SEA LAUNCH ®

User's Guide

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A	This document supersedes the Sea Launch User's Guide in its entirety - Rev New, March 26, 1996.	July 1998	Dennis D. Smith Chief Engineer
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ABBREVIATIONS AND ACRONYMS

ACS	assembly and command ship
AST	U.S. Department of Transportation, Office of the Associate Administrator for Commercial Space Transportation
BCSC	Boeing Commercial Space Company
BER	bit error rate
BLS	Boeing Launch Service
BR9DM	Zenit-3SL telemetry system
C_3	velocity squared at infinity
CCTV	closed-circuit television
CDR	critical design review
CG	center of gravity
CIS	Commonwealth of Independent States
CLA	coupled loads analysis
CPSP	customer prelaunch safety package
DBTM	Design Bureau of Transport Machinery
EGSE	electrical ground support equipment
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPTME	encapsulated payload transportation mechanical equipment
ESD	electrostatic discharge
FAA	Federal Aviation Administration
FAA/AST	Federal Aviation Administration, Office of the Associate Administrator for Commercial Space Transportation
FMH	free molecular heating
GEO	geosynchronous Earth orbit
GORR	ground operations readiness review
GSE	ground support equipment
GTO	geosynchronous transfer orbit
h_a	height of apogee
h_p	height of perigee
HP	Home Port
IC	instrument compartment
ICD	interface control document
I/F	interface
ILV	integrated launch vehicle
IPT	integrated product team
IS	interface skirt
ISPS	interface skirt and payload structure
ITRR	ILV transfer readiness review
KNSG	(automated countdown validation)
LAN	local area network

LCC	launch control center
LOX	liquid oxygen
LP	launch platform
LRR	launch readiness review
LSE	launch support equipment
LV	launch vehicle
MD	Mission Director
MECO1	main engine cutoff number 1
MEM	mission equipment manager
MEO	medium Earth orbit
MES1	main engine start number 1
MS	military standard
NASA	National Aeronautics and Space Administration
NLT	not later than
NRZL	non-return to zero level
NVR	nonvolatile residue
OASPL	overall sound pressure level
PBX	private branch exchange
PCM	pulse control modulated
PLA	payload accommodations
PDR	preliminary design review
PLF	payload fairing
PLS	payload structure
PLU	payload unit
PPF	payload processing facility
PSS	payload separation system
RAAN	right ascension of the ascending node
RF	radio frequency
RH	relative humidity
RR	readiness review
SBA	strongback assembly
SC	spacecraft
SCA	spacecraft adapter
SCC	spacecraft contractor
SL	Sea Launch
SLS	Sea Launch System
STA	station
TE	transporter/erector
TIM	technical interchange meeting
TM	telemetry
VTC	video teleconferencing
WX	weather

1.0 INTRODUCTION

Purpose

The purpose of the *Sea Launch User's Guide* is to familiarize current and potential customers with the Sea Launch system and associated launch services. This document is the starting point for understanding the Sea Launch spacecraft integration process and the overall capabilities of the system. Further information may be obtained by contacting Sea Launch directly.

1.1 Overview of the Sea Launch System

What the System Includes

The Sea Launch system includes

- The Zenit-3SL launch vehicle
- The launch platform (LP)
- The assembly and command ship (ACS)
- Spacecraft and launch vehicle processing facilities
- Tracking and communications assets

Sea Launch Standard Offerings and Options (app. B) describes the hardware, launch services, facilities, support services, and optional services provided by the Sea Launch Company, LLC.

The home port for the launch platform and the assembly and command ship is located in the Port of Long Beach in Southern California. The payload processing facility (PPF), which accommodates a full range of spacecraft electrical and mechanical processing, testing, and fueling capabilities, is also located at Sea Launch Home Port.

Advantages

Our marine-based operations provide a number of advantages over conventional launch systems that use a land site. The Sea Launch concept avoids the high infrastructure and support costs associated with existing land-based launch sites, while providing increased operational flexibility.

At sea, the spacecraft can be launched to any azimuth, largely unconstrained by terrain overflight considerations. Launching at sea permits equatorial launch of geosynchronous satellites, which improves the mass-to-orbit capability by eliminating costly plane change maneuvers.

The Sea Launch system accomplishes launch vehicle tracking, telemetry and command through the use of the assembly and command ship, NASA's Tracking and Data Relay Satellite System, and existing ground stations.

Timeline

The first launch of a new award spacecraft type can be accomplished within 18 months after contract award. Repeat missions of the same spacecraft type can be completed within 12 months after contract award.

Sea Launch is capable of reducing the time required for integrating and launching spacecraft. Deviations from the standard 18-month and 12-month flows may be accommodated on a case-by-case basis. The standard mission cycle time is 50 days between launches. Sea Launch has committed to reducing launch cycle time to 45 days with a commensurate reduction in spacecraft processing time. A typical timeline for a first-time mission is shown in figure 1-1.

Companies considering Sea Launch should complete the user questionnaire (app. A) and return it to the address indicated. On contract award, Sea Launch will use the information in the user questionnaire to begin the integration process.

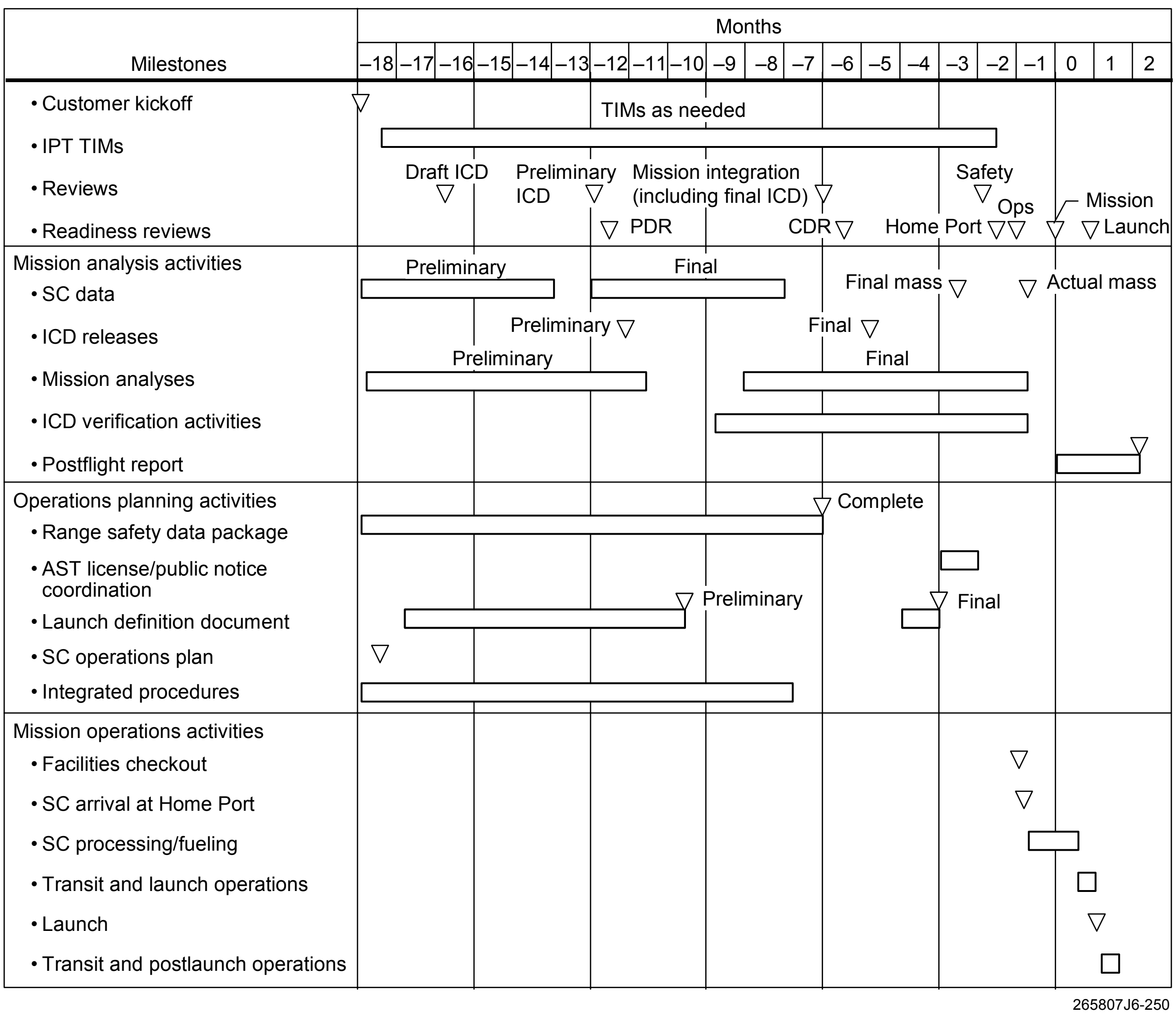

Figure 1-1. Generic Integration Timeline

1.2 Sea Launch Organization

Overview

Sea Launch Company is a limited liability company whose partners are

- Boeing Commercial Space Company
- RSC Energia
- SDO Yuzhnoye/PO Yuzhmash
- Kvaerner Group

Partner locations and operating centers are shown in figure 1-2.

Each partner is also a supplier/contractor to the company, capitalizing on the strengths of these industry leaders. The Boeing, Energia, SDO Yuzhnoye/PO Yuzhmash, and Kvaerner team of contractors has developed an innovative approach to establishing Sea Launch as a reliable, cost-effective, and flexible commercial launch system.

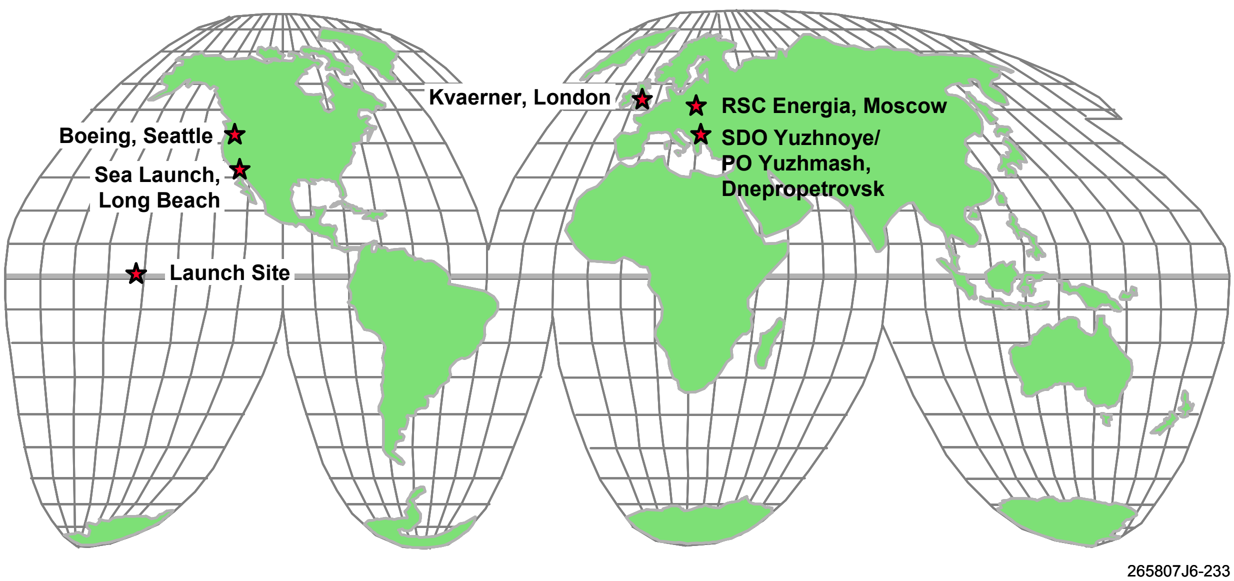

Figure 1-2. Sea Launch Partner Locations

Sea Launch Company

Sea Launch Company, headquartered in Long Beach, California, is populated by selected representatives of each of the partner companies. Charged with managing the overall program, Sea Launch responsibilities include:

- Overall operations management
- Business management
- Supplier management
- Marketing and sales
- Insurance and financing
- Chief Systems Engineering Office

Sea Launch is organized to ensure mission success by having segment managers responsible for the hardware acquisition and operational support of each program element.

Boeing Launch Services

Boeing Launch Services, Inc., is the commercial marketing and sales organization for Sea Launch and Boeing Delta launch services. Established in 2001, Boeing Launch Services has a world-class team representing a family of vehicles that meet every payload lift requirement, from 1,000 kg to 13,000 kg to geosynchronous transfer orbit. Boeing Launch Services is located in Huntington Beach, California. For more information, go to: *www.boeing.com/launch* or call 714-896-5195.

Boeing Commercial Space Company

In addition to its partnership role, Boeing Commercial Space Company brings expertise in space systems integration, a reputation for product integrity, and a dedication to customer service to Sea Launch. Boeing responsibilities include:

- Designing and manufacturing the payload fairing (fig. 1-3) and adapter
- Managing Home Port operations
- Integrating the spacecraft with the payload unit and the Sea Launch vehicle
- Performing mission analysis and analytical integration
- Leading mission operations
- Securing launch licensing
- Providing range services

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Figure 1-3. Payload Fairing

RSC Energia

RSC Energia, the premier Russian space company, brings its well-known experience in space exploration and launch system integration to Sea Launch. Energia is a joint stock company established under the laws of the Russian Federation, with its principal place of business in Korolev (6 km northeast of Moscow), Russia. Energia has the overall responsibility for:

- Manufacturing the Block DM-SL upper stage (fig. 1-4)
- Developing and operating the automated ground support equipment
- Integrating the Block DM-SL with the first and second Zenit stages and launch support equipment
- Managing the launch support equipment on board both the launch platform and the assembly and command ship
- Developing flight design documentation for the flight of the upper stage
- Performing launch operations and range services

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Figure 1-4. Block DM-SL

SDO Yuzhnoye/PO Yuzhmash

SDO Yuzhnoye/PO Yuzhmash, the leading Ukrainian aerospace companies, are established under the laws of Ukraine, with their principal place of business in Dnepropetrovsk, Ukraine. They are also contractors to the Sea Launch Company, LLC. As the principal designers of ballistic missiles and launch vehicles for the former Soviet Union, they have conducted hundreds of successful launches over the past four decades.

SDO Yuzhnoye/PO Yuzhmash design and manufacture the Zenit two-stage launch vehicle derived from the heritage Zenit 2 rocket illustrated in figure 1-5, which comprises the first two stages of the Sea Launch vehicle. Yuzhnoye/Yuzhmash are responsible for:

- Manufacturing the first and second stages of the Zenit 2S launch vehicle
- Integrating the launch vehicle flight hardware
- Developing flight design documentation for launch, with respect to the first two stages
- Supporting Zenit processing and launch operations

Several significant configuration modifications were made to allow the basic Zenit design to meet Sea Launch's unique requirements. For example, the base of the launch vehicle was stiffened to provide greater structural strength required on a dynamic launch platform.

Figure 1-5. Zenit 2 Launch Vehicle

Kvaerner Group

Kvaerner, based in London, England, is one of Europe's largest marine operators, with extensive experience in developing offshore oil platforms designed for operations in the harsh North Sea environment.

During development, Kvaerner was responsible for:

- Designing the assembly and command ship (fig. 1-6)
- Designing and building the launch platform
- Integrating the marine elements

Barber Moss Marine Management is responsible for marine operations and maintenance of both vessels.

Figure 1-6. Launch Platform and Assembly and Command Ship

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2.0 VEHICLE DESCRIPTION

Overview

The Zenit-3SL is a liquid propellant launch vehicle system capable of transporting a spacecraft to a variety of orbits. Figure 2-1 shows the Zenit-3SL principal components:

- Zenit Stage 1
- Zenit Stage 2
- Block DM-SL upper stage
- Payload unit

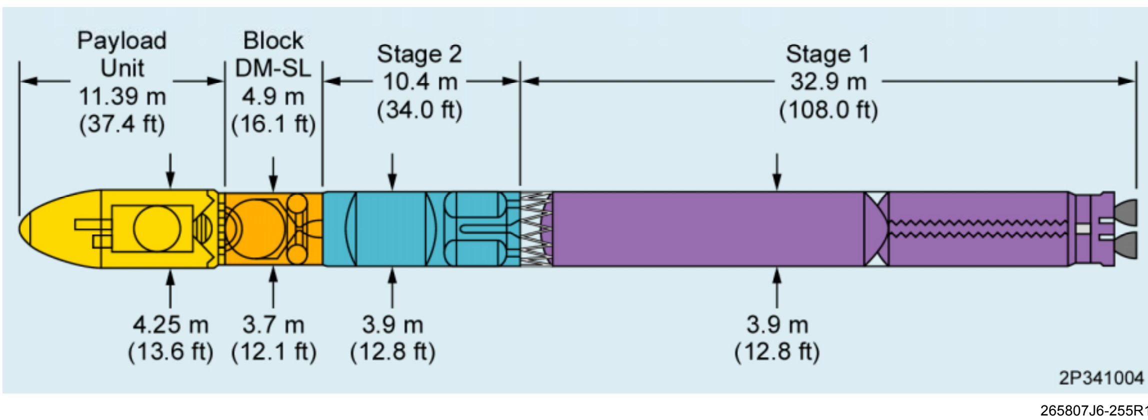

Figure 2-1. Zenit-3SL Launch Vehicle

Design

The original two-stage Zenit was designed by SDO Yuzhnoye to reconstitute former Soviet military satellite constellations quickly. The design emphasizes robustness, ease of operation, and fast reaction times. The result is a highly automated launch capability using a minimum complement of launch personnel.

Flight History

The Zenit was first launched in 1985 from Baikonur Cosmodrome in Kazakhstan. As of October 2002, the Zenit two-stage vehicle has completed 30 missions in 35 launch attempts.

The Zenit first-stage booster also served as a strap-on for the Energia launch vehicle and logged an additional eight successes in two flights in this capacity.

The Block DM-SL is a modification of the existing Block DM developed by RSC Energia. It has a long and successful history as the fourth stage of the Proton launch vehicle.

With the addition of an upgraded avionics and guidance suite, the Block DM superseded the Block D upper stage in 1974 and has since flown 211 successful missions as of October 2002. Primary missions have been geosynchronous transfer orbit; geosynchronous Earth orbit; and interplanetary, including missions to Halley's Comet, Venus, and Mars.

