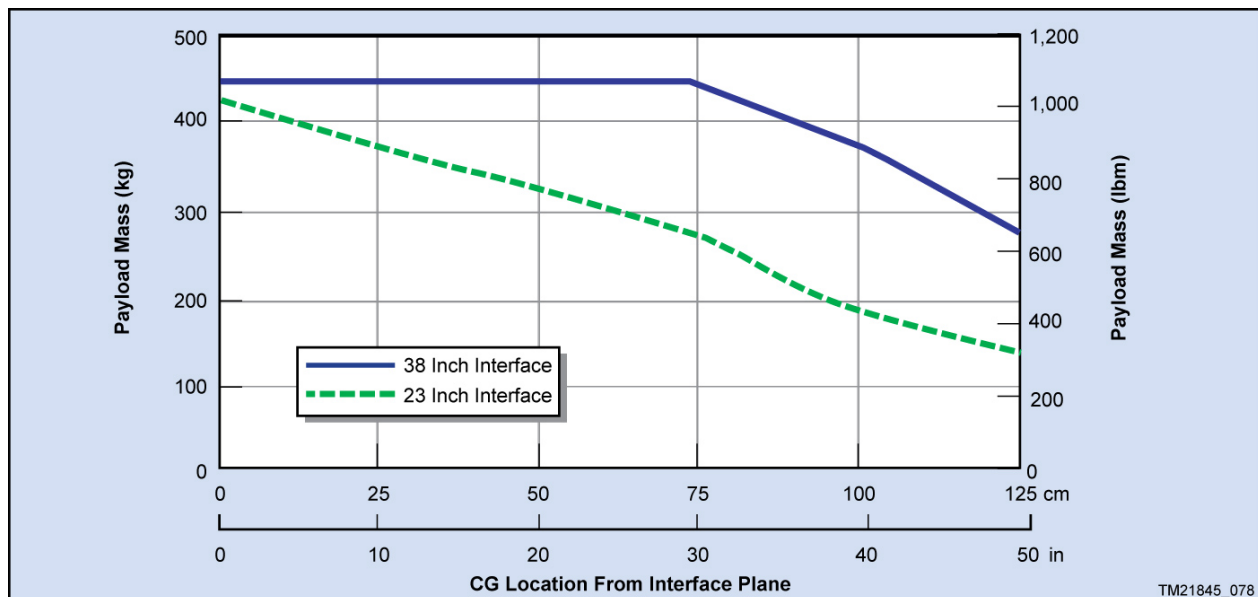
Figure 5-11. Payload Mass vs. c.g. Location on X Axis

Measurement	Error Tolerance
Mass	±0.5 kg (±1 lb)
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)

Figure 5-12. Payload Mass Property Measurement Error Tolerances

receivers on the Pegasus launch vehicle. Prior to launch, Orbital requires review of the payload radiated emission levels (MIL-STD-461, RE02) to verify launch vehicle EMI safety margins 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 may be required to ensure RF compatibility.

Payload RF transmission frequencies must be coordinated with Orbital and range officials to ensure noninterference with Pegasus and range transmissions. Additionally, the customer must schedule all RF tests at the integration site with

Orbital to obtain proper range clearances and protection.

5.4.4. Payload Stiffness

In order 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.

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.
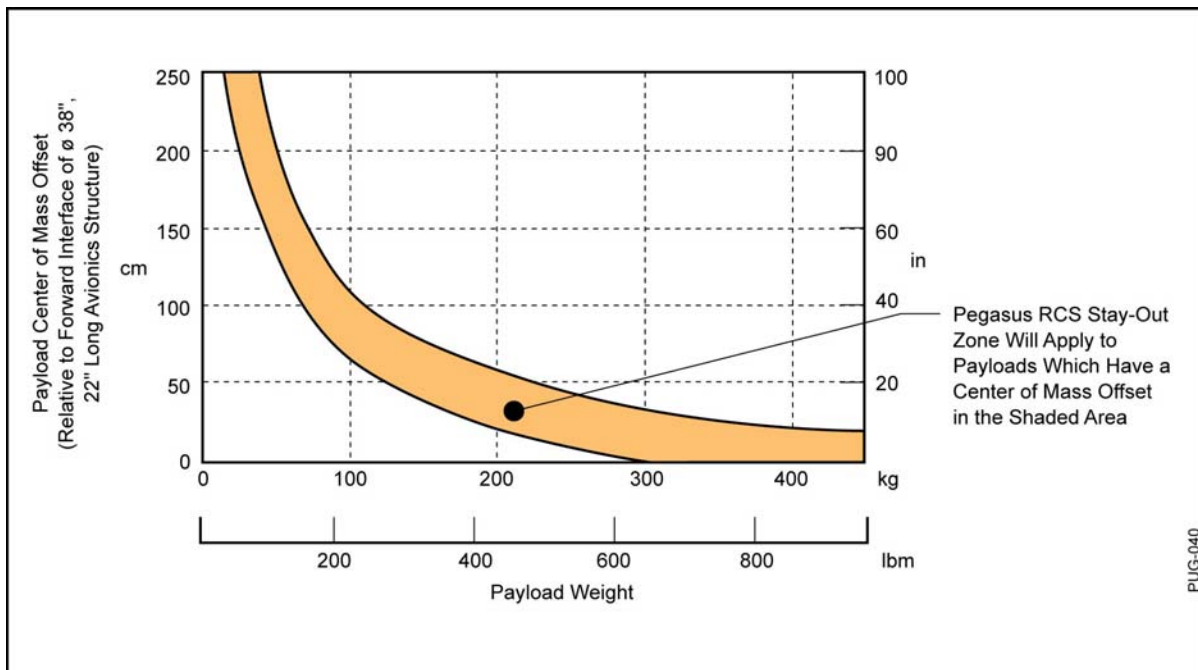
Figure 5-13. Detailed RCS Dead Band Zone

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 AFSPCMAN 91-710.

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

AFSPCMAN 91-710 outlines 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 ensure that the payload meets all Orbital and range imposed safety standards.

5.5. Carrier Aircraft Interfaces

5.5.1. Payload ASE Provisions

As a standard service, Orbital will provide up to 8U of space within an EIA 19" rack mount chassis at the LPO Station on the Carrier Aircraft for payload ASE. Power provided for payload ASE is

110 VAC, 60 Hz at maximum current of 15 A. Orbital will generate required drawings, submit required documentation to the FAA for approval and perform the installation of the payload equipment in the aircraft. If required due to the volume of payload ASE, a separate payload-provided equipment rack can be installed on the carrier aircraft as a nonstandard service.

As a standard service, Orbital will provide redundant DC power supplies and a switch panel in the LPO Station on the OCA that are dedicated for use by the payload. These power supplies may be used to provide spacecraft power and battery charging during ground operations and captive carry up until L-12 minutes at which time the spacecraft must transition to internal power. The power supplies can provide 60 V at 15 A maximum.

Figure 5-14 provides details on the Pegasus/OCA interface. The electrical interface between payload ASE and the carrier aircraft will be documented in a mission-specific EICD.
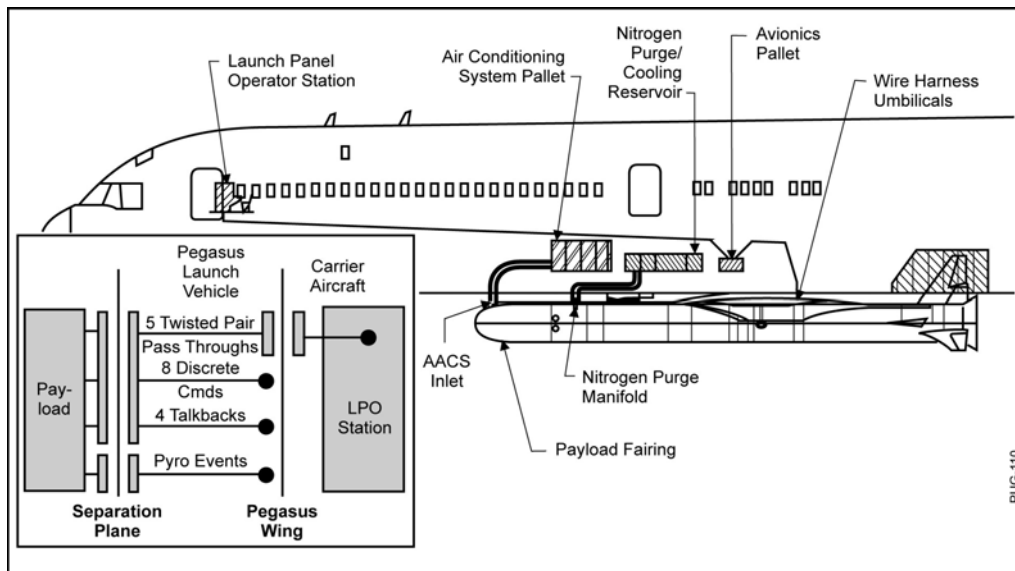
Figure 5-14. Pegasus/OCA Interface Details

5.5.2. Payload Support at Launch Panel Operator Station

Since it is not possible to accommodate payload personnel on the carrier aircraft during flight, Orbital will provide a dedicated operator to monitor and control payload ASE during launch operations. The operator, know as the Payload LPO, will monitor critical payload data, send commands, and adjust ASE settings per payload-provided procedures as required at the direction of the Launch Conductor (LC). The LC is in contact with the Payload LPO via a RF voice link provided by the Range. All steps performed by the Payload LPO shall be documented in payload-provided procedures and called out in the Launch Checklist. The payload customer is expected to provide training on all actions performed by the Payload LPO during integrated testing.

6. MISSION INTEGRATION

6.1. Mission Management Structure

Successful integration of payload requirements is important in achieving complete mission success. Pegasus has established a mission team approach to ensure all customer payload requirements are met and that all launch services are provided. A baseline of requirements and services is documented in an initial Interface Control Document (ICD) using a payload questionnaire as input to the ICD. As the mission evolves the team is responsible for documenting, tracking, and implementing new customer requirements and/or changes. A Configuration Control Board (CCB) ensures the requirement changes can be supported. Open communication between the Pegasus program and the payload customer is essential for ensuring complete customer satisfaction. To facilitate the necessary communication and interaction, the Pegasus mission integration approach includes establishing a mission team, frequent telecons, holding periodic working group meetings and supporting readiness reviews.

An organizational structure has been established to support each Pegasus mission. This organizational structure is used to manage payload integration, mission preparations, and to 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 and early identification and effective resolution of any issues.

The Pegasus and customer roles in mission integration are 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 organization 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, 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 5 areas: 1) Program Management; 2) Mission Management; 3) Mission Engineering; 4) Launch Site Operations; and 5) Safety.
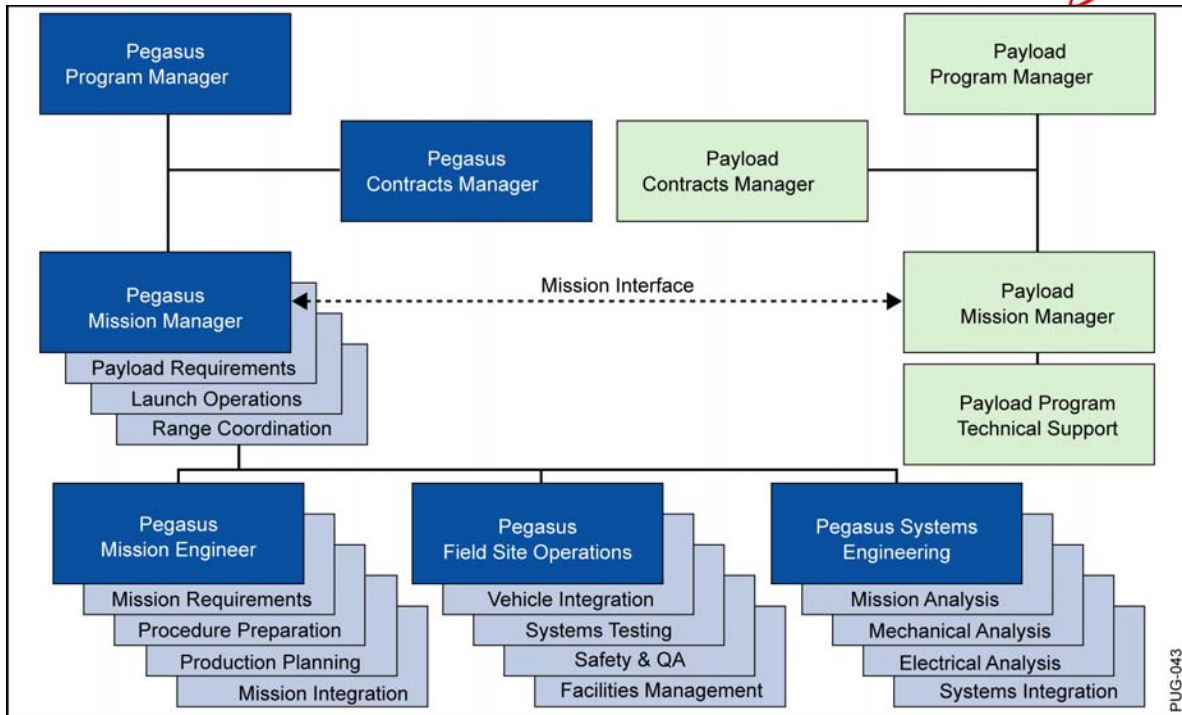
Figure 6-1. Mission Integration Management Structure

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 and the Pegasus Chief Engineer. All contractual considerations are administered between the payload and Pegasus Contract Manager. The Pegasus Chief Engineer is responsible for all technical aspects of the Pegasus launch vehicle, including vehicle processing and launch operations. The Pegasus Program Manager is responsible for management of all activities associated with providing the Pegasus launch service, including the Pegasus launch manifest, customer interface, and mission planning. The Pegasus Program Manager provides the customer with the management focus to ensure that 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's single point of contact for all aspects of a specific mission. This person has the responsibility to ensure that contractual commitments are met within schedule and budget constraints. The Pegasus Mission Manager will co-chair the MIWGs with the Payload Mission Manager. The Pegasus Mission Manager's responsibilities include detailed mission planning, launch vehicle production coordination, payload integration services, mission-unique 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 reports to the Pegasus Systems engineering lead and ensures that all mission-specific engineering is incorporated into the baseline Pegasus design and properly tested. 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.

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 that mission-specific envelopes are documented and environments, as specified in the ICD, are accurate and verified. The Mission Mechanical Engineer ensures the fairing access provisions are incorporated and the mechanical interfaces are properly tested.

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-unique hardware design and testing, mission-unique analyses, vehicle integration procedure development and implementation, and flight operations support.

6.1.1.4. 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 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.

6.1.1.5. 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 Pegasus Engineering Team during 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 that the launch vehicle and payload requirements are established and implemented to optimize both partie's 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 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 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 that all appropriate discussion items are addressed at the MIWG. Launch Operations Working Groups (LOWGs), Ground Operations Working Groups (GOWGs), Range Working Groups (RWGs), and Safety Working Groups (SWGs) 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.

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

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Figure 6-2. Summary of Typical Working Groups

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. 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 to 2 weeks prior to shipping the spacecraft to the integration facility. The MRR provides a pre-launch assessment of the launch vehicle, spacecraft, facilities, and range readiness for supporting the integration and launch effort. The LRR is typically conducted 1 to 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.

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, launch documentation, facilities planning, launch campaign planning to include range services and special operations, and integrated schedules. Orbital will conduct the working group meetings described in this section, and support 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- to 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, 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-unique 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 (GSE), 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 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 a 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:

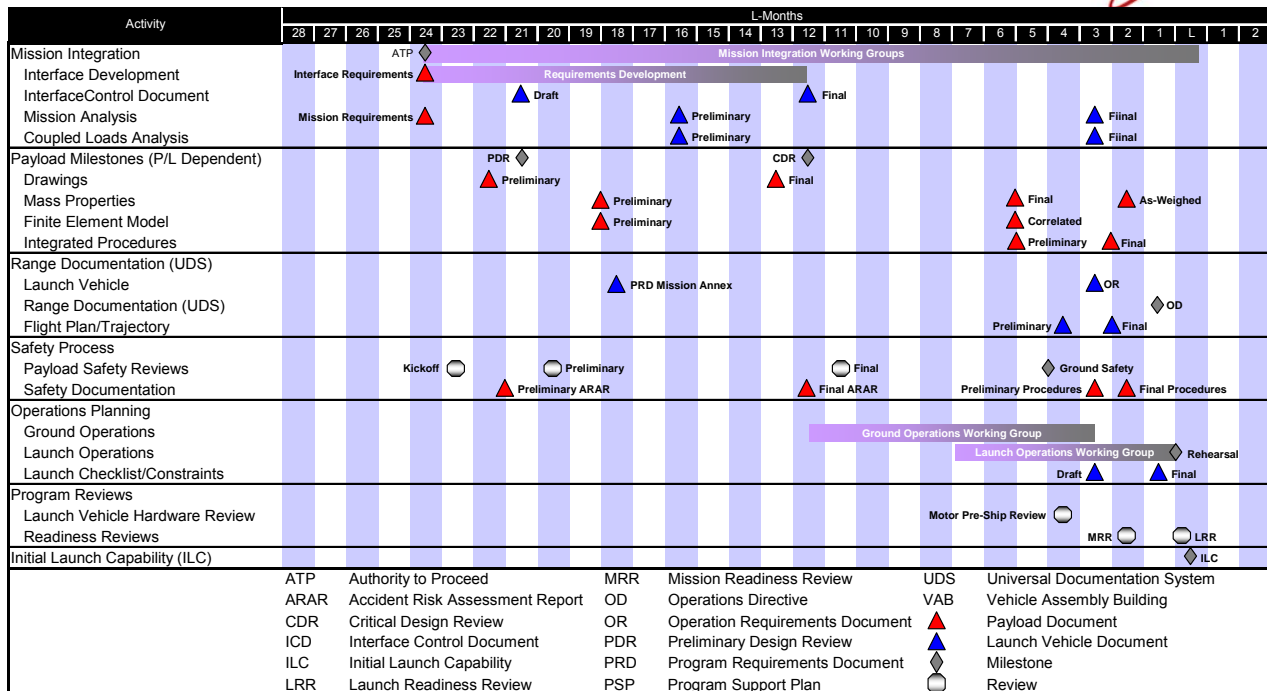(1) Baseline mission: Payload integration and launch operations are conducted at VAFB, California.

Figure 6-3 (Typical Mission Cycle) — Activity schedule by L-Months (28 down to 2 after L):

Mission Integration — Requirements Development; Mission Integration Working Groups
- Interface Development: ATP milestone; Interface Requirements (~24)
- InterfaceControl Document: Draft (~21), Final (~13)
- Mission Analysis: Mission Requirements (~24); Preliminary (~16); Final
- Coupled Loads Analysis: Preliminary (~16); Final

Payload Milestones (P/L Dependent) — PDR milestone (~22); CDR milestone (~12)
- Drawings: Preliminary (~22); Final (~12)
- Mass Properties: Preliminary (~18); Final (~5); As-Weighed (~3)
- Finite Element Model: Preliminary (~18); Correlated (~5)
- Integrated Procedures: Preliminary (~5); Final (~4)

Range Documentation (UDS)
- Launch Vehicle: PRD Mission Annex (~17); OR (~5)
- Range Documentation (UDS): OD milestone (~4)
- Flight Plan/Trajectory: Preliminary (~4); Final (~3)

Safety Process
- Payload Safety Reviews: Kickoff (~25); Preliminary (~23); Final (~11); Ground Safety (~5)
- Safety Documentation: Preliminary ARAR (~23); Final ARAR (~12); Preliminary Procedures (~5); Final Procedures (~3)

Operations Planning
- Ground Operations: Ground Operations Working Group
- Launch Operations: Launch Operations Working Group; Rehearsal (~4)
- Launch Checklist/Constraints: Draft (~4); Final (~3)

Program Reviews
- Launch Vehicle Hardware Review: Motor Pre-Ship Review (~6)
- Readiness Reviews: MRR (~3); LRR (~2)

Initial Launch Capability (ILC): ILC milestone (~L)

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

Figure 6-3. Typical Mission Cycle

(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 pre-launch operations are conducted at Orbital's VAB, Building 1555, VAFB. For campaign style missions, the spacecraft pre-launch 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., AFSPCMAN 91-710, 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.

Payload Integration Site	Launch Site	Applicable Safety Requirements Documents
VAFB	VAFB	AFSPCMAN 91-710 / Orbital TD-0005 / Orbital TD-0018
VAFB	CCAFS	AFSPCMAN 91-710 / Orbital TD-0005 / Orbital TD-0018
CCAFB	CCAFS	AFSPCMAN 91-710 / Orbital TD-0005 / Orbital TD-0018
KSC	CCAFS	AFSPCMAN 91-710 / KHB 1710 / Orbital TD-0005 / Orbital TD-0018
VAFB	WFF	AFSPCMAN 91-710 / RSM-93 / Orbital TD-0005 / Orbital TD-0018
WFF	WFF	AFSPCMAN 91-710 / Orbital TD-0005 / Orbital TD-0018
VAFB	KMR	AFSPCMAN 91-710 / KMR Range Safety Manual / Orbital TD-0005 / Orbital TD-0018

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Figure 6-4. Applicable Safety Requirements

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

6.5.2. System Safety Documentation

A Payload System Safety Program Plan (SSPP) shall be submitted to and approved by Orbital and the applicable Range Safety Organization. The SSPP shall include a description of the payloader System Safety Program as required in AFSPCMAN 91-710.

Range Safety requires certification that spacecraft 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 GSE. Hazardous systems include ordnance systems, separation systems, solar array deployment systems, power sources, RF and ionizing radiation sources, high pressure systems, 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. AFSPCMAN 91-710 Volume 3 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 work to 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 other 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.

A Ground Operations Plan (GOP) is required to be submitted to Orbital and Range Safety. After approval from Orbital and Range Safety, the GOP may be incorporated into the MSPSP. If the GOP is incorporated into the MSPSP, the MSPSP 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.

Figure 6-5. Safety Approval Process

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 SSPP, MSPSP, GOP, and hazardous procedures to ensure that 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 MIWGs and GOWGs.

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 with sufficient justification. This request for variance must contain 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.

7. PEGASUS/PAYLOAD INTEGRATION OVERVIEW

The Pegasus system is designed to minimize both vehicle and payload handling complexity as well as launch base operations time. Horizontal integration of the Pegasus vehicle and payload 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. Pegasus' well-defined payload integration process at the Vehicle Assembly Building at VAFB is readily adaptable to other potential integration sites.