Significant configuration differences between the Zenit-3SL and its predecessor are:

- New navigation system
- Next-generation flight computer
- Stiffened first stage
- Fueling lines modified for third stage

In addition, several enhancements have been made to the Zenit-3SL to upgrade the performance capability from 5250 kg to 6000 kg to GTO. These changes fall into three categories:

- Energy increase (includes Block DM-SL engine extended nozzle, second-stage main engine thrust increase from 87 tons force to 93 tons force, and the addition of propellant for all three stages)
- Mass reductions across all three stages and payload accommodations
- Optimization of the propellant usage in all three stages

Flight Success Ratios

Table 2-1 lists flight success ratios for each of the three Zenit-3SL stages as of October 2002.

The engineering reliability estimate shown in table 2-1 accounts for:

- Extensive testing performed when modifications are made to the rocket or the ground support equipment
- Expected reliability growth, using statistics of more mature boosters using similar processes and procedures also built and launched in the former USSR
- An exhaustive failure analysis team that investigates the flight anomalies and produces measures to ensure that the anomalies never occur again
- The Sea Launch mission assurance and audit process that is in place and operating

Table 2-1. Flight History

Component	Introduction	Flight success ratio	Reliability estimate
Zenit Stage 1	1985	49 of 51 (96.0%)	98.6%
Zenit Stage 2	1985	37 of 41 (90.2%)	95.3%
Block DM	1974	211 of 217 (97.2%)	98.4%

Payload Accommodations

Payload accommodations were specifically developed for the Sea Launch Company. The design is based on launch experience that extends back over three decades. The payload accommodations design protects the spacecraft from transportation, handling, launch, and flight environments.

The design features:

- Streamlined operational flows
- Flexibility to accommodate varied spacecraft models

2.1 Zenit Stage 1

Stage 1 Primary Structure

The Zenit Stage 1 primary structure is aluminum with integrally machined stiffeners (fig. 2-2). It is based on the same engine and core fuselage that is also used for the four strap-on boosters for the Russian Energia heavy-lift launch vehicle. To date there have been two such Energia launches, both successful.

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Figure 2-2. Stage 1, Zenit-3SL

RD-171 Engine

The RD-171 engine, which powers Stage 1, burns liquid oxygen and kerosene (fig. 2-3). It provides an impressive 740,000 kg (1.6 million lb) of thrust at liftoff and is one of the most powerful engines in the world. The four thrust chambers are fed by a single, vertically mounted turbopump, powered by two gas generators feeding hot oxidizer-rich gas to a single turbine. Four differentially gimbaled thrust nozzles provide directional control during Stage 1 flight.

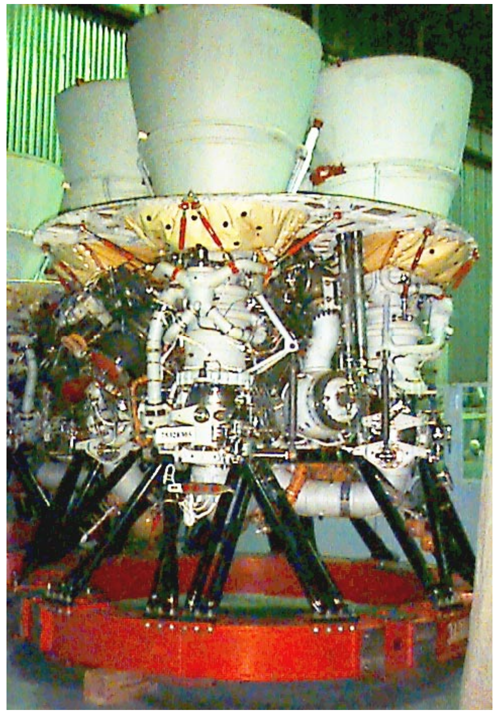

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Figure 2-3. RD-171 Stage 1 Engine

Overall Specifications and Configurations

Zenit specifications and performance parameters are shown in table 2-2. Stage 1 and Stage 2 configurations are shown in figure 2-4.

Table 2-2. Zenit Specifications

Zenit	Stage 1	Stage 2
Length	32.9 m (108 ft)	10.4 m (34 ft)
Diameter	3.9 m (12.8 ft)	3.9 m (12.8 ft)
Weight (fueled)	354,582 kg (781,719 lb)	90,757 kg (200,085 lb)
Thrust (sea level)	740,000 kg (1.63 million lb)	Not applicable
Thrust (vacuum)	806,400 kg (1.78 million lb)	101,100 kg (222,887 lb)
Fuel (kerosene)	88,768 kg (1,195,700 lb)	22,832 kg (50,336 lb)
Oxidizer (LOX)	233,512 kg (514,805 lb)	58,908 kg (129,869 lb)

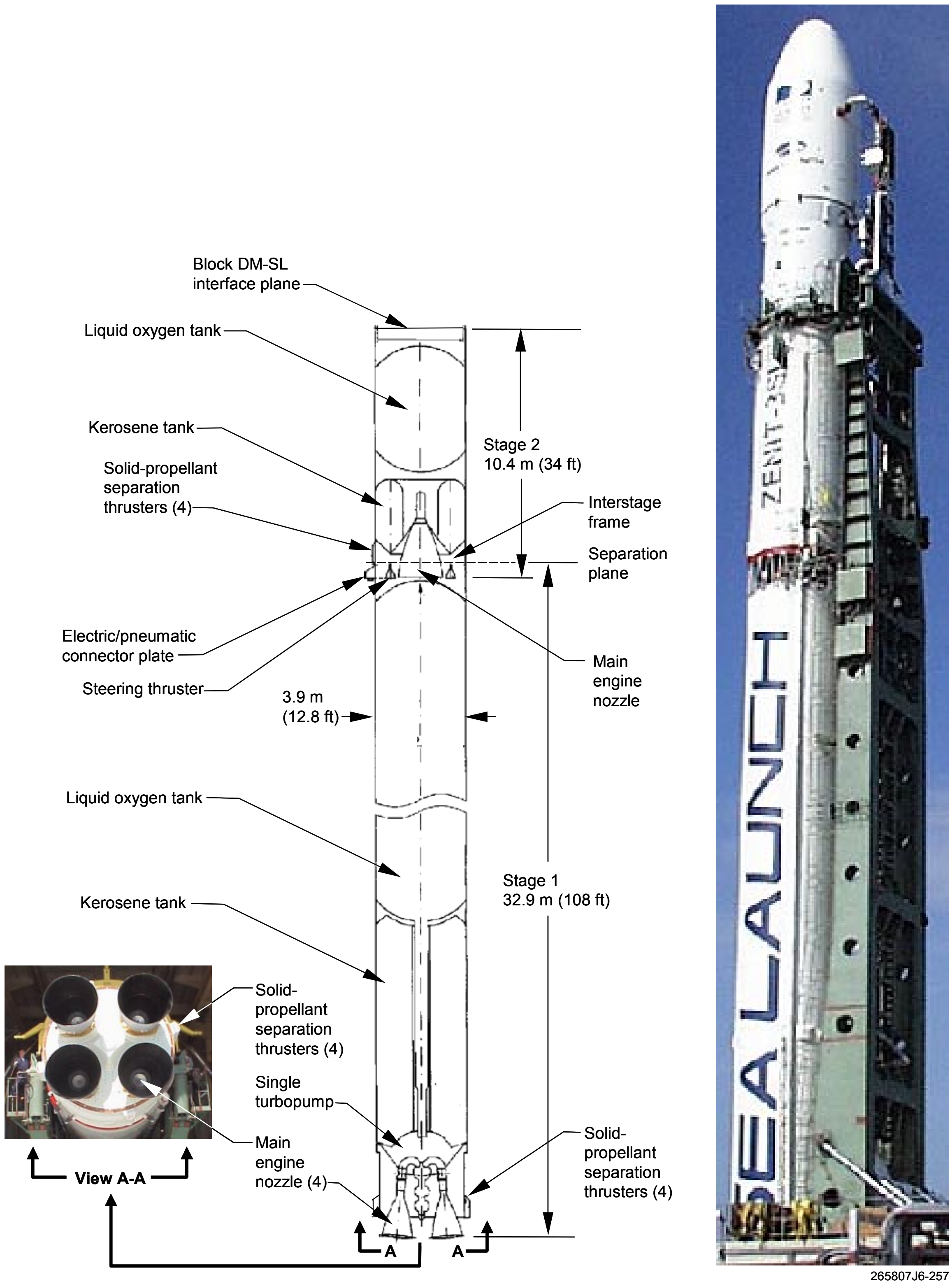

Figure 2-4. Zenit Stage 1 and Stage 2 Configuration

2.2 Zenit Stage 2

Stage 2 Primary Structure

The Zenit second stage also uses integral stiffened aluminum construction (fig. 2-5). Stage 2 propellants are liquid oxygen and kerosene. The lower kerosene tank is toroid-shaped, and the liquid oxygen tank is a domed cylinder. The stage is powered by a single-nozzle RD-120 engine.

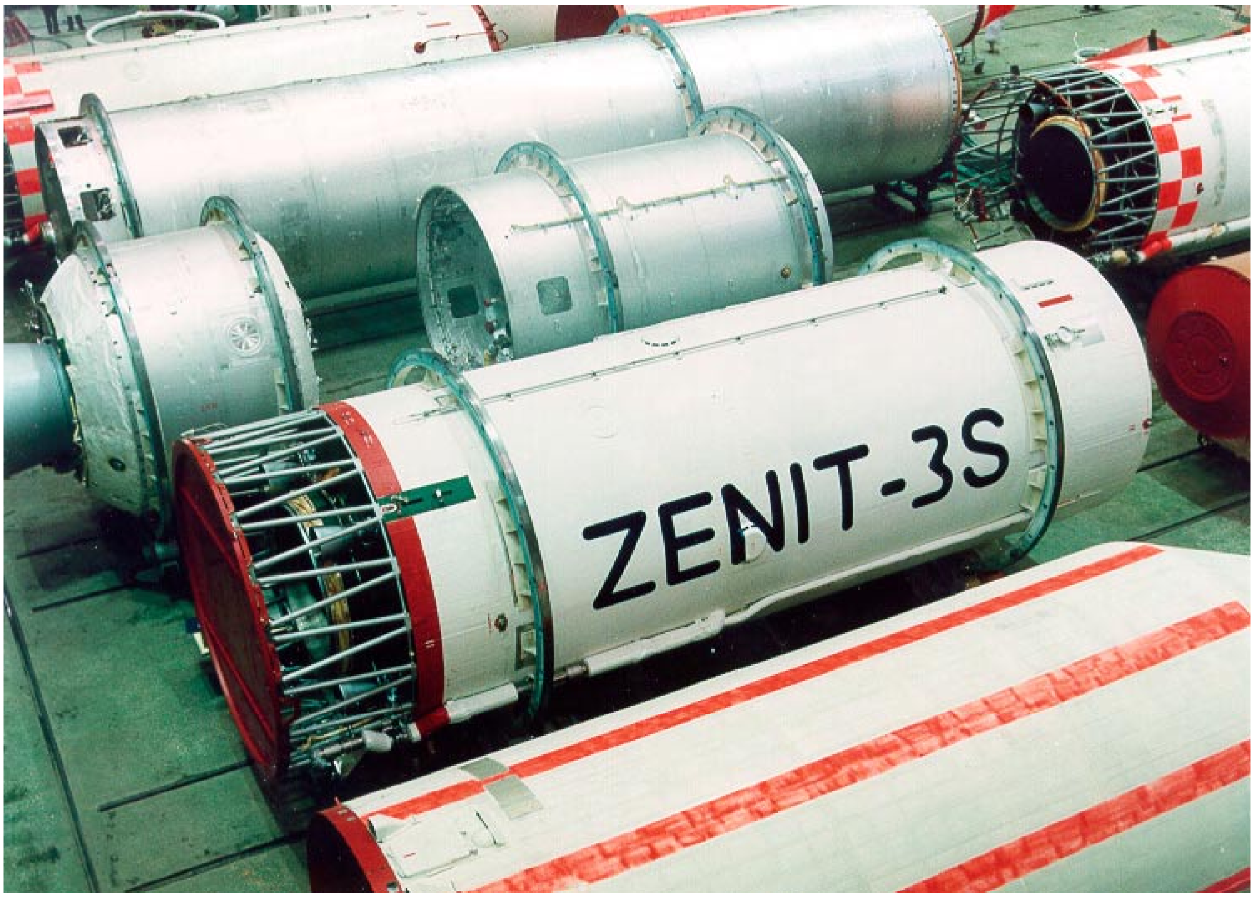

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Figure 2-5. Stage 2, Zenit-3SL

Three-Axis Control

The RD-8 vernier engine mounted in the aft end of Stage 2 provides three-axis attitude control. The RD-8 uses the same propellants as the single fixed-nozzle RD-120, with one turbopump feeding four gimbaling thrusters. The RD-8 produces 8100 kgf (17,900 lbf) of thrust.

2.3 Block DM-SL—Upper Stage

Configuration

The Block DM-SL is a restartable upper stage capable of igniting up to five times during a mission. Avionics are housed in a sealed toroidal equipment bay at the front end of the upper stage. An interstage cylinder of aluminum skin and stringer construction encloses the Block DM-SL.

The configuration of the Block DM-SL is shown in figure 2-6.

Propulsion

Propulsive capability for the upper stage is provided by the 11D58M engine, which operates on liquid oxygen and kerosene. The kerosene is contained in a toroidal tank that encircles the main engine turbopump. The spherical liquid oxygen tank is located above the fuel tank.

The 11D58M has a single gimbaling nozzle that provides directional control during propulsive phases.

Block DM-SL (without interstage)

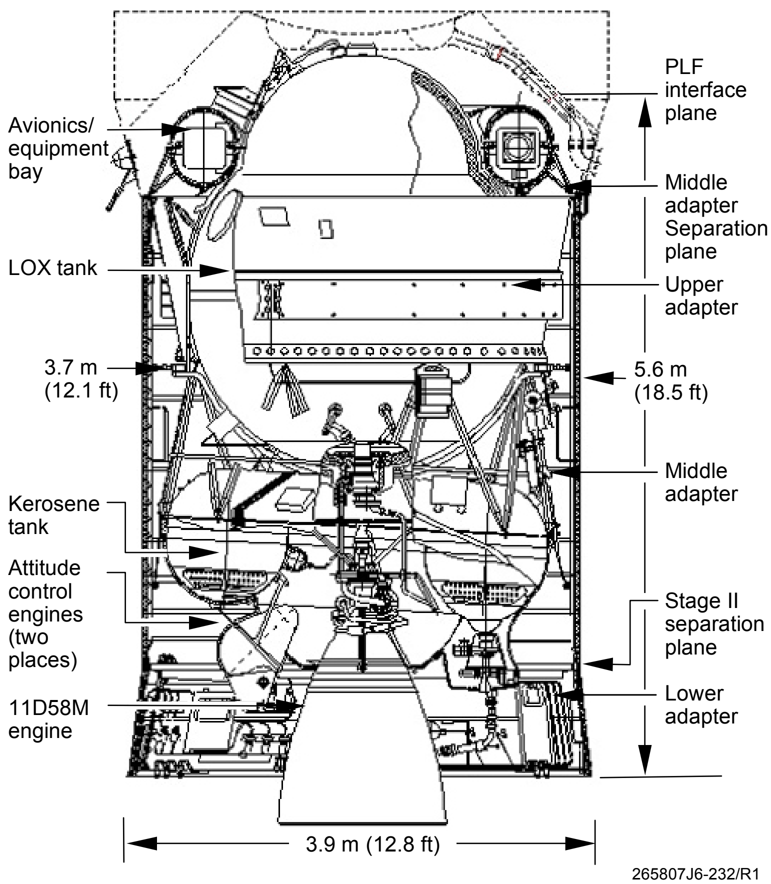

Figure 2-6. Block DM-SL

Attitude Control

Three-axis stabilization of the Block DM-SL during coast periods is provided by two attitude control/ullage engines. Each engine has four nozzles that are grouped in clusters on either side of the main engine nozzle. The attitude control system uses the hypergolic propellant nitrogen tetroxide and monomethylhydrazine.

Overall specifications for the Block DM-SL are shown in table 2-3.

Table 2-3. Block DM-SL Specifications

Length[1]	5.6 m (18.5 ft)
Diameter (primary)	3.7 m (12.1 ft)
Weight (fueled)[2]	19,711 kg (43,455 lb)
Thrust (vacuum)	8103 kg (17,864 lb)
Fuel (kerosene)	4560 kg (10,053 lb)
Oxidizer (LOX)	11,290 kg (24,890 lb)
Note 1: The bottom of the payload unit interface skirt overlays the top of the Block DM-SL by 1.1 m (3.6 ft). Note 2: Includes the Block DM-SL lower and middle adapters.	

2.4 Payload Unit

Components and Construction

The payload unit consists of the spacecraft integrated with the payload accommodations.

The payload accommodations consist of the spacecraft adapter, payload structure, interface skirt, payload fairing, and flight avionics and instrumentation. Figure 2-7 shows the arrangement of the major payload accommodations components. The construction is aluminum honeycomb and graphite/epoxy for the fairing, nosecap, and payload support structure. The payload fairing is 11.39 m (37.4 ft) long and 4.15 m (13.6 ft) in diameter. These elements are integrated in a class 100,000 clean facility during ground processing in the payload processing facility at Home Port.

The standard spacecraft adapters are procured from the industry standard supplier, Saab Ericsson Space.

Future 5-m Capability

Sea Launch is assessing customer interest in a 5-m diameter payload unit (fig. 2-7). If sufficient interest exists, Sea Launch will offer this capability to our customers no earlier than 2005. The Sea Launch 5-m design would provide a payload static envelope 4.57 m in diameter. The design will provide encapsulated operations similar to our baseline payload unit operations, as well as similar avionics and structural interfaces.