7.1. Ground and Launch Operations

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

- Launch Vehicle Integration: Assembly and test of the Pegasus vehicle;
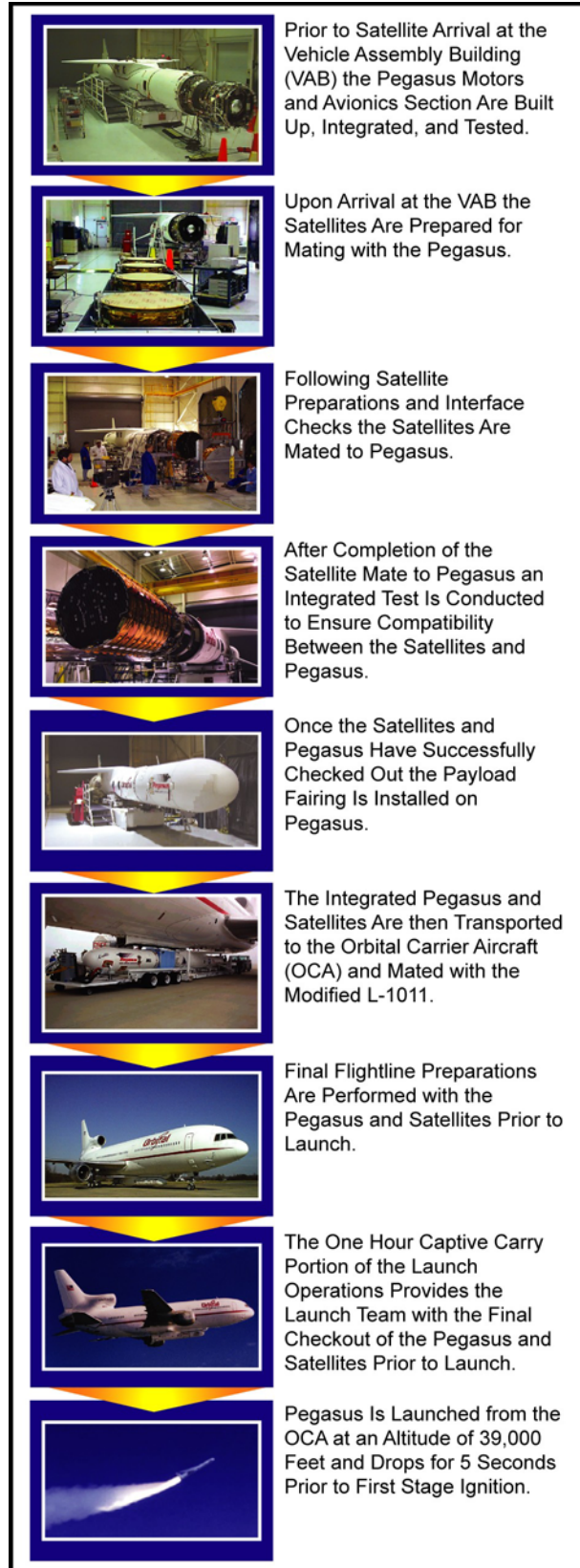
Figure 7-1. Typical Processing Flow

- 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.

7.1.1. Launch Vehicle Integration

7.1.1.1. Integration Sites
All major vehicle subassemblies are delivered from the factory to the VAB at Orbital's integration sites. Orbital's primary integration site is located at VAFB, California. Through the use of the OCA, this integration site can support launches throughout the world. The pre-launch activities (following Pegasus/OCA mate) are conducted from a hazardous cargo area referred to as the Hot Pad. The VAFB OCA Hot Pad area is shown in Figure 7-3.

In support of Pegasus processing at the integration site, the following Pegasus GSE is maintained at the VAB:
- An 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).

Figure 7-2. Typical Pegasus Integration and Test Schedule

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

7.1.1.2. Vehicle Integration and Test Activities

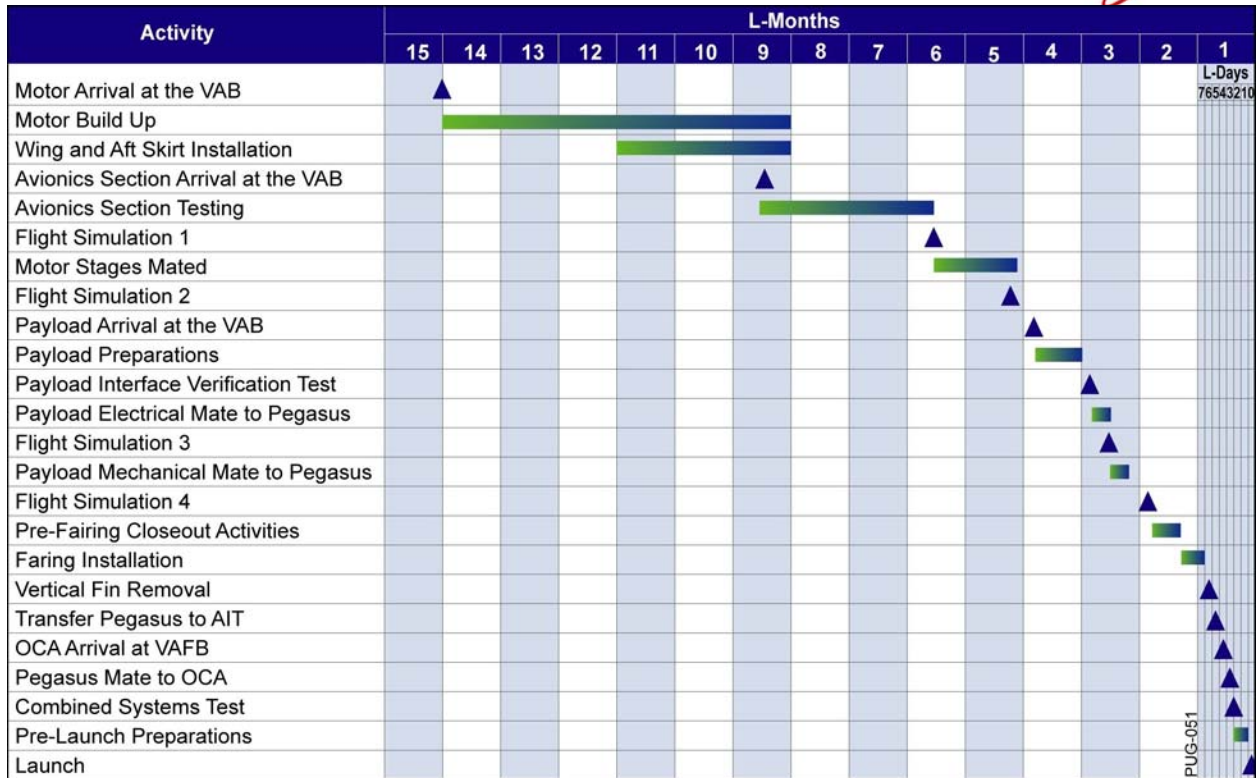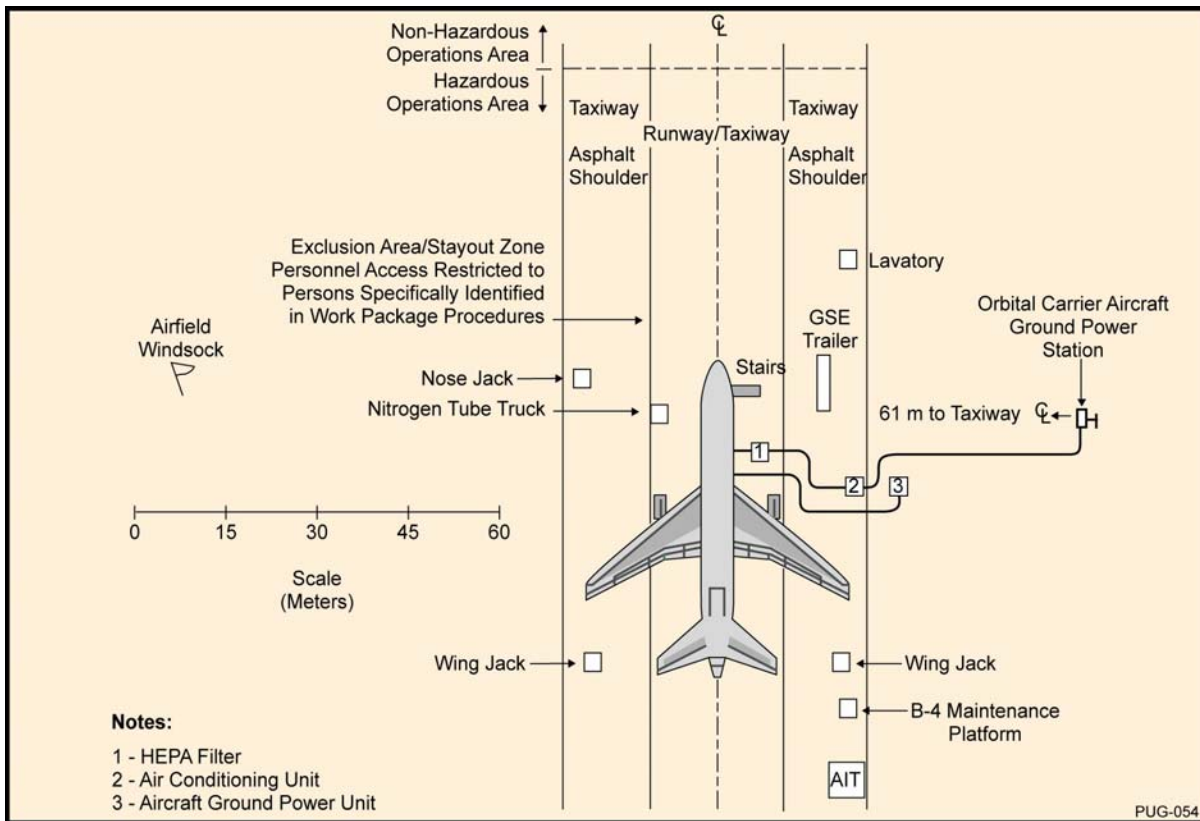Figure 7-4 shows the Pegasus stages being integrated horizontally at the VAB prior to the arrival of the payload. Integration is performed at a convenient working height, which allows easy access for component installation, test, and inspection. The integration and test process ensures that all vehicle components and subsystems are thoroughly tested before and after final flight connections are made.

Figure 7-4. Pegasus Integration

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 tests 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 INS. In this test, the INS 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 the motor stages are built-up, Flight Simulation #2 after the motor stages are mated, Flight Simulation #3 after the payload is 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 thorough data review of the test is complete, which usually takes 1 to 2 days. The payload nominally participates in Flight Simulations #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. Any discrepant items associated with the test activities are documented in Non-Conformance (NC) Reports.

7.1.2. Payload Processing

For a launch at the integration site, a typical Pegasus payload is delivered to the integration site at launch minus 30 calendar days. If the launch occurs at another location, the payload may be required to be delivered up to 10 days earlier to accommodate the additional ferry and staging operations. The payload completes its own independent verification and checkout prior to beginning integrated processing with Pegasus. 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).

7.1.2.1. Ground Support Services
The payload processing area capabilities depend on which mission option is chosen based on launch site: integrate and launch; integrate, ferry, and launch; or Pegasus campaign to launch site. Payload-unique ground support services are defined and coordinated as part of the MIWG process.

Vandenberg ground support services that would be used in the launch and ferry scenarios are outlined in Appendix B.

7.1.2.2. 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 that all interfaces are verified after final connections are made.

7.1.2.2.1. 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 integration site, Pegasus components 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, INS 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.

7.1.2.2.2. Payload Mating and Verification
Once the pre-mate payload 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.

7.1.2.2.3. 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.

7.1.2.2.4. 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 at VAFB. All launch integration facilities will be configured to handle these sealed systems in the integration process with the launch vehicle. The propellant loading area of the VAB is maintained visibly clean.

7.1.3. Launch Operations

7.1.3.1. Orbital Carrier Aircraft Mating

The Pegasus is transported on the AIT to the OCA for mating. This activity typically takes place about 3 to 4 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, known 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 that 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 1 hour prior to aircraft engine start (approximately T.O. minus 2 hours). After engine #2 start, the nitrogen truck is disconnected, the GACS 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.

7.1.3.2. Pre-Flight Activities

The pre-flight activities and launch checklist flow are shown in Figure 7-5. The first procedure for the mission operations team begins after the range communications checks and setup at 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 that 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 that the payload can be controlled by the LPO control switches as required. End-to-end checks are made to verify that Pegasus and payload (if applicable) telemetry transmissions are received in the telemetry room.

7.1.3.3. 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 Pegasus engineering team and the LC. 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.

The second group is the Operations/Engineering Group, including the LC, the Vehicle and Payload Engineers, and the Range Control Officers. The Orbital LC is responsible for running the
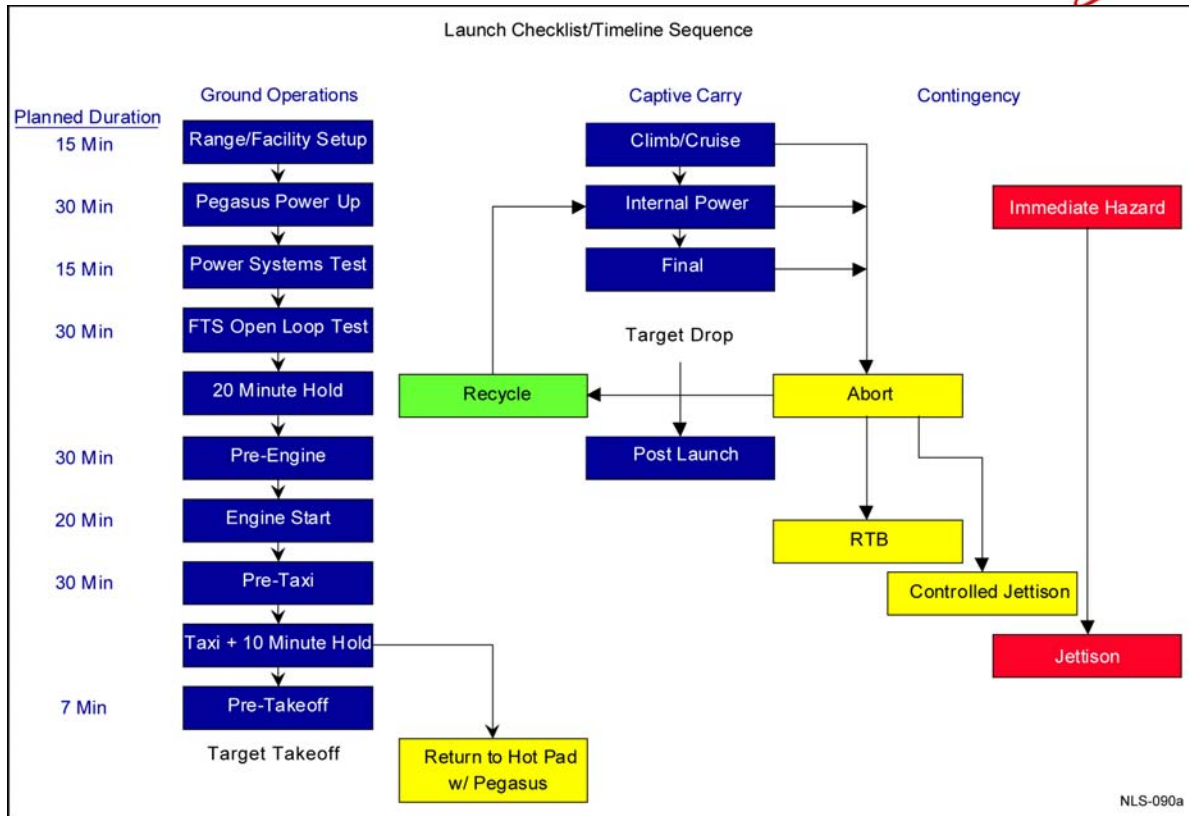
Figure 7-5. Typical Pegasus Launch Checklist Flow

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 that 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 LC.

The third group is the Airborne Operations Group, which includes the LPO and the aircraft crew. The LPO monitors on-board systems from the launch panel station on-board 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.

7.1.3.4. Flight Activities

The launch checklist begins prior to OCA 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 Hot Pad, about 1 hour before T.O., 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 T.O.

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 MIWG process.

Once airborne, Pegasus is configured into a launch condition by switching the FTS to internal battery power at approximately L-10 minutes, the avionics bus to internal power at approximately L-7 minutes, and the transient power bus to internal power at approximately L-3.5 minutes. 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 seconds, the fin thermal batteries are activated and a sinusoidal fin sweep is commanded by the flight computer to all fins to verify functionality prior to drop. The fin sweep telemetry, fin position, and command current are monitored and verified. Once this is completed, Pegasus is "Go For Launch." The Orbital LC relays this "Go" from the Pegasus control center to the OCA pilot commander. After confirmation from the pilot commander of a Go For Launch, the LC performs the drop countdown. The pilot releases Pegasus on the LC's command. After release, the Pegasus flight is completely autonomous.

7.1.3.5. Abort/Recycle/Return-to-Base Operations

Should an in-flight abort call be made, the approximate time to recycle in the air is 30 minutes. If an in-flight recycle opportunity cannot be exercised, 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.

8. DOCUMENTATION

8.1. Interface Products and Schedules

Orbital divides external interfaces into two areas: (1) interfaces with the Pegasus production team (i.e., our subcontractors and vendors), typically for hardware products; and (2) 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 various US Government agencies. 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
Customer	Preliminary ICD	L-21M
	Preliminary Mission Analysis/ Mission Profile	L-12M
	Final ICD	L-12M
	Final Mission Analysis /Mission Profile	L-3M
	Post-Flight Report	L+2M
Range	PRD Mission Annex	L-18M
	Pegasus Flight Termination System Report	As Required
	Pegasus Accident Risk Assessment Report	As Required
	Preliminary Mission Constraints Document	L-2M
	Preliminary Launch Checklist	L-2M
	Operations Requirements Document	L-3M
	Preliminary Trajectory	L-3M
	Final Trajectory	L-1.5M
	Final Launch Checklist	L-0.5M
	Mission Constraints Document	L-0.5M
Department of Transportation	Launch Specific Flight Plan	L-2.5M
	Payload Description	L-2.5M
	Vehicle Information Message	L-0.5M

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

Delivered by	Product	Due Date
Customer	Mission Unique Services Definition	L-24M
	Mission Requirements Summary	L-23M
	Preliminary Payload Drawing/Mass Properties	L-22M
	Payload PRD Input	L-20M
	Final Payload Drawing	L-15M
	Payload Accident Risk Assessment Report	L-13M
	Checklist/Launch Constraint Inputs	L-2M
	Integration Procedures	L-6M
	Final Payload Mass Properties	L-0.5M
Range	Program Support Plan	L-15M
	Operations Directive	L-1M
	Flight Plan Approval	L-1M

Figure 8-2. Documentation Required 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 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 first generates an optimal trajectory design to the desired target orbit, and this design is then used to develop the MDL which contains all mission sequencing, guidance, and autopilot inputs required for the mission. The MDL, in conjunction with the Orbital-developed Non-Real-Time Simulation (NRTSIM), a high-fidelity 6DOF simulation, is then subjected to a suite of tests designed to verify robust autopilot stability margins and compliance with all mission-specific requirements.

8.3.1. Trajectory Analysis

Orbital performs Preliminary and Final Mission Analyses using POST and the NRTSIM 6DOF analysis tool. The primary objective of these analyses is to verify the compatibility of the payload with Pegasus and to provide succinct, detailed mission requirements, such as payload environments, performance capability, orbit insertion accuracy estimates, and preliminary mission sequencing. Much of the data derived from the Preliminary Mission Analysis is used to verify or refine ICD requirements and perform initial range coordination.

Orbital also performs recontact and relative motion analyses for post-separation events to determine if a C/CAM is required. The analyses verifies that sufficient separation distance exists between the payload and final Pegasus stage following payload separation and includes effects of separation dynamics and of residual motor thrust.

8.3.2. Guidance, Navigation, and Control Analyses

These consist 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 dispersions for motor performance, mass uncertainties, aerodynamic characteristics, and INS performance. These dispersions are simulated to obtain estimated variability in perigee, apogee, inclination, and argument of perigee at orbit insertion. 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 performs a CLA (using finite element structural models of the Pegasus and payload) 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 CLA also contains a "rattlespace analysis." This analysis verifies that the payload does not violate the payload fairing dynamic envelope.

8.3.4. Payload Separation Analysis

Orbital uses the Pegasus STEP simulation to ensure that the payload is in the desired orientation for successful separation at the end of boost. Orbital performs 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

A RF link analyses is updated for each trajectory to ensure that sufficient RF link margins exist between range assets and the Pegasus vehicle for both the telemetry and flight termination systems.

8.3.6. Mass Properties Analysis and Mass Data Maintenance

Orbital tracks and maintains all mass properties, including inertias, relating to the Pegasus vehicle.

Payload-specific mass properties provided to Orbital by the customer are included. All flight components are weighed prior to flight and actual weights are employed in final GN&C analyses. Orbital requires estimates of the payload mass to facilitate preliminary mission planning and analyses. Delivery of the payload mass properties are defined in the mission ICD and tracked in the Mission Planning Schedule (MPS).

8.3.7. Power System Analysis

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

8.3.8. Fairing Analyses

Two payload-specific analyses performed by Orbital relate to the payload fairing: a critical clearance analysis (contained in the CLA) 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 approximately 5 seconds after drop of Pegasus from the OCA during the pull-up maneuver.

The fairing separation point is nominally timed to coincide with dynamic pressure falling below 0.01 psf that 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 Laboratory (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 provides a detailed mission report to the customer normally within 6 weeks of launch. Included in the mission report is the actual trajectory, event times, environments, and other pertinent data as reduced from telemetry from on-board sensors and range tracking. Orbital also analyzes telemetry data from each launch to validate Pegasus' performance.

8.4. Interface Design and Configuration Control

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

8.5. Mission Planning Schedule

Orbital develops a MPS tailored to each mission's schedule requirements. The MPS is a dynamic document used to support the MIWG planning and scheduling process. In conjunction with the MPS, a detailed (day-to-day) integration schedule is used at the integration and launch site to schedule and coordinate vehicle and payload activities.

8.6. Payload Documentation Support

The timely and accurate delivery of payload information is imperative in support of a number of Orbital's documents and analyses. Coordination of these deliverables is provided for in the MIWG process and tracked in the MPS.

9. SHARED LAUNCH ACCOMMODATIONS

Orbital has extensive experience in integrating and launching multiple payloads. Multiple spacecraft configurations have been flown on a number of 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.
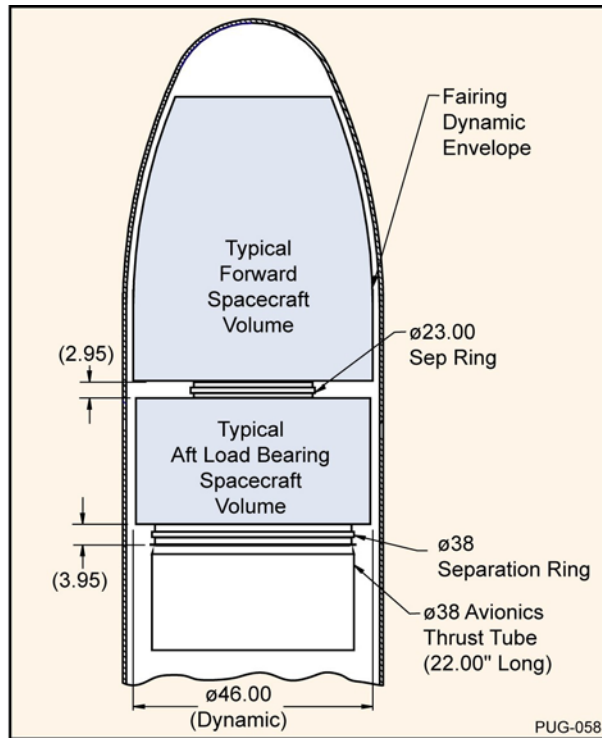
Figure 9-1. Load-Bearing Spacecraft Configuration

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 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.