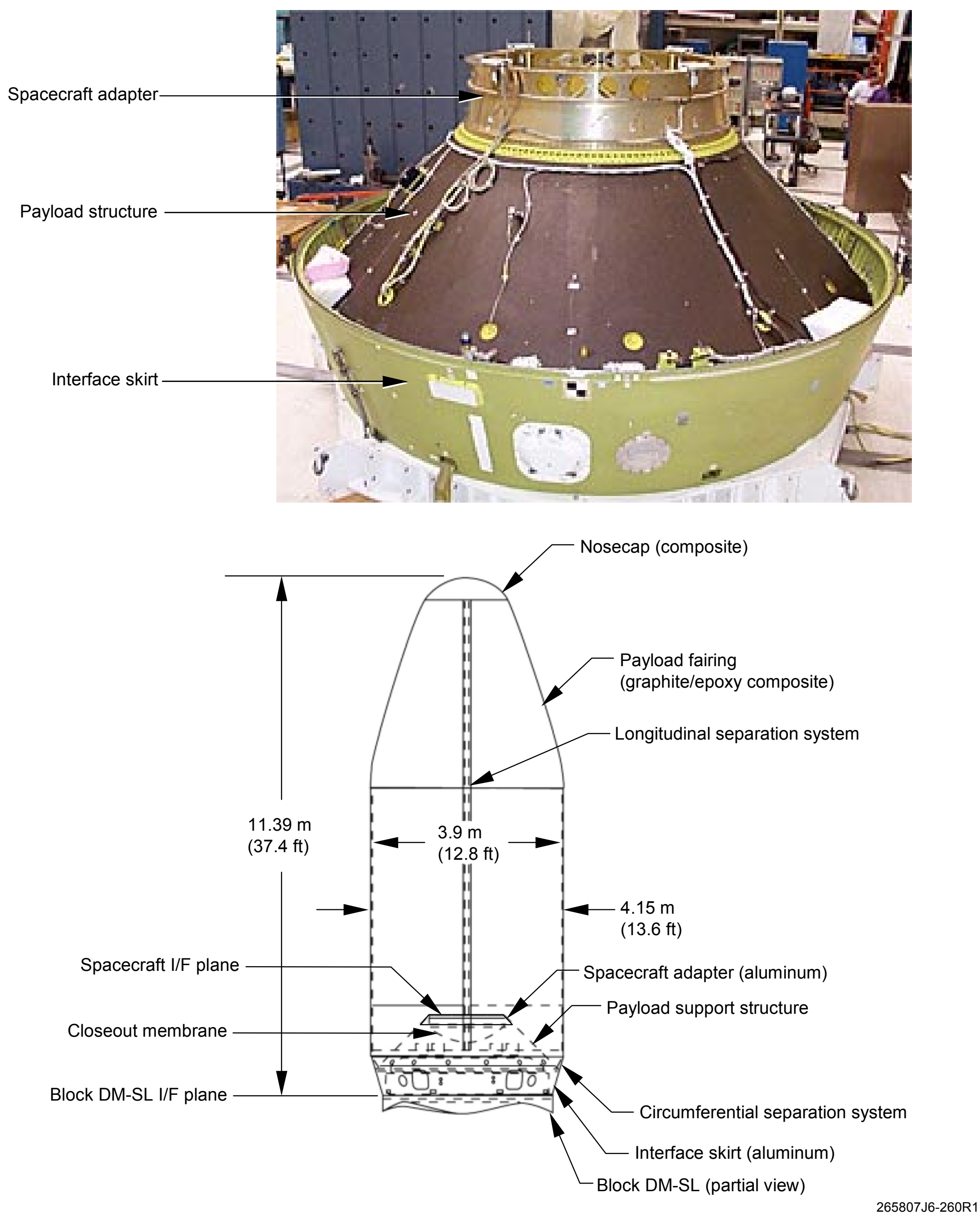

Figure 2-7. Sea Launch Payload Unit

Payload Fairing

The payload fairing (fig. 2-8) provides environmental protection for the spacecraft from encapsulation through launch and ascent. It can accommodate a wide range of payload designs.

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Figure 2-8. Payload Fairing

Access Characteristics

Access to the spacecraft before rollout to the launch pad is gained through doors in the payload fairing. The baseline design includes two payload fairing access doors approximately 610 mm (2 ft) in diameter. These doors are located on opposite sides of the payload fairing longitudinal separation plane and at least 17 deg from the separation plane.

Within payload fairing structural constraints, variations in the number, location, and size of the doors can be accommodated (fig. 7-5).

Cooling Air

From encapsulation to launch, conditioned air is provided to the payload fairing volume. The cooling air flows from an entry on the side of the payload fairing to the aft end, where it exits through one-way valves on the payload structure. Conditioned air capabilities are described in detail in Section 5.

Thermal Insulation

External thermal insulation protects the payload fairing structure and limits the interior payload fairing surface temperatures. Payload fairing jettison is constrained to a time sufficient to ensure that the maximum dispersed free molecular heating never exceeds spacecraft requirements. The customer can tailor the time of payload fairing jettison (and associated maximum free molecular heating). The thermal environments are described in Section 5.

Interface Skirt

The interface skirt joins the payload fairing to the Block DM-SL and also supports the spacecraft loads through the spacecraft adapter and payload structure.

The interface skirt is constructed of aluminum with integral stiffeners (fig. 2-9). The interface skirt is 0.81 m (2.6 ft) long and accommodates the transition from a 3.7 m (12.1 ft) diameter on the Block DM-SL to a 4.15 m (13.6 ft) diameter on the payload fairing.

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Figure 2-9. Payload Unit Interface Skirt

Spacecraft Adapters

The spacecraft adapter mechanical interface with the spacecraft can be either a bolted or a typical clampband (Marmon-type) interface. The specific spacecraft interface information for the bolted and clampband based adapters is provided in Section 7. Spacecraft separation is achieved by redundant initiation, which causes the separation of the retaining bolts or clampbands.

Payload Structure

The payload structure acts as a physical support for the spacecraft during horizontal and vertical operations and functions as an environmental barrier. It is a graphite/epoxy composite structure.

One-way valves in the payload structure allow airflow out of the payload unit and prevent backflow of air from the Block DM-SL cavity. The closeout membrane, located at the upper diameter of the payload structure, provides a barrier that limits thermal and contamination exchange between the Block DM-SL and the spacecraft.

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3.0 PERFORMANCE

Overview

The Zenit-3SL can deliver spacecraft to a wide variety of orbits, including geosynchronous transfer orbit, medium Earth orbits, highly elliptical orbits, and Earth escape. The data presented in this section assumes a generic set of spacecraft requirements. Please contact Sea Launch for a performance quote for specific mission requirements.

The current maximum geosynchronous transfer orbit payload capability for a mission with two Block DM-SL main engine burns is 6000 kg. For a mission with one Block DM-SL burn, the maximum payload capability is 6066 kg.

Characteristics of performance are covered in Sections 3.1 through 3.5, including:

- Launch site
- Ascent trajectory
- Payload capability
- Coast phase attitude
- Spacecraft separation

Trajectory Design Process

Trajectory design is part of the overall mission analysis process described in Section 4. Boeing Commercial Space Company (BCSC) flight design engineers work with the spacecraft customer to optimize the mission design and coordinate all customer requirements with the Russian and Ukrainian partners. The Russian and Ukrainian partners generate the final trajectory and perform software and hardware simulations to verify the flight performance reserve and injection accuracy. Finally, BCSC verifies that all customer requirements are satisfied.

3.1 Launch Site

Site Location

Figure 3-1 depicts the location of the Sea Launch launch site. Located on the equator in the Pacific Ocean at coordinates 0° N, 154° W, this site was chosen based on a number of factors, including stage impact zones, weather, and vessel transit times. For inclined missions that affect range safety (e.g., a population center located along the ascent groundtrack), Sea Launch may select an alternative launch site.

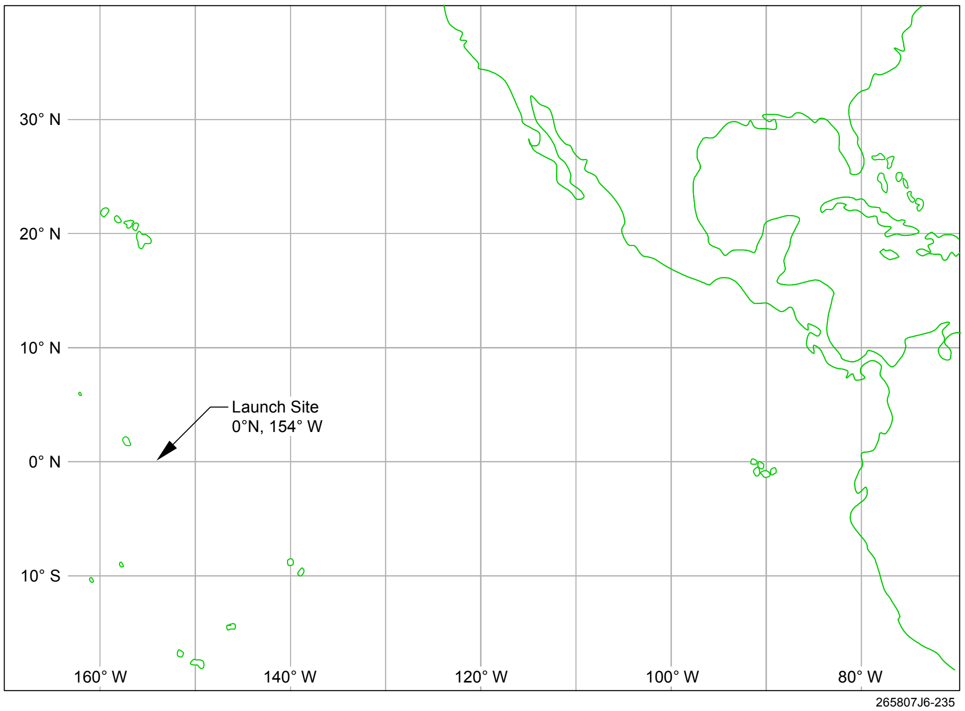

Figure 3-1. Launch Site Location

Performance Benefits

Because the designated site is located on the equator, no plane change maneuvers are required to reach a 0-deg orbital inclination. In terms of final spacecraft mass to geosynchronous Earth orbit, a Sea Launch payload capability of 6000 kg is equivalent to approximately 6800 kg of payload capability if launched into an inclined geosynchronous transfer orbit from Cape Canaveral. Also, many orbital inclinations are possible because of the absence of land and major shipping lanes in the launch range area.

3.2 Ascent Trajectory

Stage 1 Flight

The Zenit Stage 1 main engine provides the thrust for the first 2.4 min of flight. The vehicle begins a roll to the appropriate launch azimuth at approximately 10 sec. The pitch profile is designed to minimize the loads during the periods of highest dynamic pressure. The engine is throttled during the final seconds of Stage 1 flight to limit the maximum axial acceleration.

Stage 2 Flight

The Zenit Stage 2 main and vernier engines provide the thrust for the next 6.0 min of flight. The Stage 2 vernier ignites before Stage 1 separation and operates alone for the initial 5 sec and final 75 sec of Stage 2 operation. The payload fairing is jettisoned 1.4 min into Stage 2 flight. Immediately after Stage 2 separation, the middle adapter surrounding the Block DM-SL is jettisoned.

Block DM-SL Flight

The Block DM-SL provides the final segment(s) of powered flight. Depending on mission requirements, the Block DM-SL performs one to five main engine burns. Most missions use two burns, because this usually provides a higher lofted perigee and may also be used to target a specific apogee location. For missions with multiple burns, the initial burn establishes a stable parking orbit.

Flight Timeline

Table 3-1 lists the times when the main flight events occur for a two-burn 6000-kg geosynchronous transfer orbit mission.

Table 3-1. Flight Timeline—Two-Burn, 6000-kg Geosynchronous Transfer Orbit Mission

Time, sec	Event
0	Liftoff
8	Begin pitchover
10 to 20	Roll to launch azimuth
64	Maximum dynamic pressure
114	Maximum axial acceleration
114 to 131	Stage 1 engine throttle to 50%
141	Stage 2 vernier engine ignition
143	Stage 1 engine shutdown
146	Stage 1 separation
151	Stage 2 main engine ignition
229	Payload fairing jettison
429	Stage 2 main engine shutdown
504	Stage 2 vernier engine shutdown
505	Stage 2 separation
506	Block DM-SL middle adapter jettison
514	Block DM-SL main engine ignition 1
784	Block DM-SL main engine shutdown 1
2,584	Block DM-SL main engine ignition 2
3,009	Block DM-SL main engine shutdown 2
3,609	Spacecraft separation

Flight Profile

Figure 3-2 shows a flight profile with key trajectory events and parameters labeled for a two-burn, 6000-kg geosynchronous transfer orbit mission.

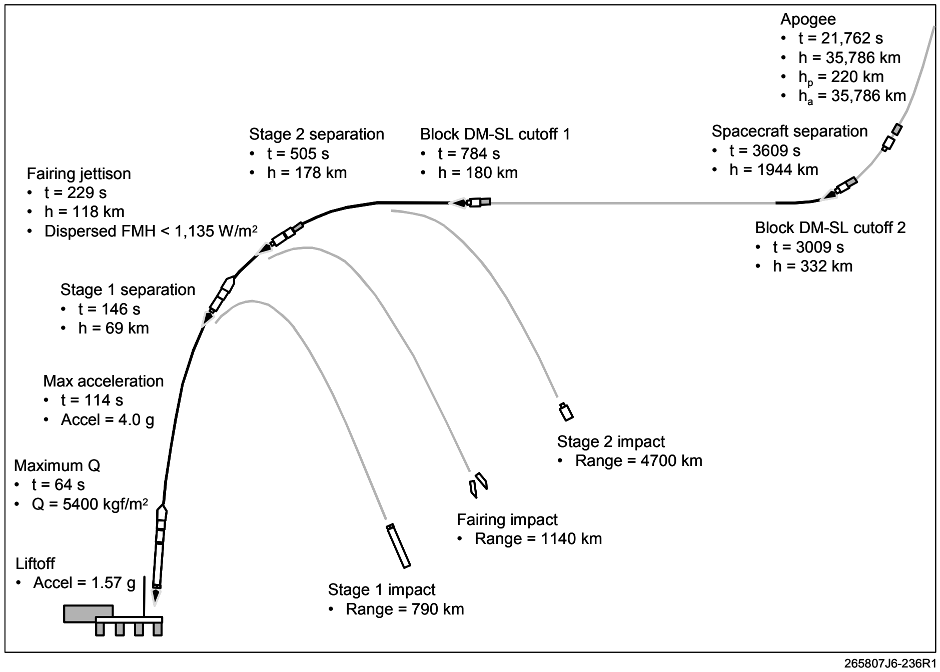

Figure 3-2. Flight Profile—Two-Burn, 6000-kg Geosynchronous Transfer Orbit Mission

Groundtrack

Figure 3-3 shows the Zenit-3SL ascent groundtrack and indicates the location of the major events for a two-burn, 6000-kg geosynchronous transfer orbit mission.

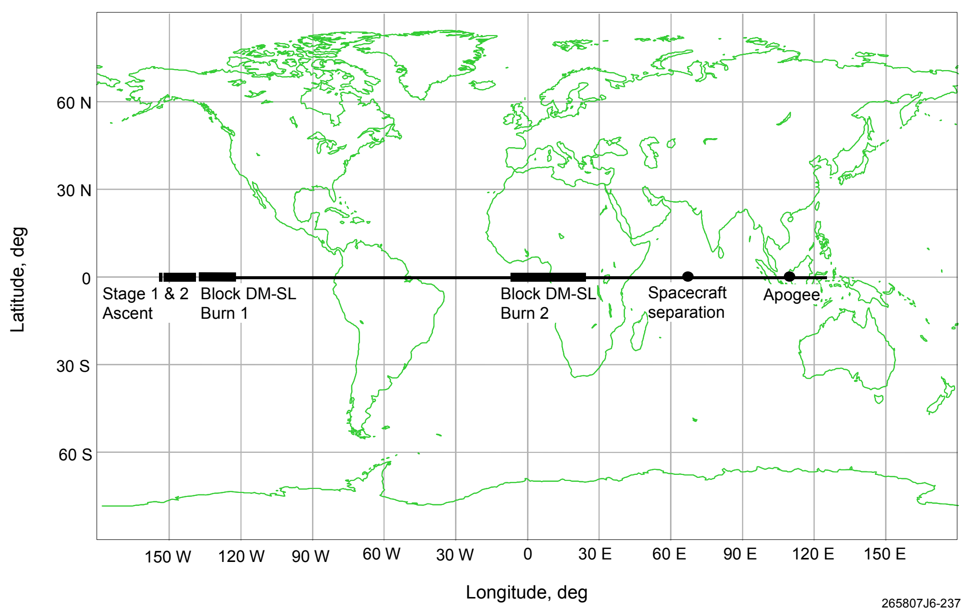

Figure 3-3. Groundtrack—Two-Burn, 6000-kg Geosynchronous Transfer Orbit Mission

3.3 Payload Capability

Ground Rules

This section presents payload capability for a wide variety of missions. Performance data is based on the following set of generic ground rules:

- Payload capability is defined as the separated spacecraft mass and assumes our heaviest spacecraft adapter.
- Sufficient flight performance reserves are maintained to reach the specified orbit with a confidence level of 2.7σ.
- At the time of fairing jettison, the free molecular heating is less than 1,135 W/m^2 with a confidence level of 3σ.
- Orbital altitudes are specified with respect to an Earth radius of 6,378 km.
- For elliptical orbits, the orbital parameters correspond to the osculating orbital elements at the time of first apogee passage.
- Maximum payload capability is assumed to be 6100 kg. Contact SL for a performance quote for spacecraft exceeding 6100 kg. See Section 6 for more details on structural limitations.
- For missions with multiple Block DM-SL main engine burns, the minimum park orbit perigee altitude is 180 km. For missions with a single Block DM-SL burn, the minimum final orbit perigee altitude is 200 km.
- All performance data corresponds to the current vehicle capability, which is equivalent to a two-burn, 6000-kg geosynchronous transfer orbit mission.

Geosynchronous Transfer Orbit

The Zenit-3SL can deliver large satellites to a variety of geosynchronous transfer orbits. For a mission with two Block DM-SL burns, the maximum payload capability is 6000 kg. For a mission with one Block DM-SL burn, the maximum payload capability is 6066 kg. The orbital parameters for these cases are shown in table 3-2.

Table 3-2. Maximum Geosynchronous Transfer Orbit Payload Capability

Orbital parameter	Two Block DM-SL burns	One Block DM-SL burn
Perigee altitude	220 km	200 km
Apogee altitude	35786 km	35786 km
Inclination	0 deg	0 deg
Maximum spacecraft mass	6000 kg	6066 kg

For lighter spacecraft, the excess Zenit-3SL performance may be used to provide a lofted perigee altitude. Either one or two Block DM-SL burns may be used but, for most cases, two burns provide the maximum perigee. A one-burn mission is optimal only for the heaviest spacecraft, and may be selected if spacecraft requirements do not necessitate the use of two burns.