For preliminary design purposes, coupled effects with the forward payload can be considered as a rigid body design case with Orbital-provided mass and c.g parameters. Integrated CLA 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 tests 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 that provides independent load paths for each satellite. The worst-case "design payload" for the DPAF is a 193 kg (425 lbm) spacecraft with 51 cm (20 in.) c.m. 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
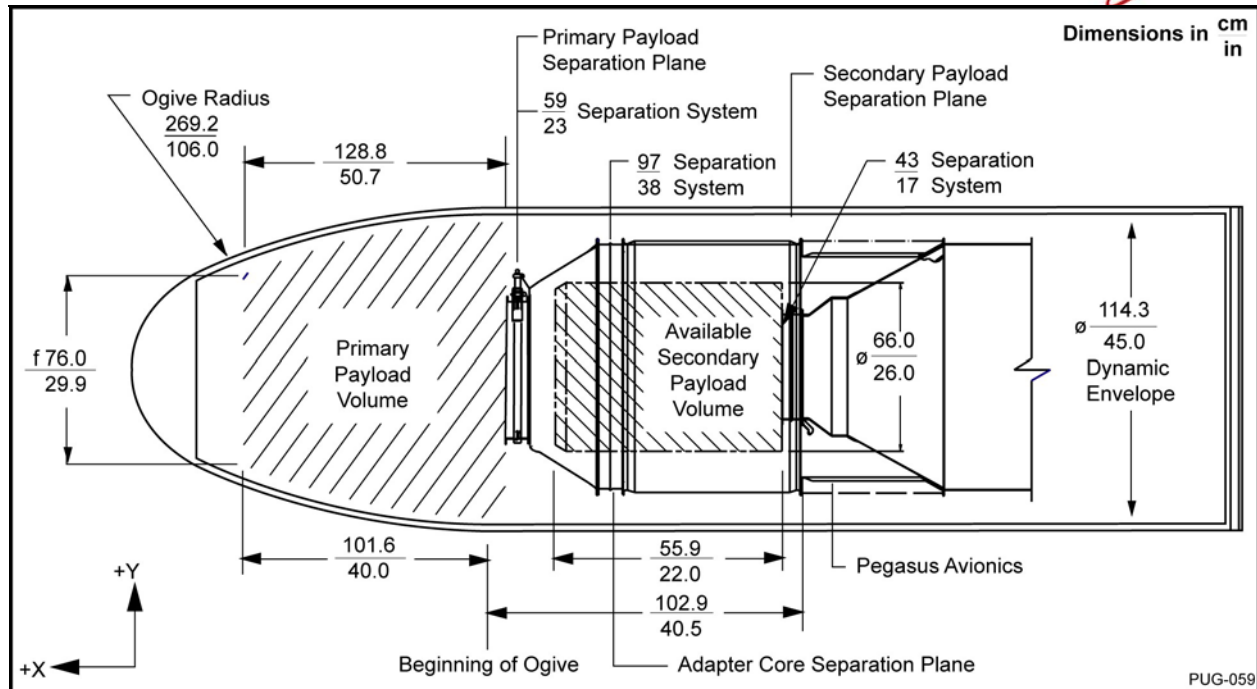
Figure 9-2. Dual Payload Attach Fitting Configuration

transmitted around the lower spacecraft via the DPAF structure, thus avoiding any structural interface between the two payloads.

For the upper payload the DPAF uses either an Orbital standard 97 cm (38 in.) Marmon clamp band interface, or an Orbital 59 cm (23 in.) Marmon clamp band interface on a separable adapter cone. The aft satellite support structure consists of either an Orbital 59 cm (23 in.) separation system, or an Orbital 43 cm (17 in.) separation system, both of which include an adapter cone to transition 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.

The separation sequence for the stack begins with initiation of the forward payload separation system followed by the separation of the conical adapter (if present). The aft payload is then separated and

ejected from within the cylinder that remains with the third stage.

10. NONSTANDARD SERVICES
Orbital offers a wide variety of nonstandard services. This section describes optional nonstandard services that are available. Within the description of each nonstandard service, the required authorization time is provided. Many of these nonstandard services have flight heritage on one or more Pegasus flights.

10.1. Alternative Integration Sites

Authorize by: L-24 months

Pegasus can offer 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.

10.2. Alternative Launch Sites

Authorize by: L-24 months

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;
- Reagan Test Site (RTS), Kwajalein, Republic of the Marshall Islands; 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. Integration facilities will not be provided at the range location.

10.3. Downrange Telemetry Support

Authorize by: L-12 months

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 downrange location or in near real-time (airborne systems) to support the acquisition of telemetry from either Pegasus or spacecraft (spacecraft telemetry downlink dependent) telemetry. These systems have been used

successfully on a number of Pegasus missions and prove to be an 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 that appropriate operational support and data products are provided to the payload customer.

10.4. Additional Fairing Access Doors

Authorize by: L-24 months

Additional access doors are available. Standard sizes are 8.5" x 13" and 4.5" circular. The following restrictions apply to door location.

The additional access doors are 13" x 8.5". The long dimension must be aligned with the Pegasus x-axis. The number of access doors in each half of the fairing cannot exceed two. Each additional door has an impact on payload performance to orbit of approximately 1 kg (2.2 lbm) each.

The additional rectangular access doors can be located in the standard zone in the cylinder section or at pre-approved locations in the ogive section of the fairing. Doors located in the pre-approved zone of the cylinder section are subject to the same restrictions that apply to the standard service doors.

The additional rectangular access doors can be located in the ogive section of the fairing. The center of the door must be located at fairing station 137.94 (equates to station 652.74 of Pegasus) with an angular location between 35° and 145° on the starboard half of the fairing or between 215° and 325° on the port half. Only one door is allowed in the ogive section of each half of the fairing. The placement of an access door in the ogive may reduce the local payload static and dynamic envelope by an amount equivalent to the door doubler thickness. A clearance analysis will be performed as part of the nonstandard service.

10.5. Optional Payload/Vehicle Integration Environment

Authorize by: L-20 months

Orbital is capable of providing a payload/vehicle integration environment that is clean, certified, and maintained at ISO 14644-1 Class 7 (10,000), to support payload integration through fairing encapsulation. As a part of this service, Orbital will provide and certify a Class 7 softwall cleanroom. The Pegasus Stage 3 motor, avionics section, and fairing halves will be located within this area. As much as possible, all integration activities will be performed within the cleanroom. All personnel will follow appropriate Class 7 cleanroom practices.   Note that the softwall cleanroom does not allow for overhead crane operations.   If the facility crane is required to support payload mate to the launch vehicle, the spacecraft and launch vehicle avionics section will be bagged and the cleanroom will be moved to allow crane access. The cleanroom will be moved back into position after the mate operation is complete. For spacecraft using a handling fixture for mate operations, all activities can occur within the cleanroom.

10.6. Enhanced Fairing Environment

Authorize by: L-20 months

Orbital can provide payload fairing purge with air meeting ISO 14644-1 Class 7 (10,000), in accordance with TD-0289, Pegasus Contamination Control Plan, NASA ISO 14644-1 Class 7 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 VAB;
- During transport to Hot Pad;
- During Hot Pad ground operations; and
- During OCA mated operations.

10.7. Enhanced Fairing Internal Surface Cleaning

Authorize by: L-20 months

Orbital can clean, certify, and maintain internal surfaces of the Pegasus payload fairing to IEST-STD-1246D, Level 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.

10.8. Hydrocarbon Monitoring

Authorize by: L-20 months

Orbital will provide monitoring of hydrocarbon levels during all integrated payload/Pegasus operations.   This service comprises the installation, calibration, and frequent round-the-clock monitoring of fixed and portable hydrocarbon (VOC) detectors in the VAB, during rollout to Hot Pad, and during Hot Pad operations through fairing closeout.

10.9. Instrument Purge System

Authorize by: L-20 months

Payload Instrument Purge is an optional service that provides up to two dedicated nitrogen lines to payload defined locations in the fairing. Flow is turned on/off by the LPO at payload discretion. Flow rate and nozzle location are documented in the mechanical ICD.   Flow is controlled within ±10% by a mission-unique choked orifice. Flow rates can be selected between 0 and 535 slpm (19.2 scfm). Nitrogen flow is limited to 267 slpm (9.6 scfm) per nozzle. Higher flow rates cannot be maintained indefinitely in flight due to aircraft nitrogen tank limitations. Total nitrogen mass for the payload purge is limited to 200 lbm after the

tube truck is disconnected. Ground nitrogen is continually supplemented by a tube truck, so capacity limitations are generally not a problem. The payload purge can be routed directly to the payload interior via a quick disconnect device as an additional mission-unique optional service. The quick disconnect exerts less than 50 lbf on the payload fitting. Back pressure must be limited to 10 psig when the purge gas is plumbed directly into a payload supplied device.

All fairing nitrogen systems receive nitrogen via a manifold installed in fairing near the split line. Fairing and/or payload purge lines can be installed on the right or left half of the fairing. Nitrogen lines can generally be routed to accommodate payload requests, however, they cannot cross the fairing split line.

10.10. Increased Capacity Payload-to-GSE Interface

Authorize by: L-24 months

Orbital can incorporate 40 additional circuits (20 shielded twisted wire pairs) from the payload interface to payload-provided ASE installed in the carrier aircraft. This harnessing is routed to the LV 0º connector at the separation plane. This wiring matches the specifications of the standard pass-through pairs: 22 gauge wire, 90% shielding, 2.5 ohms resistance, and a maximum carrying capability of 3.0 A per wire pair. The 40 circuits replace the standard 3 separation loopback circuits at this connector (if desired, the payload may elect to retain the 3 separation loopback circuits in this connector and use 34 circuits for spacecraft to ASE connectivity). Because additional harnesses are added to the launch vehicle, there is an approximately 2.7 kg (6 lbm) performance to orbit penalty associated with this nonstandard service

The 40 circuits of the nonstandard service are routed to the LPO Station or to a floor box

connector in the carrier aircraft. Orbital will support the installation of a payload-provided standalone ASE rack in the carrier aircraft as part of this nonstandard service. This significantly increases the ASE that may be installed on the carrier aircraft. Orbital will assist the payload in securing FAA certification of the ASE rack.

The added pass-through circuits and payload ASE will be documented on the mission-specific EICD.

10.11. Improved Insertion Accuracy Options

Authorize by: ATP

As a nonstandard service, an integral liquid fourth stage called the Hydrazine Auxiliary Propulsion System (HAPS), shown in Figure 10-1, can be provided on Pegasus.

Located inside an extended Pegasus avionics structure, HAPS is a monopropellant hydrazine propulsive system, which functions in blowdown mode. HAPS consists of a flight proven and EWR-127-1 qualified titanium propellant tank, three 45 lbf nominal Rocket Engine Assemblies (REA), and a redundantly initiated pyrotechnic isolation valve.

Being a liquid stage, the accuracy achievable by HAPS is limited only by the accumulated navigation errors during flight, which are dependent on the mission time line and trajectory chosen. In addition to improving accuracy, HAPS will also improve performance to altitudes above approximately 550 km (highly dependent on orbital requirements).