For two-burn missions, there are two types of injection schemes: "perigee inject" and "post-perigee inject." These have different intermediate park orbits and placement of the second burn, which are illustrated in figure 3-4. Perigee inject is optimal for the lower perigees, and post-perigee inject is optimal for the higher perigees, with the crossover occurring near a perigee altitude of 2000 km.

Figure 3-5 and table 3-3 show the geosynchronous transfer orbit payload capability for a synchronous apogee. Figure 3-6 and table 3-4 show the geosynchronous transfer orbit payload capability for subsynchronous and supersynchronous apogees.

All data assumes a geosynchronous transfer orbit orbital inclination of 0 deg. A small nonzero inclination can be accommodated with minimal performance loss.

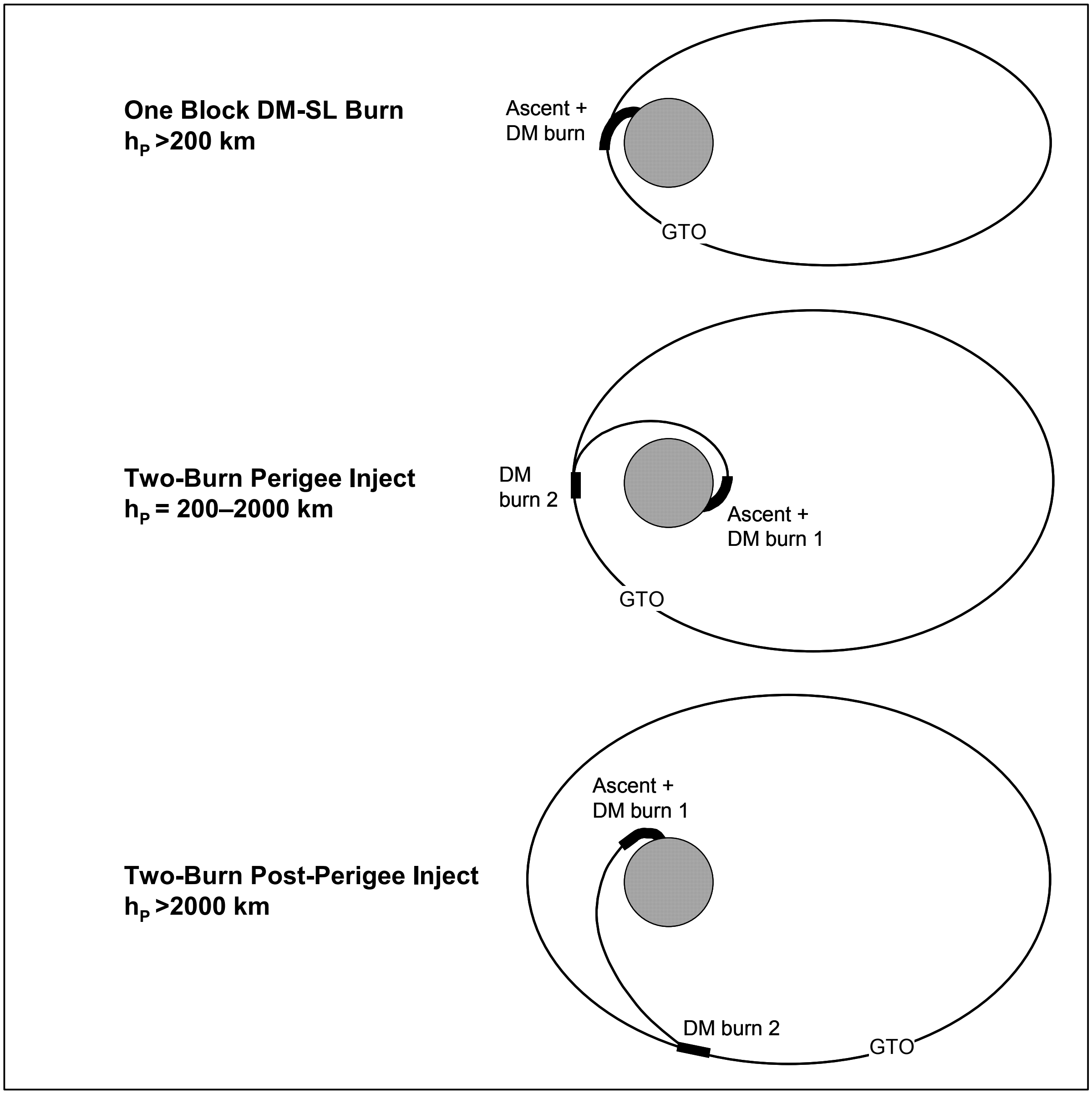

Figure 3-4. Geosynchronous Transfer Orbit Injection Schemes

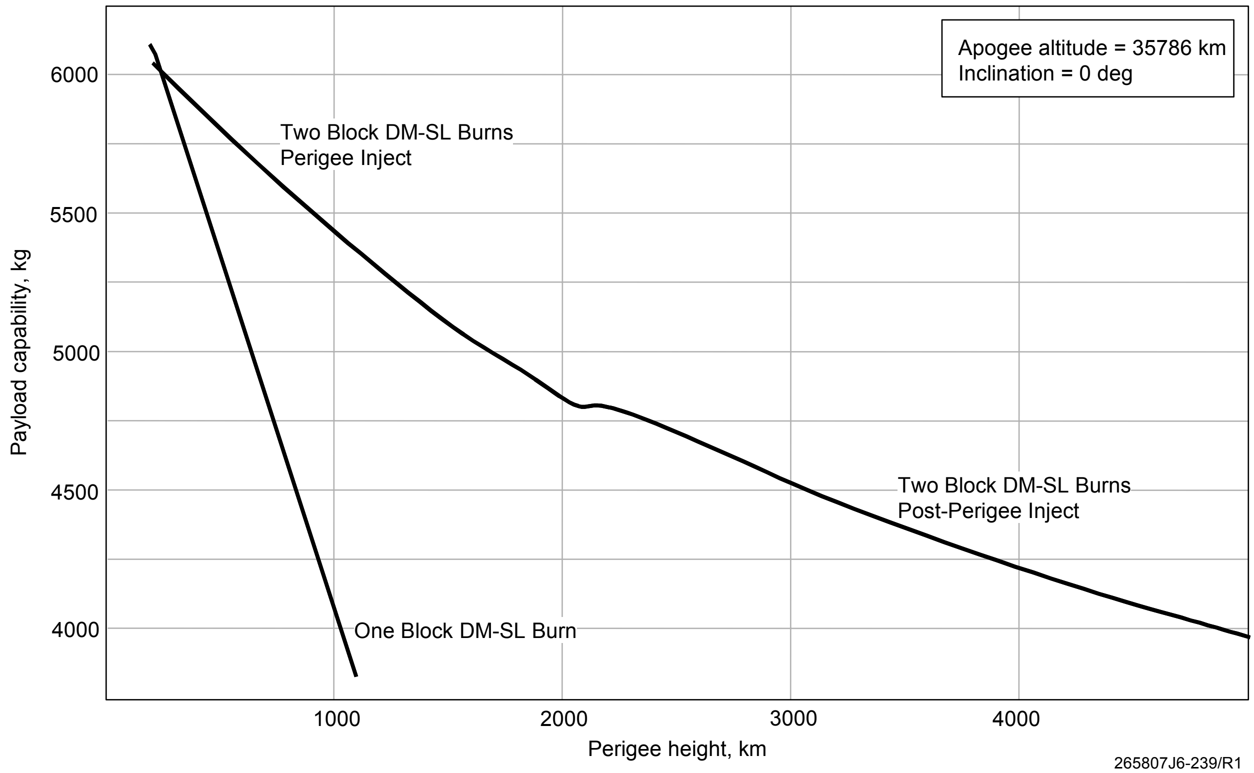

Figure 3-5. Geosynchronous Transfer Orbit Payload Capability—Synchronous Apogee

Table 3-3. Geosynchronous Transfer Orbit Payload Capability—Synchronous Apogee

Perigee height, km	Spacecraft ΔV to GEO, mps	Payload capability, kg	
		One Block DM-SL burn	Two Block DM-SL burns
200	1477	6066	—
220	1475	6039	6000
250	1472	5967	5980
300	1466	5852	5940
400	1456	5616	5859
500	1446	5374	5779
600	1436	5129	5700
700	1426	4880	5625
800	1416	4628	5551
900	1406	4372	5479
1000	1397	4114	5409
1250	1373	3477	5244
1500	1349	2866	5092
1750	1327	—	4952
2000	1304	—	4825
2100	1296	—	4804
2250	1283	—	4782
2500	1261	—	4706
3000	1220	—	4526
3500	1180	—	4368
4000	1142	—	4228
4500	1106	—	4103
5000	1070	—	3989
6000	1003	—	3792
7000	941	—	3625
8000	882	—	3481

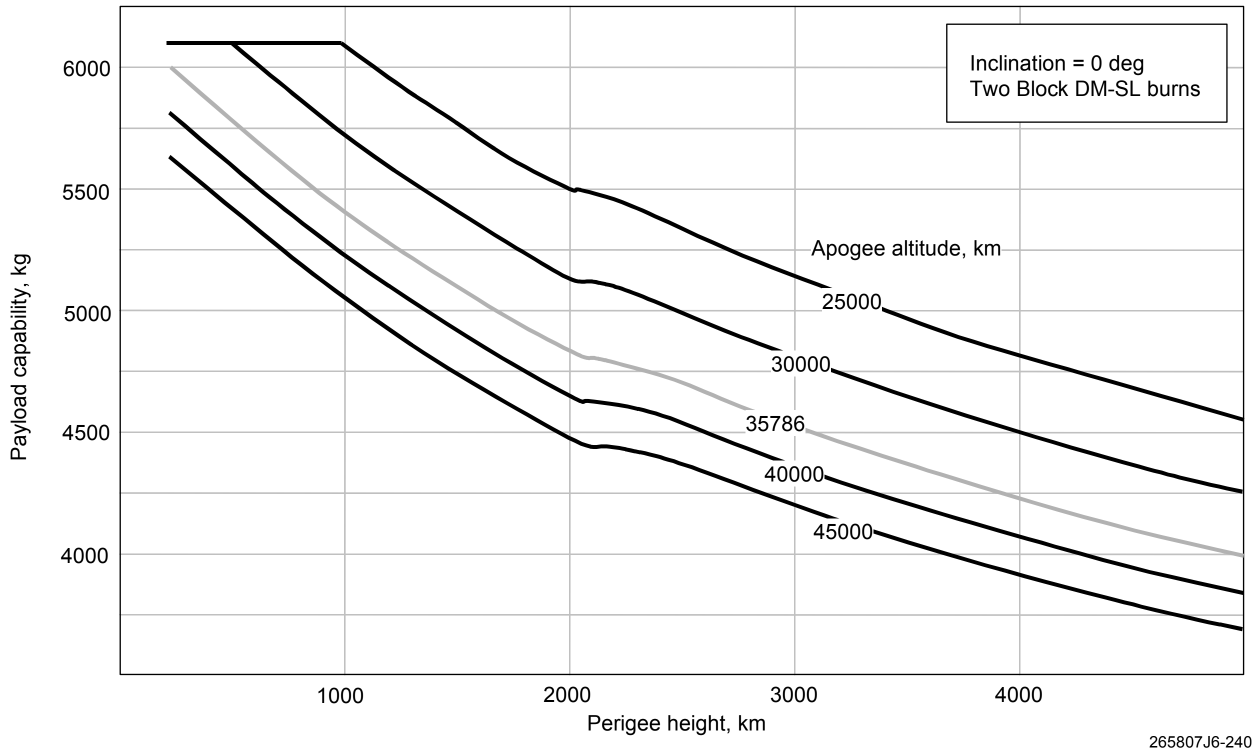

Figure 3-6. Geosynchronous Transfer Orbit Payload Capability—Sub/Supersynchronous Apogees

Table 3-4. Geosynchronous Transfer Orbit Payload Capability—Sub/Supersynchronous Apogees

Perigee height, km	Payload capability, kg			
	Apogee ht 25000 km	**Apogee ht 30000 km**	**Apogee ht 40000 km**	**Apogee ht 45000 km**
220	6100	6100	5815	5634
250	6100	6100	5796	5617
300	6100	6100	5756	5577
400	6100	6100	5675	5497
500	6100	6098	5596	5418
600	6100	6019	5518	5341
700	6100	5942	5443	5266
800	6100	5867	5370	5193
900	6100	5795	5298	5122
1000	6088	5724	5229	5054
1250	5917	5556	5065	4892
1500	5760	5402	4914	4741
1750	5615	5260	4776	4604
2000	5492	5131	4649	4478
2100	5477	5117	4624	4447
2250	5436	5087	4606	4434
2500	5332	4997	4538	4374
3000	5138	4811	4362	4201
3500	4967	4647	4208	4050
4000	4814	4501	4071	3916
4500	4676	4370	3948	3797
5000	4551	4251	3838	3689
6000	4331	4044	3646	3502
7000	4144	3868	3483	3344
8000	3982	3716	3344	3209

Circular and Elliptical Orbits

Figure 3-7 and table 3-5 show the payload capability for a range of circular orbit altitudes and inclinations. Figure 3-8 and table 3-6 show the payload capability for a range of elliptical orbit apogees and inclinations. For the nonzero inclinations, southeastern launch azimuths are generally preferred to avoid flight/impact point passage over highly populated areas in North America.

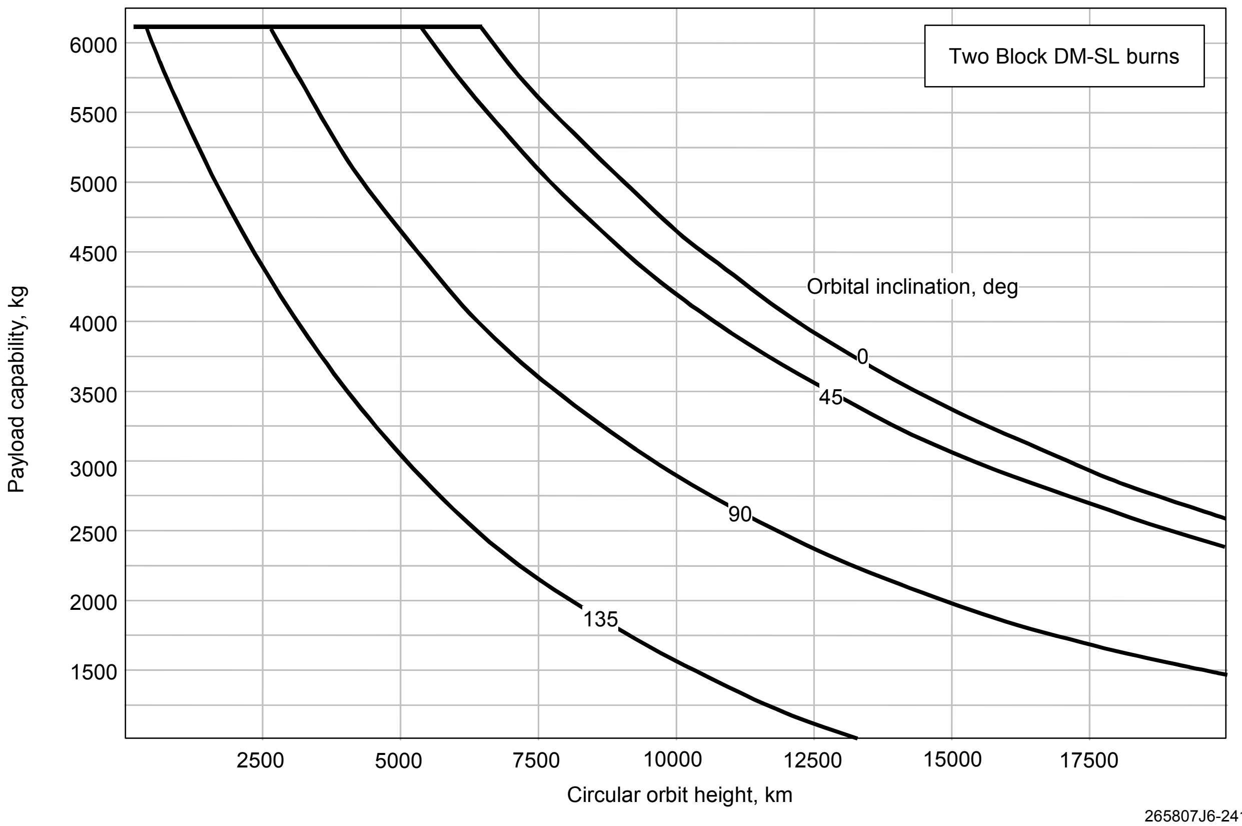

Figure 3-7. Circular Orbit Payload Capability

Table 3-5. Circular Orbit Payload Capability

Height, km	Payload capability, kg			
	Inclination, 0 deg	**Inclination, 45 deg**	**Inclination, 90 deg**	**Inclination, 135 deg**
1000	6100	6100	6100	5523
2000	6100	6100	6100	4720
3000	6100	6100	5844	4061
4000	6100	6100	5192	3508
5000	6100	6100	4642	3040
6000	6100	5773	4175	2644
7000	5840	5292	3778	2305
8000	5389	4876	3436	2018
10000	4643	4196	2882	1547
12000	4052	3666	2456	1188
14000	3577	3246	2122	—
16000	3186	2904	1856	—
18000	2857	2623	1641	—
20000	2579	2387	1465	—
22000	2340	2187	1320	—
24000	2134	2014	1200	—
26000	1952	1861	1100	—
28000	1793	1731	1014	—
30000	1650	1612	—	—

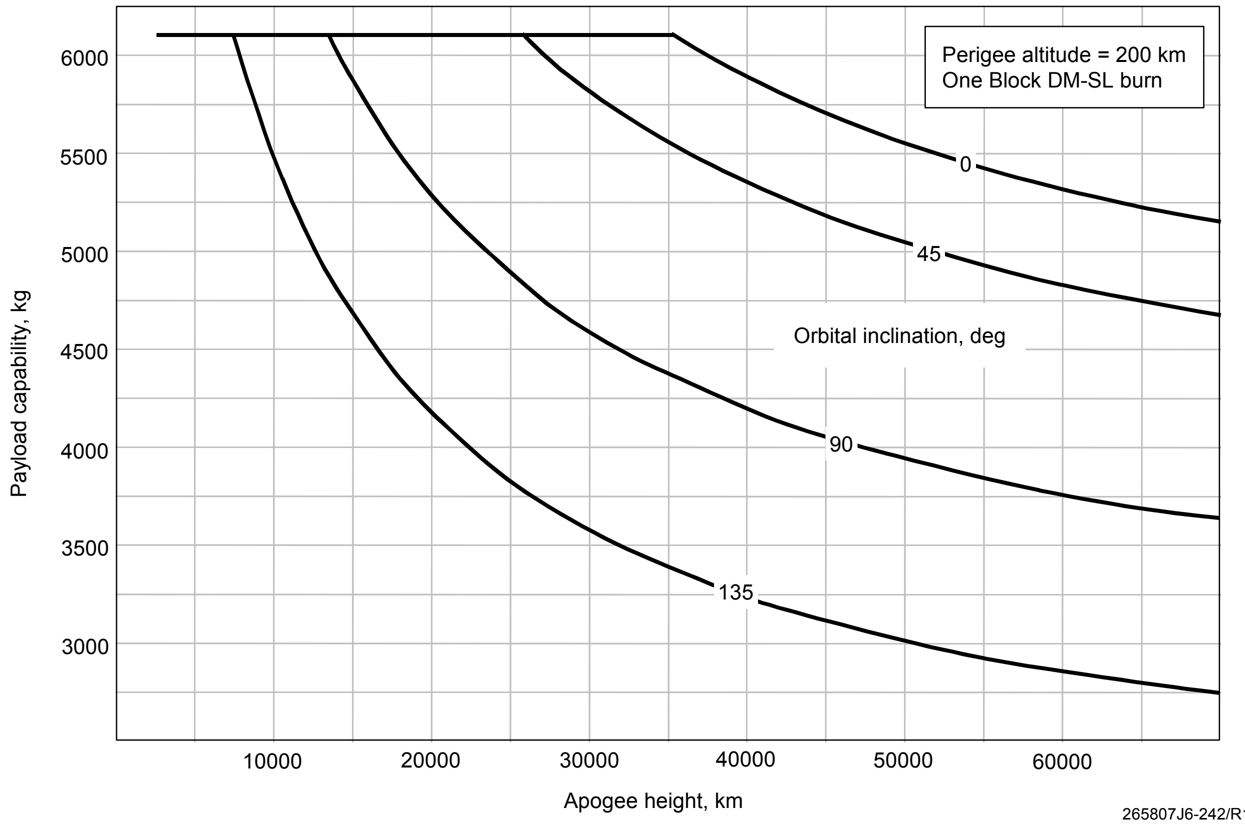

Figure 3-8. Elliptical Orbit Payload Capability

*Table 3-6. Elliptical Orbit Payload Capability**

Apogee height, km	Payload capability, kg			
	Inclination, 0 deg	Inclination, 45 deg	Inclination, 90 deg	Inclination, 135 deg
10000	6100	6100	6100	5473
12500	6100	6100	6100	5022
15000	6100	6100	5864	4675
17500	6100	6100	5545	4400
20000	6100	6100	5285	4176
22500	6100	6100	5068	3989
25000	6100	6100	4885	3832
27500	6100	5978	4729	3697
30000	6100	5819	4594	3580
32500	6100	5680	4476	3478
35000	6100	5558	4372	3389
37500	5991	5450	4280	3309
40000	5884	5353	4198	3238
42500	5787	5265	4124	3175
45000	5700	5185	4057	3117
47500	5621	5113	3996	3065
50000	5549	5047	3941	3017
52500	5483	4986	3891	2973
55000	5422	4931	3844	2933
57500	5366	4879	3801	2896
60000	5315	4831	3762	2862
65000	5222	4746	3691	2801
70000	5142	4671	3629	2748

*Applies to one Block DM-SL burn flight profile with a perigee altitude of 200 km.

Molniya and Tundra Transfer Orbits

Figure 3-9 and table 3-7 show the Zenit-3SL payload capability for transfer to 12-hr Molniya and 24-hr Tundra orbits. All cases have an orbital inclination of 63.4 deg and argument of perigee of 270 deg.

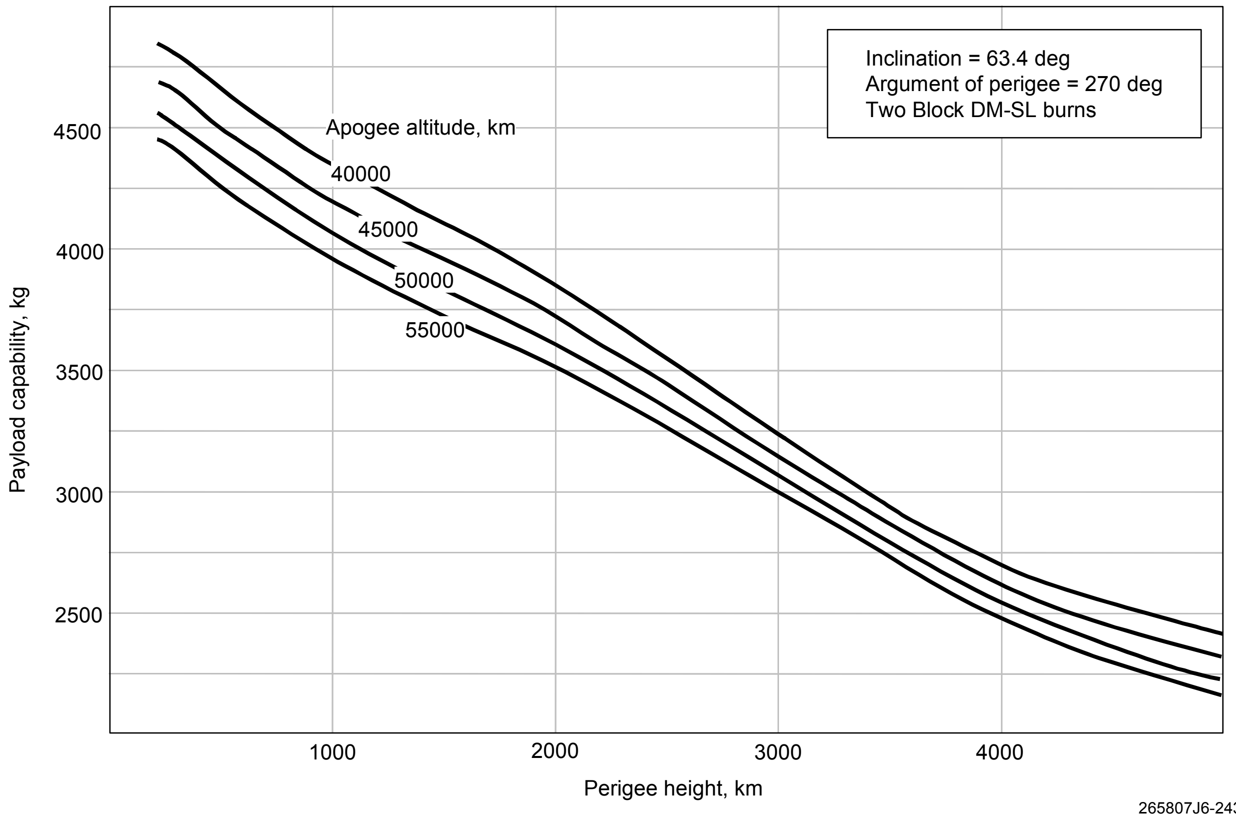

Figure 3-9. Molniya and Tundra Transfer Orbit Payload Capability

Table 3-7. Molniya and Tundra Transfer Orbit Payload Capability

Perigee height, km	Payload capability, kg			
	Apogee ht, 40000 km	**Apogee ht, 45000 km**	**Apogee ht, 50000 km**	**Apogee ht, 55000 km**
213	4848	4690	4560	4451
300	4799	4642	4512	4403
400	4728	4571	4442	4333
500	4658	4501	4372	4264
600	4590	4433	4305	4197
700	4524	4369	4240	4133
800	4462	4307	4179	4071
900	4403	4248	4120	4013
1000	4346	4192	4064	3958
1250	4218	4064	3937	3831
1500	4106	3953	3826	3720
1750	3986	3845	3725	3622
2000	3849	3720	3610	3515
2500	3549	3442	3349	3267
3000	3236	3147	3069	3000
3500	2935	2856	2790	2731
4000	2703	2615	2542	2479
4500	2541	2446	2364	2295
5000	2422	2315	2230	2163
6000	2238	2133	2046	1973
7000	2106	2002	1916	1844
8000	2002	1900	1816	1745
9000	1916	1817	1734	1668
10000	1843	1746	1666	1600

High-Energy Orbits and Earth Escape

Figure 3-10 and table 3-8 show the Zenit-3SL payload capability to high energy orbits and Earth escape. These are presented as a function of C_3 (velocity squared at infinity) and declination of the outgoing asymptote.

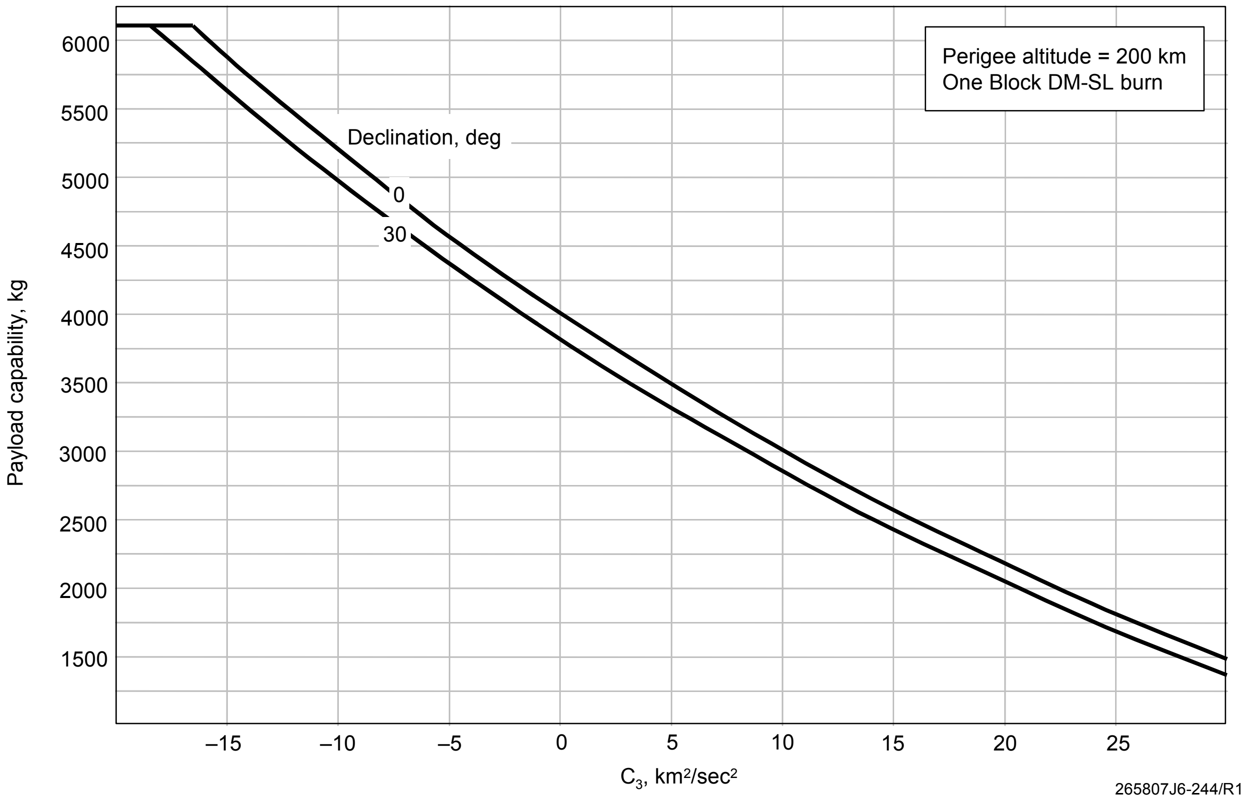

Figure 3-10. High-Energy and Earth Escape Payload Capability

Table 3-8. High-Energy and Earth Escape Payload Capability

	Payload capability, kg	
C_3, km²/s²	**Declination = 0 deg**	**Declination = 30 deg**
–18	6100	6045
–16	6024	5767
–14	5742	5496
–12	5467	5231
–10	5200	4975
–8	4944	4726
–6	4696	4487
–4	4457	4256
–2	4227	4033
0	4005	3818
2	3791	3611
4	3585	3411
6	3386	3218
8	3194	3032
10	3010	2853
12	2831	2679
14	2659	2512
16	2493	2351
18	2332	2195
20	2177	2045
22	2028	1899
24	1884	1759
26	1744	1623
28	1609	1492
30	1479	1365

3.4 Coast Phase Attitude

Three-Axis Pointing

The Block DM-SL can accommodate three-axis attitude pointing (including sun pointing) while coasting between Block DM-SL main engine burns. Attitude accuracy depends heavily on spacecraft mass properties but, for preliminary purposes, may be assumed to be ±3 deg (2.3σ) in all three axes.

Roll Maneuvers

For missions with lengthy coasts between Block DM-SL main engine burns, continuous rolls for spacecraft thermal control and battery charging are supported. For a roll rate of 5 deg/s, the roll-axis pointing accuracy is ±4 deg, and the attitude rate accuracy is ±0.2 deg/s in all three axes (2.3σ).

For preliminary purposes, it may be assumed that 40 min of each coast phase is reserved for Block DM-SL attitude maneuvers other than a continuous roll.

3.5 Spacecraft Separation

Separation and Postseparation Events

Spacecraft separation typically occurs 10 to 11 min after the final Block DM-SL main engine shutdown. This allows for engine cooling and reorientation to the required spacecraft separation attitude.

Several hours after separation, the Block DM-SL performs a contamination and collision avoidance maneuver, which prevents future contact with the spacecraft. The Block DM-SL then vents all residual propellant and gases and depletes any remaining charge in its batteries.

Injection Accuracy

The injection accuracy at spacecraft separation is a function of the injection orbit and the mission flight duration. Table 3-9 indicates the injection accuracy for a typical geosynchronous transfer orbit mission (2.3σ).

Table 3-9. Typical Geosynchronous Transfer Orbit Injection Accuracy (2.3σ)

Orbital parameter	Injection accuracy
Perigee height	± 10 km
Apogee height	± 80 km
Inclination	± 0.25 deg

Separation Capabilities

Sea Launch uses a line of highly successful and reliable Saab Ericsson spacecraft adapters to provide a number of spacecraft separation modes:

- Transverse spin—Two sets of springs with differing energies are used to impart relative separation velocity as well as the desired angular velocity about a specified spacecraft axis.
- Longitudinal spin—Before the separation event, the Block DM-SL rotates the integrated launch vehicle to achieve the desired angular velocity about the longitudinal axis. Uniform separation springs impart relative separation velocity to the spacecraft.
- Three-axis stabilized—Uniform separation springs impart relative separation velocity while the Block DM-SL minimizes pre-separation rotational rates about each axis.

The tolerances of the separation parameters associated with each of the different spacecraft separation events depend heavily on the mass properties and associated uncertainties of the spacecraft for each mission.

Sea Launch works closely with the spacecraft customer to understand and define separation requirements that ensure mission success. Boeing proprietary nonlinear dynamic analysis code is used to statistically ensure that all separation requirements are met. The analysis input database and subsequent results are documented in a spacecraft separation report provided to the customer. This report also includes dynamic clearance calculations for the spacecraft relative to the launch vehicle during the separation event. Postflight analysis of the spacecraft separation has shown excellent correlation with predicted results.

4.0 MISSION INTEGRATION

Overview

This section details the mission management structure and the roles and responsibilities of mission personnel, and defines baseline and mission-specific documentation.

The following characteristics of the mission integration are covered in Sections 4.1 through 4.3:

- Management structure
- Mission analysis and operations planning
- Mission documentation

4.1 Management Structure

To provide the customer with an efficient mission integration and launch operations process, Sea Launch provides direct lines of contact between the customer and the Sea Launch organization. Figure 4-1 illustrates this management structure for both the planning phase and the launch campaign.