The additional length of the HAPS avionics section moves the payload interface plane forward by 10.45" relative to the standard 38" or 23" payload adapters. This reduces the available payload volume and increases the payload random vibration and acceleration levels. The addition of a separation system between the Stage 3 motor

Fill/Drain
Valve (3)

Hydrazine Tank

Pyro
Isolation
Valve

+X

+Z

Rocket Engine
Assemblies (3)

Isometric View

Dimensions in $\frac{cm}{in}$

$\frac{70.74}{27.85}$
Assemblies (3)

$\emptyset \frac{100.97}{39.75}$
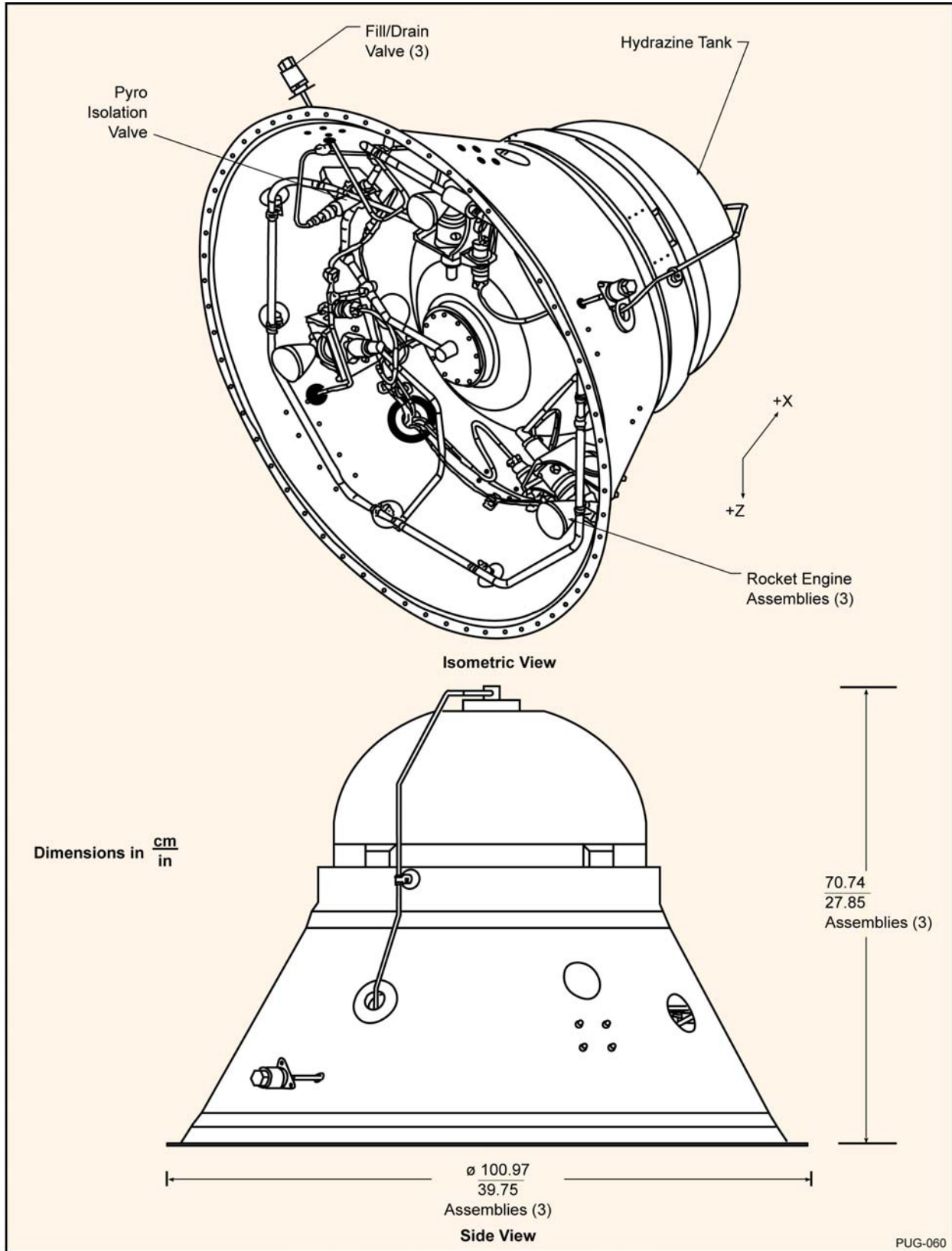Assemblies (3)

Side View

PUG-060

Figure 10-1. Hydrazine Auxillary Propulsion System (HAPS)

and the avionics section also alters the maximum expected shock response spectrum at the base of the payload. Environmental levels for a vehicle configured with HAPS will be provided on a mission-specific basis.

10.12. Load Isolation System

Authorize by: L-24 months

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.

10.13. Low Tip-Off Rate with Reduced Clamp Band Tension

Authorize by: L-12 months

For payloads that are significantly below the structural capabilities of the separation system, Orbital can perform analysis to verify system structural capability and coupled loads model analysis of clamp band with reduced Marmon clamp tension in order to reduce payload tip-off. Clamp band separation impulse is one of the primary causes of tip-off on the Pegasus separation system, and reduced clamp band tension will reduce the tip-off from clamp band release proportionally. Testing will be performed if required to validate the analysis results. This tip-off reduction technique can be performed with the 97 cm (38 in.), 59 cm (23 in.), or 43 cm (17 in.) PA.

10.14. Enhanced Telemetry Capabilities – Payload Data

Authorize by: L-20 months

Orbital offers a payload Serial Telemetry Interface that is used to incorporate payload telemetry and state of health data into Pegasus launch vehicle telemetry. This interface may be either a 4-wire

RS-422 or a 2-wire RS-485 serial communication link between the Pegasus flight computer and the spacecraft. The interface uses a poll/response protocol. The Pegasus flight computer polls the payload at a 1 Hz rate and receives a pre-determined block of payload data to be incorporated into the launch vehicle telemetry stream. The payload telemetry data volume cannot exceed 250 bytes/sec. As part of this nonstandard service, Orbital can incorporate two text-based and one graphical-based data display pages into Pegasus telemetry software to display this payload data in the launch control facility during ground operations, captive carry, and powered flight. Orbital will support up to two standalone tests with the spacecraft prior to integrated operations as a means to verify the interface protocol and spacecraft data format. These tests will be performed with an EDU flight computer.

The serial telemetry interface utilizes reserved pins in one of the 42-pin connectors at the separation interface and, therefore, does not affect the capacity of the standard payload electrical interface. The interface wiring will be documented on a mission-specific EICD. The interface protocol will be documented in a mission-specific serial communication specification.

10.15. State Vector Transmission From Pegasus

Authorize by: L-20 months

Pegasus can utilize a serial communication 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 Technical Document, TD-0271, Pegasus State Vector Technical Specification. Accuracy of the state vector will be that of the Pegasus inertial navigation system. This service must be exercised in conjunction with the enhanced telemetry service described in Section 10.14.

10.16. Payload Electrical Connector Covers

Authorize by: L-20 months

Orbital can provide flight-proven connector covers for the payload side of the separation system to cover the 42-pin interface connectors. The connector covers are spring loaded and attach to the standard umbilical support brackets. A bracket on the launch vehicle side of the separation system is used to hold the cover open until the two halves of the separation system are physically separated. At payload separation, the spring-loaded aluminum cover snaps closed over the exposed ends of the electrical connectors.

10.17. Payload Fit Check Support

Authorize by: L-18 months

Pegasus can provide flight and non-flight hardware and test support personnel to the payload contractor site for a fit check. Support hardware and technical and engineering support will be sent to the payload contractor's designated site to support a fairing fit check with the appropriate hardware.

10.18. Payload Propellant Loading

Authorize by: L-18 months

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

10.19. Pegasus Separation System Test Unit

Authorize by: L-18 months

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 2 weeks prior to the required need date for pyroshock testing and returned to Orbital no later than 2 working days after the conclusion of pyroshock testing. Orbital will review and check the test setup prior to firing the bolt cutters for pyroshock testing. Orbital must witness the test.

10.20. Round-the-Clock Payload Support

Authorize by: L-6 months

Pegasus supports a nominal 8 hours per day, 5 days 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 nonstandard service, payload support requirements prior to payload fairing mate outside these hours can be satisfied.

10.21. Stage 2 Onboard Camera

Authorize by: L-20 months

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. Thermal Coated Forward Separation Ring

Authorize by: L-12 months

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.

10.23. 43 cm (17 in.) Payload Adapter

Authorize by: L-24 months

As a nonstandard service, Pegasus can accommodate a 43 cm (17 in.) PA. The 43 cm (17 in.) PA is comprised of a 43 cm (17 in). Marmon clamp band separation system on a 97 cm (38 in.) to 43 cm (17 in.) adapter cone. Due to the height of the 97 cm (38 in.) to 43 cm (17 in.) adapter cone, available payload volume is reduced by 3.74" relative to a standard 23" PA. The 43 cm (17 in.) PA can support a payload of approximately 181 kg (400 lbm) with a c.g. 50 cm (20 in.) forward of the payload interface plane. Orbital will perform a mission-specific analysis to verify payload compatibility as part of this service. The 43 cm (17 in.) PA mechanical interface is a circle of 24 equally spaced 0.251" diameter through holes located on a 17" diameter bolt circle.

The electrical interface for the 43 cm (17 in.) PA consists of two 42-pin connectors both of which are mounted on a bracket that spans the inner diameter of the PA.

The forward placement of the payload may drive the Pegasus random vibration and drop transient environmental specifications higher. Orbital will perform mission-specific analysis utilizing actual payload mass properties to determine the required environmental test levels.

There is a performance to orbit penalty of approximately 2.8 kg (6 lbm) associated with the use of the 43 cm (17 in.) PA relative to the 97 cm (38 in.) PA.

10.24. Multiple Payload Adapters Including Related Mission Integration Support

Authorize by: L-24 months

Pegasus has the capability of flying multiple payloads in the payload fairing in several different configurations. For this nonstandard service two payloads are assumed.

10.25. Dual Payload Adapter with 97 cm (38 in.) Primary PA

Pegasus offers a Dual Payload Adapter (DPA) that supports primary and secondary payloads in a non-load bearing configuration. The DPA uses a structural cylinder of variable length to support the primary payload PA. The cylinder encapsulates the secondary payload. The primary or upper PA is the standard 97 cm (38 in.) separation system. The secondary payload is attached to the forward end of the avionics structure via a 59 cm (23 in.) or 43 cm (17 in.) PA. Following separation of the primary payload, the secondary payload is released and pushed out of the DPA cylinder by the action of the separation system's matched springs. A separation tip-off and clearance analysis is performed to ensure that the secondary payload does not contact the cylinder during separation. The price of the secondary PA is not included in this nonstandard service (see Sections 10.25 and 10.26).

The volume available to the secondary payload is limited by the height of the primary payload, the height of the primary PA, and tip-off rates of the secondary payload. The primary and secondary payloads must share the 10 pass-through circuits of the standard electrical interface capabilities of Pegasus. The standard launch vehicle and payload separation breakwire circuits provided by Pegasus will be duplicated for both the primary and secondary payloads.

The impact on Pegasus performance associated with the DPA will be based on the configuration chosen and must be determined on a mission-specific basis.

10.25.1. Dual Payload Adapter with 59 cm (23 in.) Primary PA

Pegasus offers a DPA that supports primary and secondary payloads in a non-load bearing configuration. The DPA uses a structural cylinder of variable length to support the primary payload PA. The cylinder encapsulates the secondary payload. The primary or upper PA is the standard 59 cm (23 in.) PA. This PA is attached to the DPA cylinder using a 97 cm (38 in.) separation system. The secondary payload is attached to the forward end of the avionics structure via a 59 cm (23 in.) or 43 cm (17 in.) PA. Following separation of the primary payload, the 59 cm (23 in.) PA is released from the DPA cylinder. The secondary payload is then released and pushed out of the DPA cylinder by the action of the separation system's matched springs. A separation tip-off and clearance analysis is performed to ensure that the secondary payload does not contact the cylinder during separation. The price of the secondary PA is not included in this nonstandard service (see Sections 10.25 and 10.26).

The volume available to the secondary payload is limited by the height of the primary payload, the height of the primary PA, and tip-off rates of the secondary payload. The primary and secondary payloads must share the 10 pass-through circuits of the standard electrical interface capabilities of Pegasus. The standard launch vehicle and payload separation breakwire circuits provided by Pegasus will be duplicated for both the primary and secondary payloads.

The impact on Pegasus performance associated with the DPA will be based on the configuration chosen and must be determined on a mission-specific basis.

10.25.2. Dual Payload Adapter with 43 cm (17 in.) Primary PA

Pegasus offers a DPA that supports primary and secondary payloads in a non-load bearing configuration. The DPA uses a structural cylinder of variable length to support the primary payload PA. The cylinder encapsulates the secondary payload. The primary or upper PA is the nonstandard 43 cm (17 in.) PA. This PA is attached to the DPA cylinder using a 97 cm (38 in.) separation system. The secondary payload is attached to the forward end of the avionics structure via a 59 cm (23 in.) or 43 cm (17 in.) PA. Following separation of the primary payload, the 43 cm (17 in.) PA is released from the DPA cylinder. The secondary payload is then released and pushed out of the DPA cylinder by the action of the separation system's matched springs. A separation tip-off and clearance analysis is performed to ensure that the secondary payload does not contact the cylinder during separation. The price of the secondary PA is not included in this nonstandard service (see Sections 10.25 and 10.26).

The volume available to the secondary payload is limited by the height of the primary payload, the height of the primary PA, and tip-off rates of the secondary payload. The primary and secondary payloads must share the 10 pass-through circuits of the standard electrical interface capabilities of Pegasus. The standard launch vehicle and payload separation breakwire circuits provided by Pegasus will be duplicated for both the primary and secondary payloads.