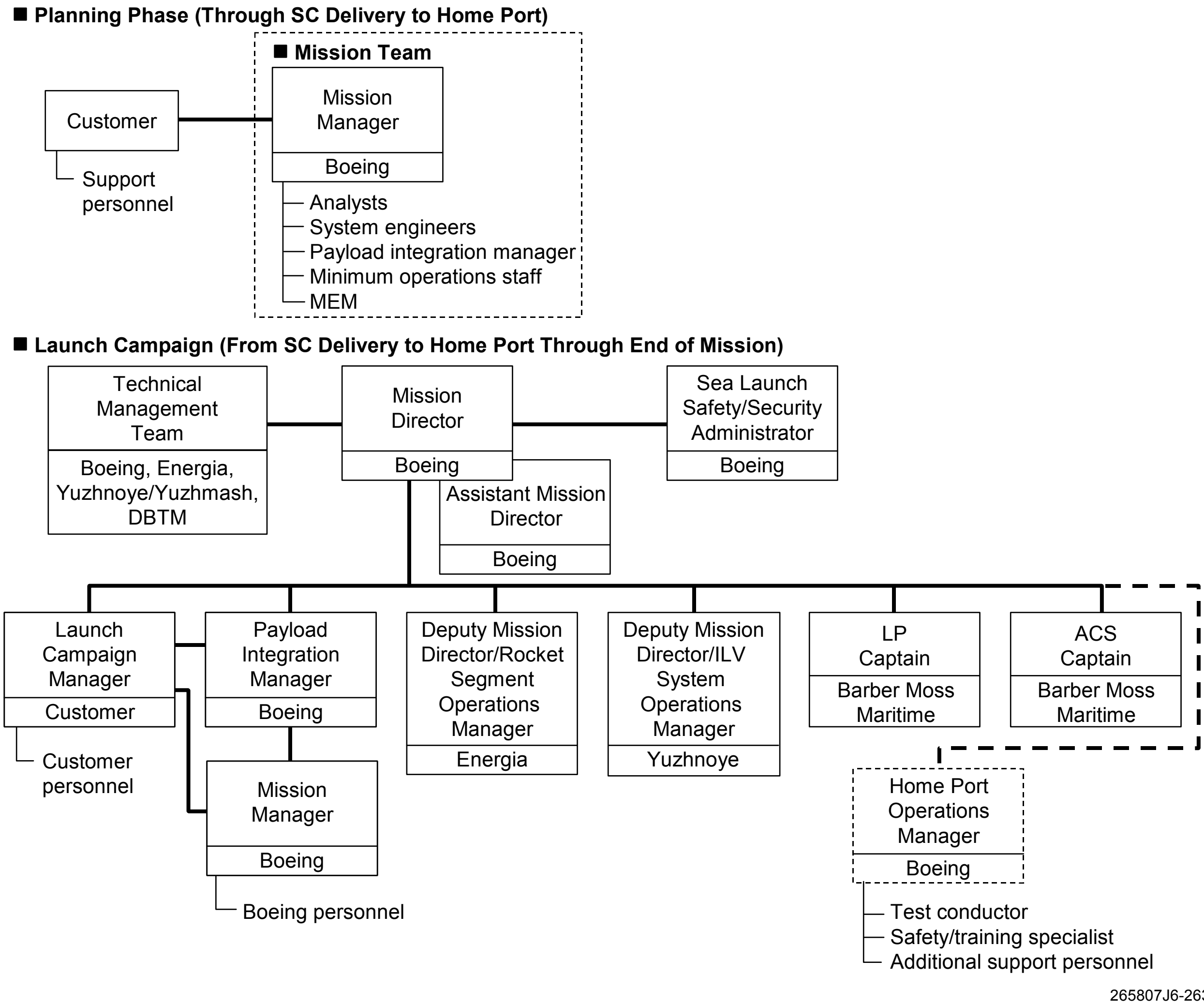

Figure 4-1. Management Structure

Mission Manager and Team

For each mission, Sea Launch assigns a mission manager from Boeing to be responsible for all mission-related customer support through launch. The mission manager leads a mission team comprising analysts and operations personnel.

The mission team is responsible for all mission analyses, operations planning, and integration activities.

Mission Team Roles and Responsibilities

When the spacecraft arrives at Home Port, the focus changes from analytical integration to the physical integration of the spacecraft and the launch campaign. Table 4-1 shows mission team roles and responsibilities.

Table 4-1. Mission Team Roles and Responsibilities

Title	Roles and responsibilities
Customer-provided focal point	• Works closely with the mission manager and the payload integration manager and has a direct line of contact with the mission director during operations
Operations team	• Includes a customer-provided focal point and other customer personnel as required
Mission manager	• Primary customer interface • Leads the mission team
Payload integration manager	• Leads the physical integration team • Responsible for all operations at Home Port and on board the assembly and command ship and launch platform that directly affect the spacecraft and the integrated payload unit • Member of the mission team throughout the planning phase • Supports the operations planning effort during planning phase • Reports directly to the mission director at time of spacecraft delivery to Home Port

4.2 Mission Analysis and Operations Planning

Mission Analysis

The mission analysis process ensures compatibility of the spacecraft with the launch vehicle and with the overall Sea Launch system. These tasks encompass:

- Interface requirements development
- Verification planning
- Verification
- Performance, interface, and environmental analyses

Mission analysis begins when Sea Launch and the customer reach a launch agreement and continues until submittal of the final postflight report to the customer.

Mission Specialists

Mission analysis personnel include specialists in:

- Systems engineering
- Electrical and mechanical interface design
- Structural loads and dynamics analysis
- Mass properties
- Thermal analysis
- Electromagnetic interference and compatibility
- Communications
- Venting analysis
- Trajectory and orbit design
- Spacecraft separation systems
- Contamination control

Operations Planning

Operations planning focuses on tailoring the baseline operations process and products to accommodate each specific mission. The mission-specific spacecraft campaign document is used to document all of the planning and products. These operations products include:

- Operations flows
- Timelines and checklists
- Operations policies
- Detailed procedures

Operations planning also addresses mission-specific requirements for personnel training and certification, readiness reviews, and rehearsals.

4.3 Mission Documentation

Overview

Sea Launch has developed baseline documentation for a generic mission, which is used as a template for each mission. This proven process ensures consistency and repeatability across missions. This generic documentation includes:

- Mission analysis documentation that defines the spacecraft interfaces and the initial mission integration process
- Operations plans and products that define and support the actual mission conduct

Mission-specific documentation is also defined in this section. Figure 4-2 illustrates the documentation set that supports each mission.

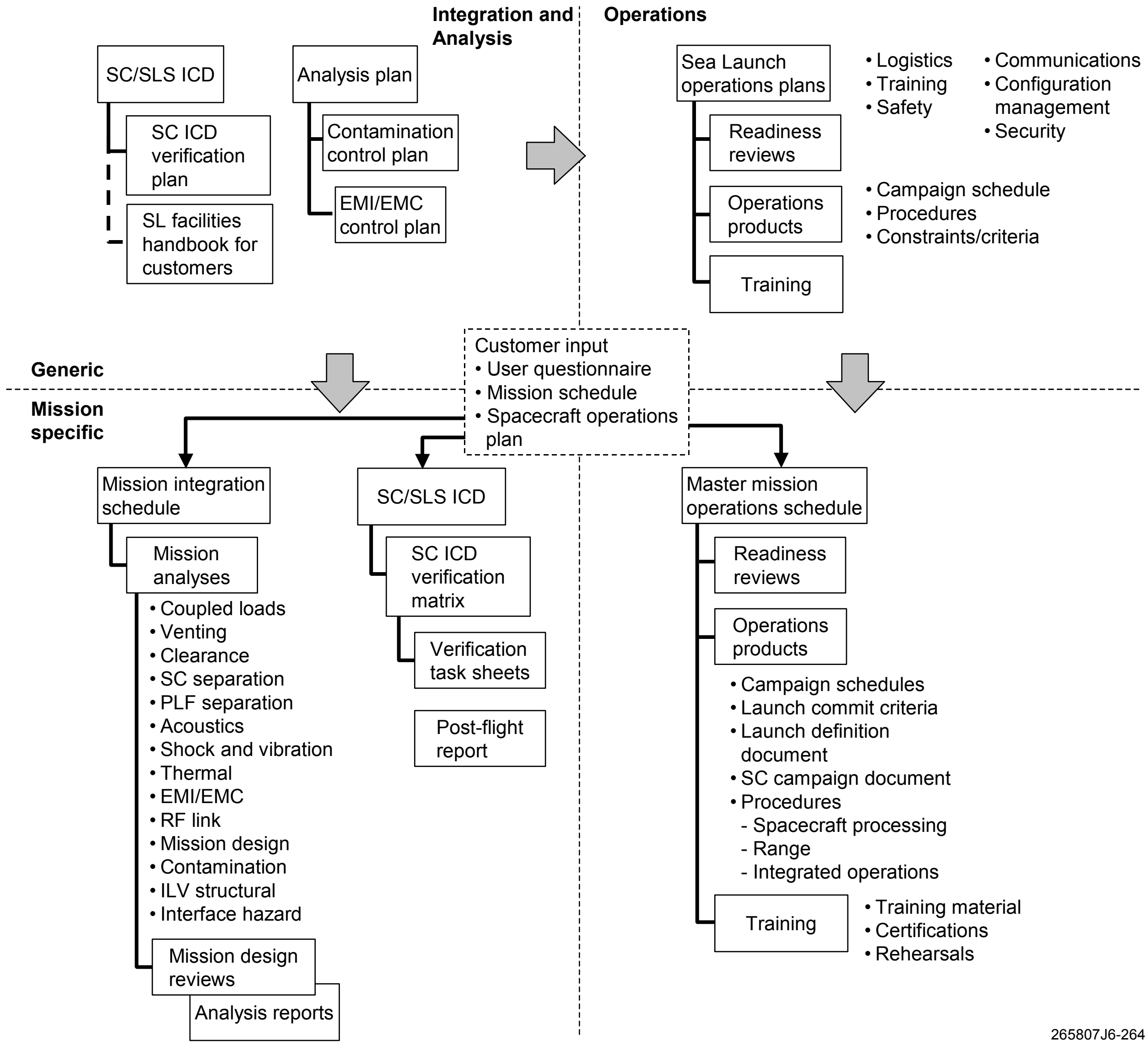

Figure 4-2. Mission Documentation and Related Products

Integration Documentation

At the beginning of the integration process, the customer will receive the generic documentation used for spacecraft integration on all Sea Launch missions. These documents allow the customer to understand the generic integration process. This documentation includes:

- Mission integration schedule
- Analysis plan
- Contamination control plan
- Electromagnetic interference and electromagnetic control plan

If the customer provides an interface requirements document, it will be the basis for generating the mission-specific spacecraft interface control document. The interface control document allows the customer to define unique interfaces between the spacecraft and the Sea Launch system.

Operations Documentation

The generic operations documentation available to the customer for understanding the operations details consists of:

- Sea Launch operations plan
- Sea Launch safety regulations manual
- Training, certification, and rehearsal plan

Mission-Specific Documentation

The user questionnaire (app. A) and the generic integration schedule template are used to define the specific documentation for each individual mission. A generic mission integration schedule is shown in figure 1-1.

The mission-specific integration documentation consists of:

- Unique mission integration schedule
- Mission-specific spacecraft/Sea Launch system interface control document
- Verification matrix
- Mission design and analysis reports

The mission-specific operations documentation consists of:

- Spacecraft campaign document
- Tailored operations procedures
- Launch commit criteria
- Master countdown procedure
- Training materials

Following the mission, a postflight report is generated for the customer.

Mission Integration Schedule

The mission integration schedule and detailed schedule will be developed after a contract is established or a launch option is exercised and the spacecraft is committed on the Sea Launch manifest.

The integration schedule is produced by the mission manager and agreed to by the customer. This schedule includes:

- Spacecraft integration milestones
- Data deliverables (spacecraft models and analysis reports)
- Reviews
- Integration activities
- Schedule of customer reviews
- Hardware need dates
- Spacecraft integration milestones

The detailed schedule for the launch campaign will be produced by the payload integration manager. This schedule delineates:

- General operations flow
- Overall training and rehearsal requirements
- Integrated schedules for processing and launch operations
- Key Home Port, assembly and command ship, and launch platform events

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Analysis Plan

The analysis plan defines:

- Each of the specialty areas where analyses are performed
- Inputs required from the customer
- Tasks to be accomplished
- Specific products to be provided to the customer

The plan covers analyses in the areas of:

- Thermal
- Acoustic
- Radio frequency links
- Contamination
- Loads
- Shock and vibration
- Orbit and trajectory details
- Separation clearances
- Electromagnetic interference and electromagnetic compatibility

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Operations Plan

The operations plan defines the detailed plans and processes for all Sea Launch operations activities, which include:

- Operations phases
- Concepts and activities for each phase
- Management team
- Support facilities and capabilities
- Personnel training and certification processes
- Rehearsals
- Readiness reviews
- Operations products
- Overall control processes

Spacecraft/Sea Launch System Interface Control Document

The spacecraft/Sea Launch system interface control document defines all spacecraft and spacecraft ground support equipment to Sea Launch environmental, orbital, and operational interfaces. It also contains the mission-unique facility interfaces. (Standard facility interfaces are described in the *Sea Launch Facilities Handbook* for customers.)

Spacecraft Verification Matrix

A spacecraft verification matrix defines the process by which the interface control document requirements and functions are verified before and during launch processing. The matrix is included in the interface control document.

***Sea Launch Facilities Handbook* for Customers**

The Facilities Handbook for customers describes those portions of the Sea Launch Home Port, payload processing facility, assembly and command ship, and launch platform used by the customer during spacecraft processing and launch operations.

Any modifications made to standard facility interfaces will be included in the mission-specific spacecraft/Sea Launch system interface control document.

5.0 SPACECRAFT ENVIRONMENTS

Overview

This section describes the major environments the spacecraft is exposed to from the time of its arrival at Home Port until its separation from the launch vehicle, including:

- Transportation and handling at sea
- Structural loads
- Random vibration
- Acoustics
- Shock
- Electromagnetic radiation
- Thermal changes
- Humidity
- Pressure
- Cleanliness
- Contamination

Ground and Flight Environments

For each of the above environments, the levels are generally categorized by time of occurrence. The levels designated as “ground transportation and handling” cover the period of time from the arrival of the spacecraft at Home Port until Stage 1 ignition. The levels designated as “flight” cover the period of time from Stage 1 ignition (liftoff) through spacecraft separation from the launch vehicle and end with the completion of the Block DM-SL contamination and collision avoidance maneuver.

Although the Sea Launch system has a unique processing flow, every effort has been made to ensure that the environments experienced by the spacecraft will be less than or comparable to those provided by other launch systems.

5.1 Transportation and Handling at Sea

Fatigue

The fatigue loads during ocean transit are usually less than those experienced during rail transport at other launch sites. Table 5-1 depicts fatigue loads on the spacecraft for Sea Launch, covering ocean transit and all ground handling operations at Home Port.

Table 5-1. Spacecraft Fatigue Environment for Transportation and Handling

Load, g	0.39	0.37	0.33	0.29	0.25	0.22	0.18	0.14	0.10
Number of cycles	1	5	21	92	387	1,569	6,086	21,842	1.0E+08

Notes:

- Vertical loads are in addition to gravity: g (vertical) = 1.0 ± load (g).
- Environment covers three trips (1.5 round trips) between Home Port and the equatorial launch site.
- Loads act uniformly along the length of the spacecraft.
- The dynamic loads act in all directions simultaneously.

Pitch and Roll

Table 5-2 gives the maximum pitch and roll motions during transport between Home Port and the launch site. Launch platform motions apply to spacecraft and ground support equipment while assembly and command ship motions apply only to ground support equipment.

The quasi-static load factors for ocean transport in figure 5-1 account for launch platform motions. In particular, the effect of the launch platform pitch and roll motions on spacecraft fluid slosh is already accounted for in figure 5-1.

Table 5-2. Motions During Transit to Launch Site

Maximum motions	**Assembly and command ship**	**Launch platform**
Pitch	8 deg	8 deg
Pitch rate	5.5 deg/s	5.5 deg/s
Roll	25 deg	10 deg
Roll rate	21 deg/s	7.5 deg/s

5.2 Structural Loads

Overview

The structural loading environments on all spacecraft primary and secondary structure are examined for:

- Ground transportation and handling
- Flight
- Spacecraft sinusoidal vibration testing

Compliance requirements of the spacecraft to these environments are discussed in Section 6

Quasi-Static Load Factors for Ground Handling and Transportation

The Sea Launch system will not induce loads on the spacecraft that exceed the load factor envelope shown in figure 5-1 during spacecraft ground and ocean transportation, handling, and processing.

The load factor levels are applied quasi-statically at the spacecraft center of gravity. The (x,y,z) load factor components are contained within a sphere with radius 0.5 g centered about the 1.0 g contribution due to gravity. The load factor envelope in figure 5-1 includes all contributions generated from the launch platform motion (angles, rates, and accelerations) during ocean transport. In particular, angle changes of the spacecraft as a result of the pitch and roll of the launch platform are included. The quasi-static load factors in figure 5-1 also determine the maximum change in angle of a fluid's free surface in a tank to be 30 deg for spacecraft slosh frequencies ≥0.25 Hz.

The load factors in figure 5-1 envelop all ground transportation and handling events from arrival at Home Port to Stage 1 ignition and apply to all orientations of the spacecraft. The orientation of the spacecraft when the Zenit-3SL is horizontal or vertical is shown in figures 5-2 and 5-3, respectively.

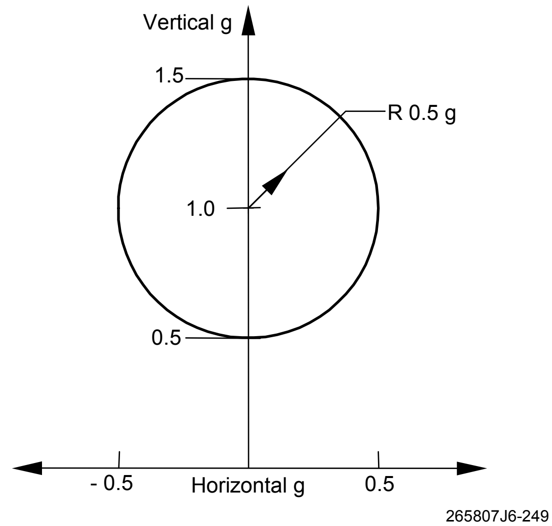


Figure 5-1. Transportation and Handling Limit Load Factors

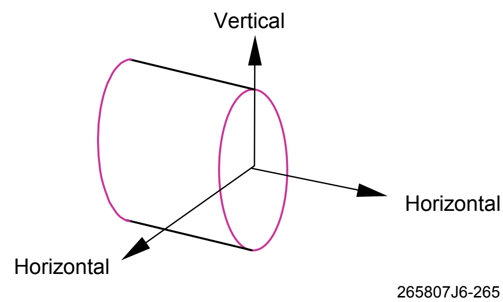


Figure 5-2. Integrated Launch Vehicle Horizontal

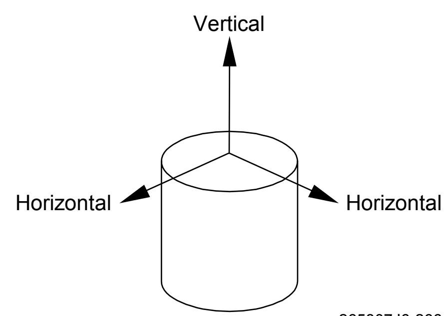


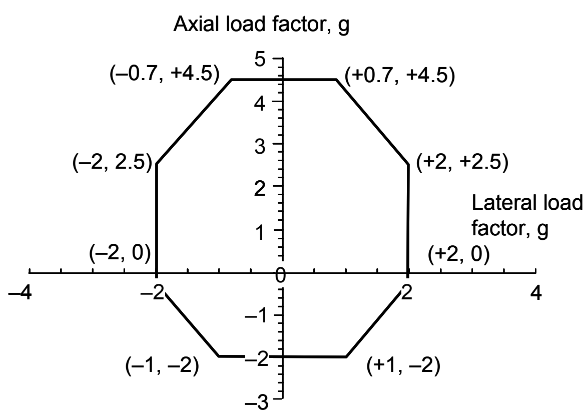
Figure 5-3. Integrated Launch Vehicle Vertical

Coupled Loads Analysis Required to Determine Quasi-Static Loads for Flight

Determining the ability of the spacecraft primary and secondary structure to withstand the dynamic loading events from flight requires a coupled loads analysis. Sea Launch performs a coupled loads analysis for all critical flight events to determine the accelerations, loads, and deflections of all primary and secondary structure of the spacecraft caused by the coupled elastic behavior of the Zenit-3SL launch vehicle and the spacecraft. The results determine the interface loads of the spacecraft with the spacecraft adapter. The resulting equivalent spacecraft quasi-static load factors at the spacecraft center of gravity are then determined for a specific spacecraft with given mass and stiffness properties.

Flight Quasi-Static Load Factors for Primary Structure

The quasi-static limit load factors for flight that envelop the loads over a wide range of spacecraft are given in figure 5-4. These factors are to be used as a guide only. Specific limit load factors for spacecraft with given mass and stiffness properties will be specified in the spacecraft interface control document after a coupled loads analysis has been performed. Lateral load factors ranging from 1.5 to 2.5 g have been calculated for spacecraft with unique mass and/or stiffness properties.



Notes:
- Positive axial acceleration results in compression at the SC-LV separation plane.
- Guide only. Specific values determined after spacecraft CLA.

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Figure 5-4. Typical Quasi-Static Load Factors for Flight

Sinusoidal Vibration During Flight

The low-frequency sinusoidal vibration environment generated at the spacecraft separation plane during launch and flight will not exceed that defined in figure 5-5. A coupled loads analysis performed by Sea Launch determines the minimum sinusoidal vibration environment for all flight events. The results determine the maximum notching that can be used during the spacecraft sinusoidal vibration testing.

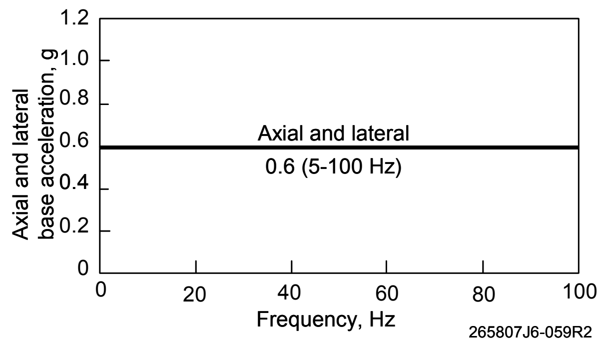


Figure 5-5. Sinusoidal Vibration at the Spacecraft Interface

5.3 Random Vibration

Random Vibration for Components Near Spacecraft Interface

The random vibration environment for flight measured at the spacecraft interface is shown in figure 5-6.

Maximum values occur during liftoff and are closely correlated with the acoustic environment.

The environment in figure 5-6 applies to components within 0.5 m from separation plane along any structural path. This environment is not to be applied to the complete spacecraft as a rigid base excitation.

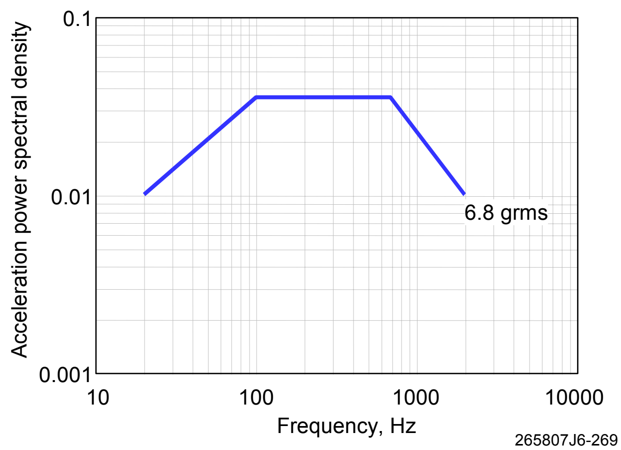


Figure 5-6. Random Vibration Environment During Flight

5.4 Acoustics

Space Average Sound Pressure Levels

The launch vehicle internal acoustic levels shown in table 5-3 and figure 5-7 are average sound pressure levels internal to the payload unit. These values apply to a spacecraft with an equivalent radius that results in a spacecraft-to-payload fairing gap of 0.43 m (1.5 ft).

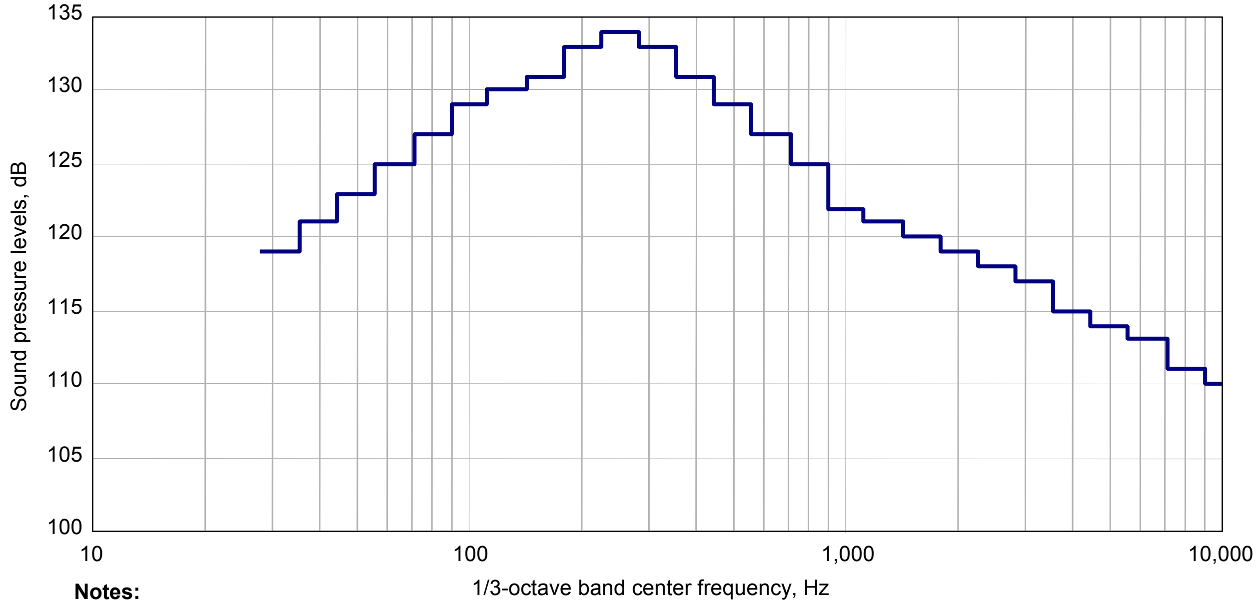
Fill Effects to be Considered

The equivalent radius of the spacecraft is defined as the radius of a circle with a cross-sectional area equal to the spacecraft cross-sectional area. The envelope of the internal maximum expected sound pressure levels also can be provided after clocking and fill effects for a specific spacecraft are determined.

Section 6 discusses the compliance requirements of the spacecraft to the internal acoustic environment.

Table 5-3. Acoustics During Flight—1/3-Octave Band Sound Pressure Levels

1/3-octave band center frequency, Hz	**Sound pressure levels, dB**
31.5	119
40	121
50	123
63	125
80	127
100	129
125	130
160	131
200	133
250	134
315	133
400	131
500	129
630	127
800	125
1,000	122
1,250	121
1,600	120
2,000	119
2,500	118
3,150	117
4,000	115
5,000	114
6,300	113
8,000	111
10,000	110
• OASPL = 142 dB • Reference: 2 x 10^{-5} Pa (2.9 x 10^{-9} psi)	



Notes:
- Overall sound pressure level = 142 dB
- Reference: 2 x 10^{-5} Pa (2.9 x 10^{-9} psi)

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Figure 5-7. Acoustic Environment During Flight

5.5 Shock

Overview

Shock environments are provided for the three spacecraft adapter types:

- The SCA1194VS: has a diameter of 1194 mm and a Marmon clamp separation system.
- The SCA1666: has a diameter of 1666 mm and a Marmon clamp separation system.
- The SCA702+ and SCA702+GEM: have diameters of 1663 mm and four-bolt separation systems.

The maximum shock environments for these systems are consistent with industry standards.

Check with Sea Launch for availability of other spacecraft adapters.

SCA1194VS

Sea Launch, together with the Boeing Delta team, is developing a low-shock, 1194-mm spacecraft separation system to be provided by Saab Ericsson Space (designated the SCA1194VS). In addition to reduced shock environment, the SCA1194VS will provide the ability to accommodate spacecraft weighing up to 8 metric tons by using a 60-kN clampband tension (for structural capability of the Zenit-3SL launch vehicle, see Sec. 6.1). The only significant difference for the SCA1194VS from the previous Saab 1194-mm adapter is the use of a fast-acting clampband opening device in place of bolt cutters to release the clampband tension, which results in a lower spacecraft shock environment.

Figure 5-8 shows a preliminary estimate of the expected shock environment. This environment represents an envelope of the maximum expected shock at any location on the spacecraft interface.

The shock spectra shown in figure 5-8 describe the maximum expected shock environment in the radial and axial directions for a spacecraft adapter having a diameter of 1194 mm and a low-shock Marmon clamp separation system. Figure 5-8 also shows the shock environment at the spacecraft interface resulting from all other integrated launch vehicle shock events. The shock environment generated by all other integrated launch vehicle shock events has comparable levels in both the radial and axial directions. The spacecraft can show compatibility with the spacecraft separation shock using matchmate shock results and analysis. Compatibility to the radial and axial shock levels from all other integrated launch vehicle shock events also must be considered.

The shock spectra are consistent with a tension of 60 kN in the spacecraft adapter clampband and are defined for a location at the interface on the spacecraft side of the separation plane.

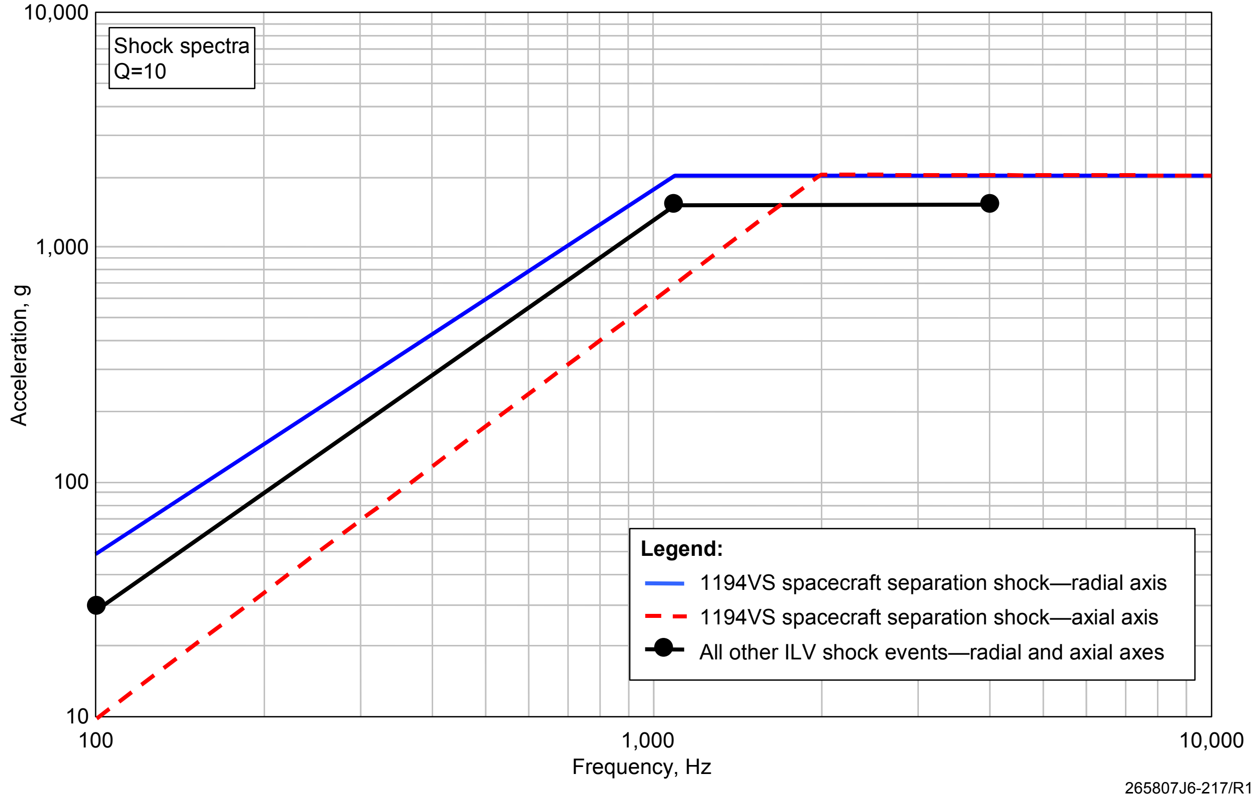

Figure 5-8. Separation Shock for SCA1194VS Spacecraft Adapter

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SCA1666

The shock spectrum shown in figure 5-9 represents the maximum expected shock environment for the spacecraft adapter with a diameter of 1666 mm and a Marmon clamp separation system.

The shock spectrum corresponds to a tension of 30 kN in the spacecraft adapter clampband and is defined for a location 12.7 cm (5 in) from the separation plane on the spacecraft side of the interface.

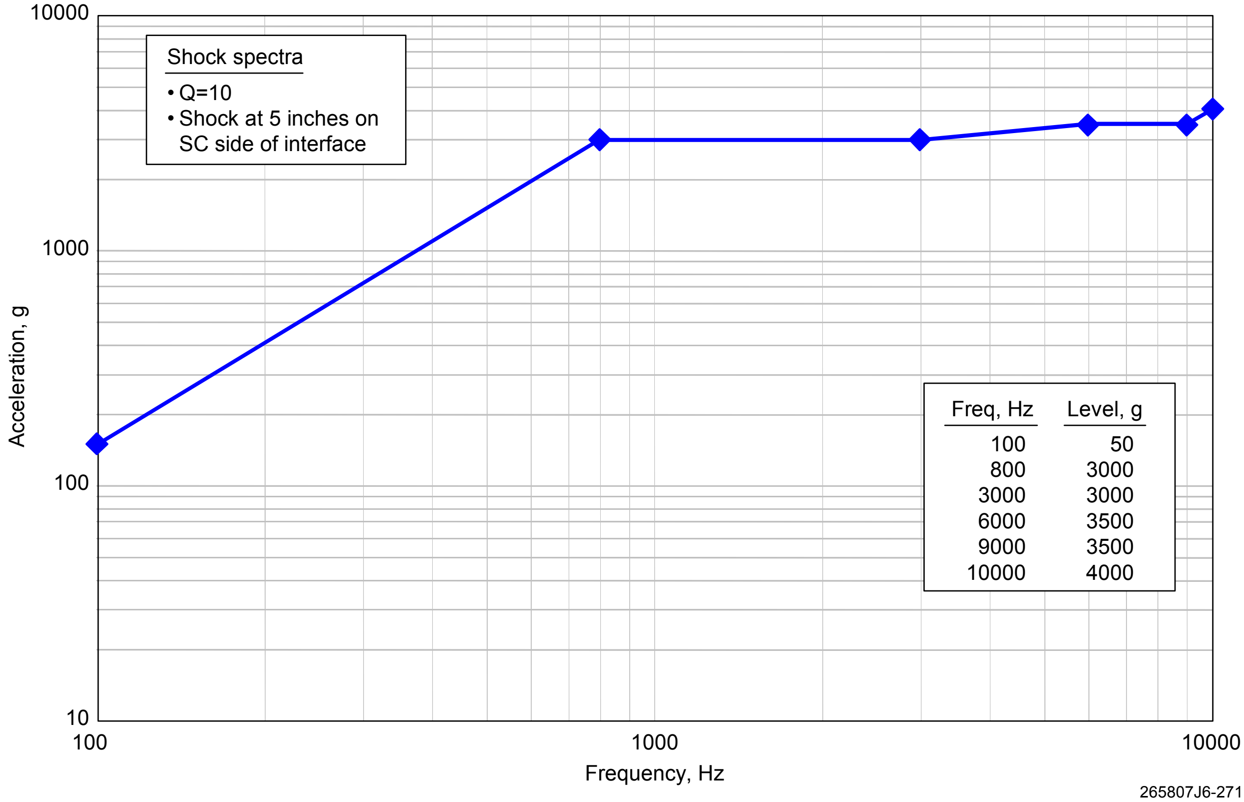

Figure 5-9. Separation Shock for SCA1666 Spacecraft Adapter

SCA702+ and SCA702+GEM

The Sea Launch system generated separation shock spectrum using the SCA702+ and SCA702+GEM spacecraft adapters will not exceed that defined in figure 5-10 as measured 12.7 cm (5 in) from the separation plane on the spacecraft side of the interface on the spacecraft attachment fittings.

Section 6.1 discusses the strength capabilities of the SCA702+ and SCA702+GEM spacecraft adapters.