The impact on Pegasus performance associated with the DPA will be based on the configuration chosen and must be determined on a mission-specific basis.

10.26. Secondary Payload Adapters for Nonseparating Secondary Payloads

Authorize by: L-24 months

10.26.1. 59 cm (23 in.) or 43 cm (17 in.) PA for Nonseparating Secondary Payloads

The DPA described in Section 10.24 can be used to accommodate a nonseparating secondary payload. In this application, the DPA cylinder is separated from the Pegasus launch vehicle. Orbital will provide a nonseparating PA for use by a secondary payload in conjunction with the DPA described in Section 10.24.   The secondary payload and PA remain attached to the forward flange of the Pegasus avionics section.   If the primary payload is using a 59 cm (23 in.) or 43 cm (17 in.) PA, the 97 cm (38 in.) separation system nominally used to separate the primary PA from the DPA cylinder is moved to the aft end of the cylinder.   This way the cylinder and primary PA can be separated from the launch vehicle at the same time. If the primary payload is using a 97 cm (38 in.) PA, an additional 97 cm (38 in.) separation system would be required at the aft end of the cylinder. This additional separation system is not included in the cost of this nonstandard service. The envelope available for the secondary payload would be dependent on the separation characteristics of the DPA cylinder. Since this is in turn dependent on the primary PA, a separation and clearance analysis must be performed on a mission-specific basis.

10.26.2. Load-Bearing Nonseparating Secondary Payload

Pegasus can accommodate a load-bearing nonseparating secondary payload.   In this configuration, the secondary payload bolts directly to the forward flange of the Pegasus avionics section. The primary PA bolts to the load-bearing secondary payload. Orbital will coordinate with the secondary payload on structural requirements and mechanical interfaces required to accommodate the primary payload adapter.

10.26.3. Secondary Payload Adapters for Separating Secondary Payloads

Authorize by: L-24 months

10.26.4. 43 cm (17 in.) Payload Adapter

Orbital will provide the 43 cm (17 in.) PA described in Paragraph 10.23 for use by a secondary payload in conjunction with the DPA described in Section 10.24.

10.26.5. 59 cm (23 in.) Payload Adapter

Orbital will provide a standard 59 cm (23 in.) PA for use by a secondary payload in conjunction with the DPA described in Section 10.24.

APPENDIX A

PAYLOAD QUESTIONNAIRE

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 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 and submit the document electronically via e-mail or fax.

Orbital Sciences Corporation

| Print Form | Submit by Email |

Pegasus Payload Questionnaire

Thank you for the opportunity to be your launch service provider. Your answers to this questionarie will help us evaluate your needs and determine how we can best serve you.

Mission Information

Spacecraft Name:		Acronym:	
Spacecraft Owner:		POC Name:	
POC Email:		POC Phone:	
Spacecraft Subcontractor:		POC Name:	
POC Email:		POC Phone:	
Spacecraft Manufacturer:		POC Name:	
POC Email:		POC Phone:	

Spacecraft Description

Spacecraft Purpose	
Spacecraft Description:	

Mission Design

Launch Site:		Nominal Launch Date:

Orbit Insertion (with respect to WGS-84 spheroid)

Insertion Apse (km):	+/-	Non-Insertion Apse (km):	+/-	
Inclination (deg.):	+/-	Argument od Perigee (deg.):	+/-	
RAAN:	+/-	Ascending Node Crossing MLT :	+/-	

Launch Window Constraints (Other than those implied by orbit insertion requirements above):

Orbital Sciences Corporation. * 21839 Atlantic Blvd. * Sterling * Virginia * Phone: 703.406.5273 Fax: 703.406.3412 * www.baldwin.bryan@orbital.com

Attitude at Separation

S/C X-axis:		(e.g., Aligned with positive velocity vector)
S/C Y-axis:		(e.g., Toward the Sun)
S/C Z-axis:		(e.g., No Requirement)

Attitude Rates at Separation

Longitudinal Axis spin required? ◯ Yes ◯ No		Spin Rate (deg/s): ____ +/- ____	
S/C Z axis (deg/s): ____ +/- ____			

Spacecraft Mechanical Information

S/C X-axis = Launch Vehicle ☐ axis: S/C Y-axis = Launch Vehicle ☐ axis: S/C Z-axis = Launch Vehicle ☐ axis:

S/C Mass (kg) : ____   S/C Length(m) : ____   S/C Maximum Diameter (m) : ____

Propellant Type: _____   Propellant Mass (kg): ____

Center of Mass Location: S/C X-axis (m): ____   S/C Y-axis (m): ____   S/C Y-axis (m): ____

Moments of Inertia: S/C Ixx (Kg·m²) ____   S/C Iyy (Kg·m²) ____   S/C Izz (Kg·m²) ____

Fundamental Frequency: Longitudiinal (Hz): ____   Lateral (Hz): ____

Separation System: Pegasus Provided? ◯ Yes ◯ No   Size: ____

Manufacturer/Model Number (if not provided by Orbital: _____

Thermal Control provisions required (paint, tape,etc.): _____

Payload Access to the Fairing: Number of doors required: ____

Describe door location with respect to Spacecraft: Nominal size doors acceptable (21.6 cm x 33.0 cm)? ◯ Yes ◯ No

Nitrogen Purge/Cooling: Describe any nitrogen instrument purge or battery cooling requirements:

Directed Flow from nozzle on fairing? ◯ Yes ◯ No   Quick Disconnect line to S/C? ◯ Yes ◯ No

Number of nozzles or lines: ____   Total flow rate (cfm): ____

Spacecraft Electrical Information

Spacecraft Battery Type: _____

Launch Vehicle Interface :   Number of separation breakwires: ____

Serial telemetry interface (RS-422/485)? ◯ Yes ◯ No   Data Volume (bytes/sec) ____

Ordnance initiation required? ◯ Yes ◯ No

Number of Circuits: ____   Minimum Duration (mS): ____   Minimum Current (A): ____

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Spacecraft Electrical Information (cont.)

Umbilical Pass-Through Circuit Interface :

Total Number of wires from S/C to EGSE: [ ]   (Attach wire list with signal name, type and purpose if available)

Describe EGSE to be installed/used on L1011 carrier aircraft:

```
[                                                                    ]
```

Approximate footprint of EGSE in standard EIA rack units (m^2) : [ ]

Number of power supplies (battery charging): [ ]   Maximum Current (A): [ ]   Orbital Provided? ○ Yes   ○ No

Do you use a Telemetry/Control Computer?:   ○ Yes   ○ No   Number of analog meters: [ ]

Describe spacecraft operations required during captive carry:

```
[                                                                    ]
```

Payload Environments

Thermal and Humidity :

Nominal Pegasus temperature, humidity and airflow rate limits acceptable?   ○ Yes   ○ No

Provide requirements if different from nominal Pegasus specification:

```
[                                                                    ]
```

S/C Thermal Dissipation :   Maximum after encapsulation (W): [ ]   Launch Configuration (W): [ ]

Aerodynamic Heating :   Nominal Pegasus specification acceptable?   ○ Yes   ○ No

Maximum free molecular heating rate at fairing separation (BTU/ft^2/s): [ ]

Contamination Control :   Cleanroom and Fairing Air: ○ No Requirement   ○ Class 100K   ○ Class 10K

Fairing Surface: ○ Visibly clean   ○ 750A   ○ 500A   Sensitivity to Helium?   ○ Yes   ○ No

Launch Vehicle materiaals: TML <= 1.0% CVCM <= 0.1% required?   ○ Yes   ○ No

Vibration :   Nominal Pegasus random vibration specification acceptable?   ○ Yes   ○ No

Provide required levels if below nominal Pegasus specification:

```
[                                                                    ]
```

Acceleration :   Nominal Pegasus acceleration levels acceptable?   ○ Yes   ○ No

Provide maximum acceleration if below nominal Pegasus specification:

```
[                                                                    ]
```

Acoustics :   Nominal Pegasus acoustic levels acceptable?   ○ Yes   ○ No

Provide required levels if below nominal Pegasus specification:

```
[                                                                    ]
```

Payload Environments (cont.)

Shock :	Nominal Pegasus shock spectrum acceptable?	○ Yes ○ No

Provide required levels if below nominal Pegasus specification:

Electromechanical Compatibility :	Nominal Pegasus EMI/EMC levels acceptable?	○ Yes ○ No

Provide required levels if below nominal Pegasus specification:

Required Services

S/C Fueling at Integration Site :	Fueling Required?	○ Yes ○ No	Pegasus to arrange?:	○ Yes ○ No
Security :	Classified Payload?	○ Yes ○ No	COMSEC equipment?:	○ Yes ○ No

Other required services:

APPENDIX B

VAFB VEHICLE ASSEMBLY BUILDING CAPABILITIES

B1.0 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 checkout. 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 that require Range notification or approval.

B2.0 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 wall cleanroom 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 B-1. Floor loading is consistent with a fully loaded Pegasus on its AIT.

B3.0 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 mini-mum 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.

B4.0 PAYLOAD WORK AREAS

Orbital will provide approximately 37 m2 (400 ft2) of work space in the west coast VAB for payload use starting 30 calendar days prior to a planned launch operation and extending to 1 week after launch. Approximately 9 m2 (100 ft2) of admini-strative office space will be provided at a site close to the VAB.
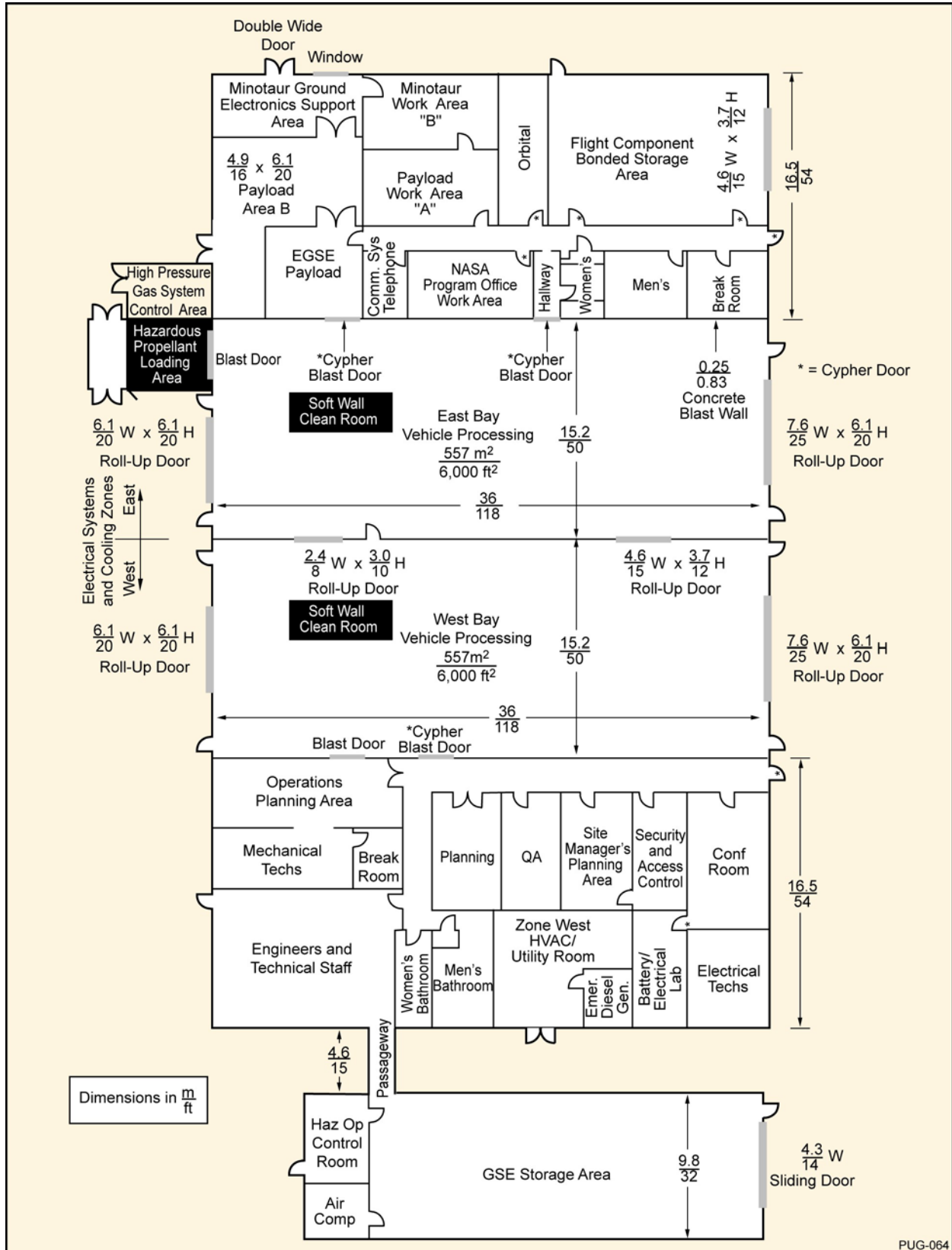
Figure B-1. The Vandenberg Vehicle Assembly Building General Layout

APPENDIX C

LAUNCH RANGE INFORMATION

C1.0 LAUNCH RANGE INFORMATION INTRODUCTION

Pegasus' air-launched design vastly increases launch point flexibility. Some ground support is required to ensure 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, Florida; Western Range, Vandenberg AFB, California; and Wallops Flight Facility, Virginia.

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 C summarizes the capabilities needed. This support could be provided by any facility meeting the following requirements.

C2.0 RANGE SAFETY

C2.1 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 ensure 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.

C2.2 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.

C2.3 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.

C2.4 Flight Termination System

Pegasus is equipped with command receivers that operate at either 421.0 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.

C2.5 FTS Controllers

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

C3.0 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 on-board 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.

C4.0 COMMUNICATIONS

C4.1 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.

C4.2 Voice Nets

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

C5.0 CONTROL CENTER

The launch team requires a control center to conduct the launch countdown.   This center requires a minimum of 20 consoles with voice nets and network computer displays.   The consoles must have the capability to remote key the radios for communications with the carrier and chase aircraft.

C6.0 DATA REQUIREMENTS

C6.1 Recording

Recording of all the telemetry downlinks is required.

C6.2 IRIG Timing

IRIG timing is required.

C6.3 Weather Forecasts

Weather forecasts are required.

C7.0 OPTIONAL LAUNCH RANGES

Figure C-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 50°
	Wallops Flight Facility (Option)	30° to 65°
Alternative Launch Sites	Kwajalein (Option)	0° to Sun-Synchronous
	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.		PUG-130

Figure C-1. Optional Launch Ranges

APPENDIX D

PEGASUS FLIGHT HISTORY

Flt	Launch Date Vehicle	Customer(s)	Payload	Payload Mission	Target Orbit Actual Orbit	Mission Results
Pegasus						
XF1	4/5/90 Standard (B-52)	DoD/NASA DoD	PegaSat NavySat SECS	• Flight Test Instrumentation • Atmospheric Research • Communications Experiment	320.0 x 360.0 nm @ 94.00° i 273.0 x 370.0 nm @ 94.15° i	• Complete Success • President's Medal of Technology Awarded to Orbital
XF2	7/17/91 Standard w/HAPS (B-52)	DoD	7 MicroSats	• Tactical Communications Network	389.0 x 389.0 nm @ 82.00° i 192.4 x 245.5 nm @ 82.04° i	• Met Mission Objectives with Reduced On-Orbit Lifetime • Stage 1/2 Separation Anomaly
F3	2/9/93 Standard (B-52)	INPE Brazil Orbital	SCD-1 OXP-1	• Data Communications • Communications Experiment	405.0 x 405.0 nm @ 25.00° i 393.0 x 427.0 nm @ 24.97° i	• Complete Success
F4	4/25/93 Standard (B-52)	DoD/DoE Orbital	ALEXIS OXP-2	• Technology Validation • Communications Experiment	400.0 x 400.0 nm @ 70.00° i 404.0 x 450.5 nm @ 69.92° i	• Complete Success
F5	5/19/94 Standard w/HAPS (B-52)	DoD	STEP-2	• Technology Validation	450.0 x 450.0 nm @ 82.00° i 325.0 x 443.0 nm @ 81.95° i	• Basic Vehicle Completely Successful • Upper Stage GN&C Anomaly
F6	6/27/94 XL	DoD	STEP-1	• Technology Validation	Failed to Achieve Orbit	• Mission Failure • Aerodynamic Loss of Control During Stage 1 Flight
F7	8/3/94 Standard (B-52)	DoD	APEX (PegaStar)	• Technology Validation	195.0 x >1000 nm @ 70.02° i 195.5 x 1372.0 nm @ 69.97° i	• Complete Success
F8	4/3/95 Hybrid	ORBCOMM NASA	FM1 &FM2 MicroLab	• Communications • Atmospheric Research	398.0 x 404.0 nm @ 70.00° i 395.0 x 411.0 nm @ 70.03° i	• Complete Success
F9	6/22/95 XL	DoD	STEP-3	• Technology Validation	Failed to Achieve Orbit	• Mission Failure • Interstage/Stage 2 Separation Anomaly

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Flt	Launch Date Vehicle	Customer(s)	Payload	Payload Mission	Target Orbit Actual Orbit	Mission Results
Pegasus (Continued)						
F10	3/8/96 XL	DoD	REX-2	• Technology Validation	450.0 x 443.0 nm @ 90.00° i 450.9 x 434.3 nm @ 89.96° i	• Complete Success
F11	5/16/96 Hybrid	BMDO	MSTI-3	• Technology Validation	298.0 x 394.0 km @ 97.13° i 293.0 x 363.0 km @ 97.09° i	• Complete Success
F12	7/2/96 XL	NASA	TOMS	• Atmospheric Research	340.0 x 955.0 km @ 97.40° i 341.2 x 942.9 km @ 97.37° i	• Complete Success
F13	8/21/96 XL	NASA	FAST	• Space Physics Research	350.0 x 4200.0 km @ 83.00° i 350.4 x 4169.6 km @ 82.98° i	• Complete Success
F14	11/4/96 XL	NASA	SAC-B HETE	• Space Physics Research	510.0 x 550.0 km @ 38.00° i 488.1 x 555.4 km @ 37.98° i	• Mission Failure • Launch Vehicle Did Not Separate the Spacecraft
F15	4/21/97 XL	INTA Spain	MINISAT 01	• Space Physics Research	587.0 x 587.0 km @ 151.01° i 562.6 x 581.7 km @ 150.97° i	• Complete Success
F16	8/1/97 XL	Orbital/ NASA	OrbView-2	• Ocean Color Imaging	310.0 x 400.0 km @ 98.21° i 300.0 x 302.0 km @ 98.28° i	• Complete Success
F17	8/29/97 XL	DoD	FORTE	• Technology Validation	800.0 x 800.0 km @ 70.00° i 799.9 x 833.4 km @ 69.97° i	• Complete Success
F18	10/22/97 XL	DoD	STEP-4	• Technology Validation	430.0 x 510.0 km @ 45.00° i 430.0 x 511.0 km @ 44.98° i	• Complete Success
F19	12/23/97 XL w/HAPS	ORBCOMM -1	8 ORBCOMM Satellites	• LEO Communications	825.0 x 825.0 km @ 45.00° i 822.0 x 824.0 km @ 45.02° i	• Complete Success
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 582.0 x 542.0 km @ 97.76° i	• Complete Success
F21	4/1/98 XL	NASA	TRACE	• Space Physics Research	600.0 x 650.0 km @ 97.88° i 599.9 x 649.2 km @ 97.81° i	• Complete Success
F22	8/2/98 XL w/HAPS	ORBCOMM -2	8 ORBCOMM Satellites	• LEO Communications	818.5 x 818.5 km @ 45.02° i 819.5 x 826.0 km @ 45.01° i	• Complete Success

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Flt	Launch Date Vehicle	Customer(s)	Payload	Payload Mission	Target Orbit Actual Orbit	Mission Results
Pegasus (Continued)						
F23	9/23/98 XL w/HAPS	ORBCOMM -3	8 ORBCOMM Satellites	• LEO Communications	818.5 x 818.5 km @ 45.02° i 811.0 x 826.0 km @ 45.02° i	• Complete Success
F24	10/22/98 HYBRID	INPE Brazil NASA	SCD-2 Wing Glove	• Data Communications • Atmospheric Experiment	750.0 x 750.0 km @ 25.00° i 750.4 x 767.0 km @ 24.91° i	• Complete Success
F25	12/5/98 XL	NASA	SWAS	• Space Physics Research	635.0 x 700.0 km @ 70.00° i 637.7 x 663.4 km @ 69.91° i	• Complete Success
F26	3/4/99 XL	NASA	WIRE	• Space Physics Research	540.0 x 540.0 km @ 97.56° i 539.0 x 598.0 km @ 97.53° i	• Complete Success
F27	5/17/99 XL w/HAPS	NASA	TERRIERS	• University Science Payload	550.0 x 550.0 km @ 97.75° i 551.0 x 557.0 km @ 97.72° i	• Complete Success
		DARPA	MUBLCOM	• Technology Validation	775.0 x 775.0 km @ 97.75° i 774.0 x 788.0 km @ 97.72° i	• Complete Success
F28	12/4/99 XL w/HAPS	ORBCOMM -4	7 ORBCOMM Satellites	• LEO Communications	825.0 x 825.0 km @ 45.02° i 826.5 x 829.0 km @ 45.02° i	• Complete Success
F29	6/7/00 XL	Orbital SSG	TSX-5	• Military Technology Demonstration	405.0 x 1,750.0 km @ 69.00° i 409.9 x 1,711.7 km @ 68.95° i	• Complete Success
F30	10/9/00 HYBRID	NASA	HETE-2	• Space Physics Research	600.0 x 650.0 km @ 2.00° i 591.9 x 651.9 km @ 1.95° i	• Complete Success
F31	2/5/02 XL	NASA	HESSI	• Solar Observation	600.0 x 600.0 km @ 38.00° i 586.4 x 602.0 km @ 38.02° i	• Complete Success
F32	1/25/03 XL	NASA	SORCE	• Solar Observation	645.0 x 645.0 km @ 40.00° i 622.3 x 647.3 km @ 40.00° i	• Complete Success
F33	4/28/03 XL	Orbital SSG NASA	GALEX	• Space Physics Research	690.0 x 690.0 km @ 29.00° i 689.8 x 711.3 km @ 28.98° i	• Complete Success
F34	6/26/03 XL	Orbital SSG ORBIMAGE	OrbView-3	• Earth Imaging	369.4 x 475.3 km @ 97.29° i 367.1 x 440.5 km @ 97.27° i	• Complete Success
F35	8/12/03 XL	Bristol CSA	SCISAT-1	• Atmospheric Measurement	650.0 x 650.0 km @ 73.92° i 647.9 x 659.7 km @ 73.95 i	• Complete Success
F36	4/15/05	NASA	DART	• Autonomous Rendezvous Technology Demonstration	538.7 x 566.7 km @ 97.73° i 541.2 x 548.8 km @ 97.73° i	• Complete Success
F37	3/22/06	NASA	ST5	• Technology Demonstration	300 x 4500 km @ 105.6° i 301.1 x 4571 km @ 105.615° i	• Complete Success
F38	4/25/07	NASA	AIM	• Space Physics Research	600 x 600 km @ 97.77° i 601.3 x 596.2 km @ 97.79 i	• Complete Success
F39	4/16/08	GD	C/NOFS	• Space Research	400 x 850 km @ 13.0° i 401.0 x 868.0 km @ 12.99° i	• Complete Success
F40	10/19/08	NASA	IBEX	• Space Research	207 x 412 km @ 11.0° i 206.4 x 445.0 km @ 10.99° i	• Complete Success

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