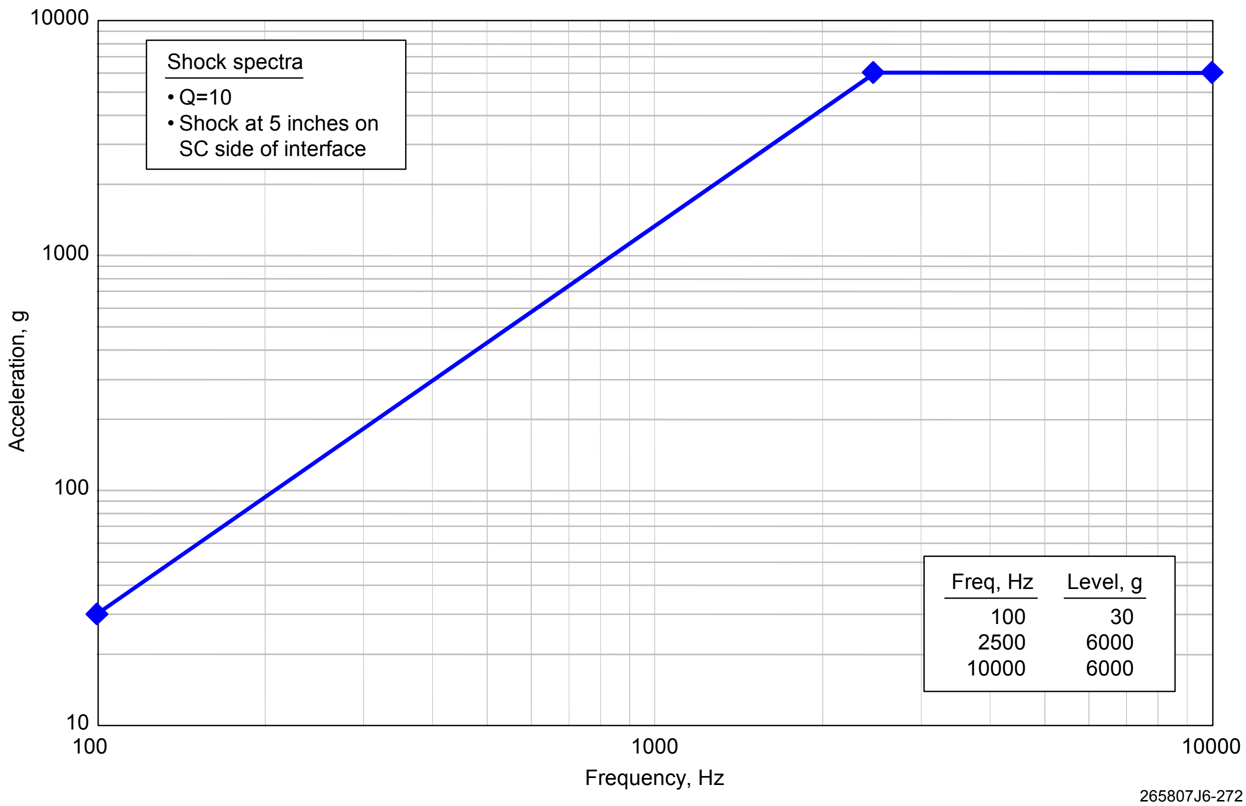

Figure 5-10. Separation Shock for SCA702+ and SCA702+GEM Spacecraft Adapters

5.6 Electromagnetic Environment

Overview

The electromagnetic radiation environment experienced by the spacecraft will be less than 10 V/m at frequencies between 1 kHz and 18 GHz. This applies to:

- Processing cells in the payload processing facility (fig. 5-11)
- The Home Port pier (fig. 5-12)
- The launch vehicle assembly compartment on board the assembly and command ship
- The launch platform hangar
- The spacecraft while erected on the launch platform

Note: Some levels shown exceed 10 V/m, but suppression and operational constraints are used to keep all levels impinging on the spacecraft below 10 V/m.

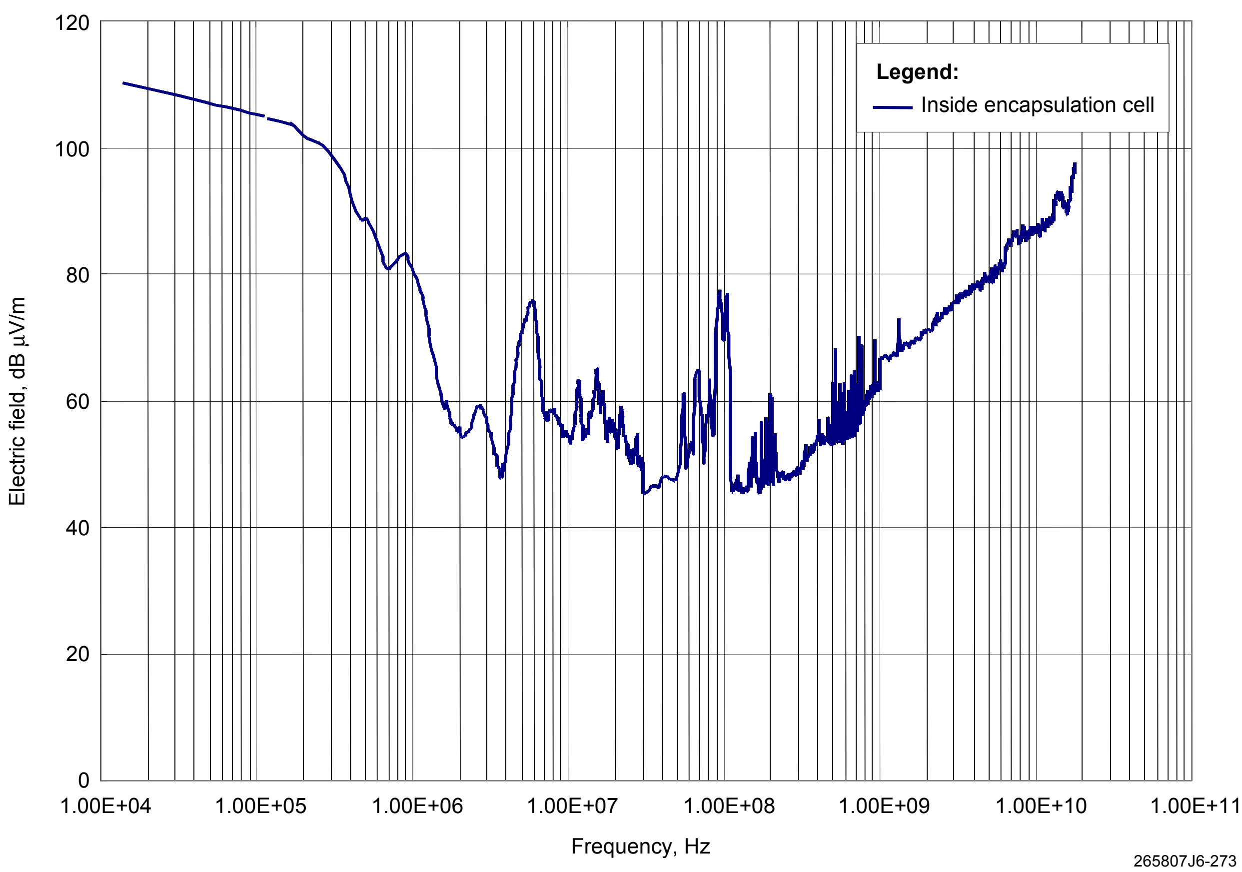

Figure 5-11. Typical Electromagnetic Environment in Payload Processing Facility—Encapsulation Cell

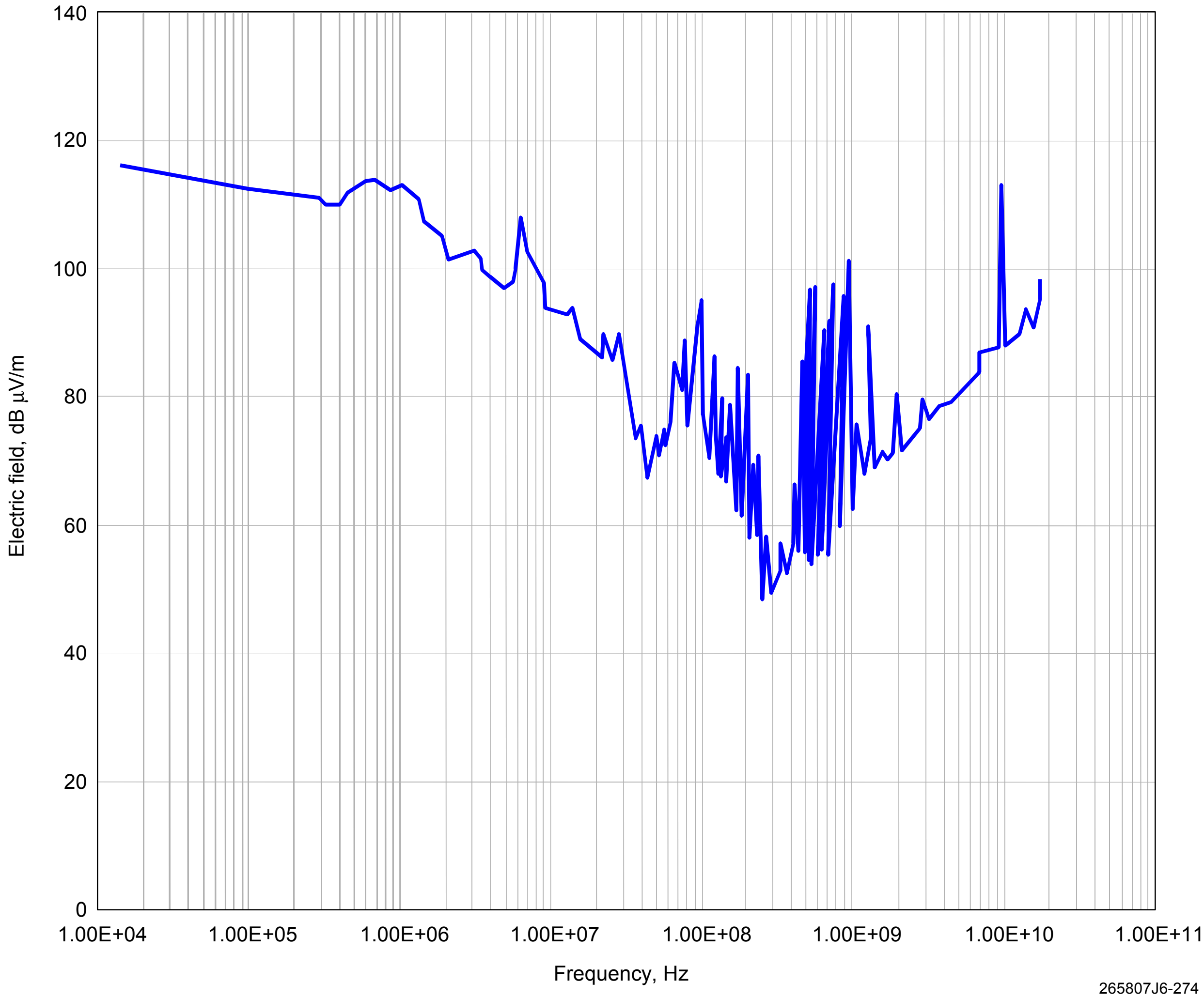

Figure 5-12. Typical Measured Electromagnetic Environment at the Sea Launch Home Port Pier

Radiated Environment

There are six telemetry transmission systems and two command-receive systems mounted on the launch vehicle, as follows:

- The Sirius and Zenit telemetry systems are located on the Zenit first and second stages. The Sirius systems transmit at 211.3, 219.3, 1010.5, and 1018 MHz, while the Zenit transmitter operates at 2211.0 MHz.
- The Kvant and BR9DM systems are located on the interface skirt. The Kvant system transmits at 922.76 MHz, and the BR9DM transmits at 166 MHz.
- The payload unit telemetry system transmits at 2272.5 MHz using several antennas that are mounted on the interface skirt.

Figure 5-13 shows the in-flight electromagnetic environment, produced by the launch vehicle transmitters.

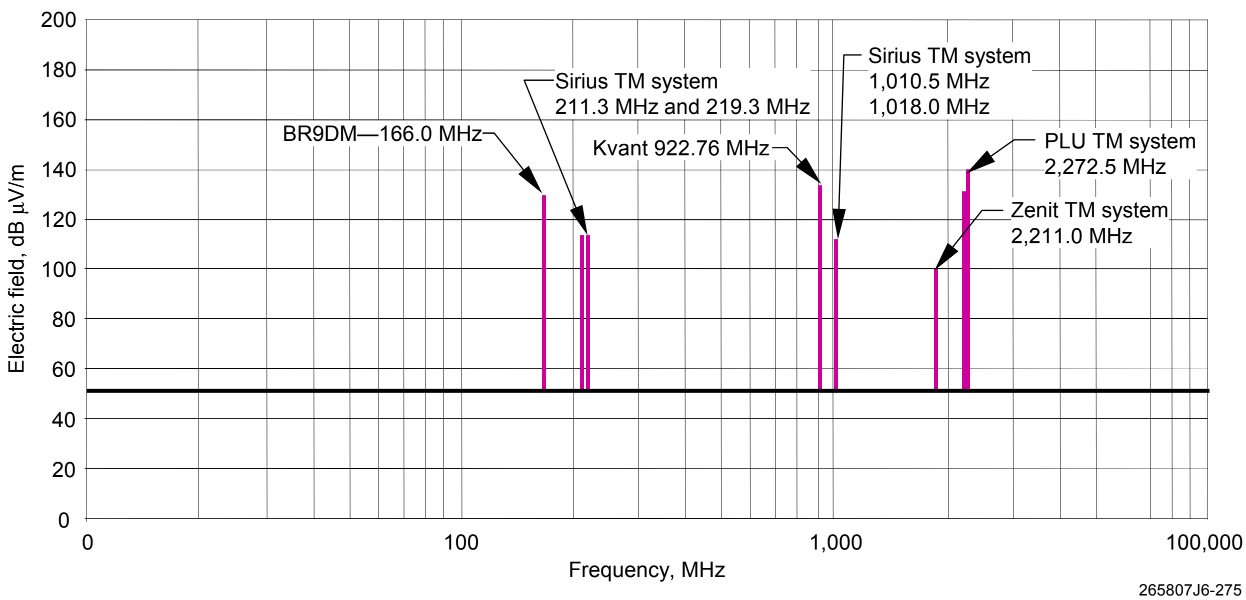

Figure 5-13. In-Flight Electromagnetic Environment

Electromagnetic Environment

Figure 5-14 shows the electromagnetic environment generated by the Sea Launch transmitters at Home Port and on the assembly and command ship, launch platform, and launch vehicle. Table 5-4 illustrates the data in figure 5-14.

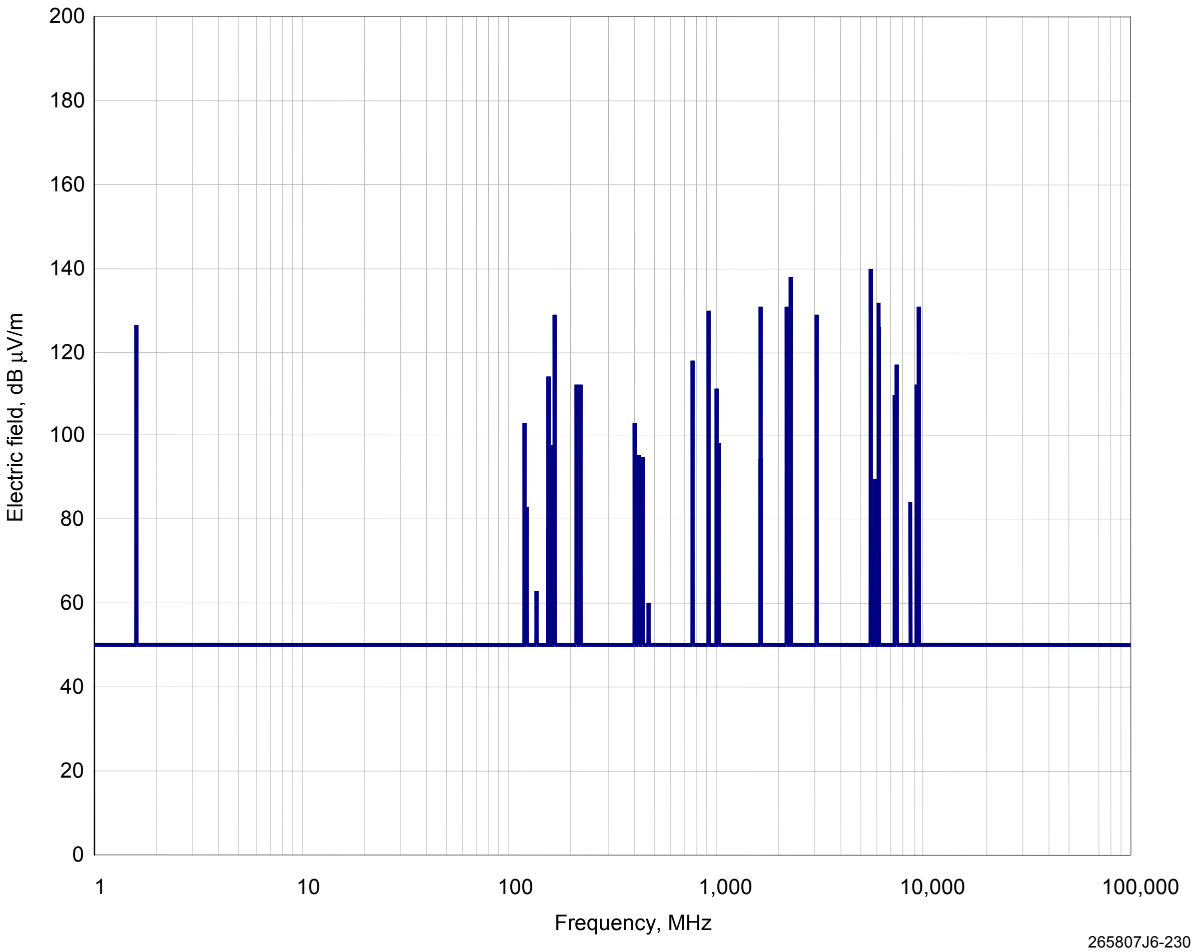

Figure 5-14. Sea Launch Radio Frequency Environment

Table 5-4. Sea Launch Radio Frequency Environment

Frequency, MHz	E-field at SC surface, dB µV/m
0.190	115
1.6	127
118.0	103
121.5	86
136.975	68
155.0	114
155.4	78
156.525	114
158.0	78
163.6	97
166.0	122
211.3	112
219.3	110
406.025	103
420.8	96
441.725	95
467.850	64
768.970	118
922.760	125
1010.5	110
1018.0	111
1626.5	131
1646.5	95
2211.0	110
2272.5	138
3050.0	129
5620.0	140
5800.0	91
6286.48	131
6295.5025	124
7194.5	77
7355.5	117
7494.5	117
7655.5	77
8700.0	84
9200.0	92
9410.0	131
9500.0	59

5.7 Spacecraft Thermal and Humidity Environments

Thermal and Humidity Environments Overview

Spacecraft thermal and humidity environments are characterized in the following sections for three primary operational phases:

- Spacecraft ground processing and handling before payload fairing encapsulation
- Operations after payload fairing encapsulation, including integrated launch vehicle integration, transportation to the launch site, and pre-launch preparations
- Liftoff, ascent, and in-flight operations

Ground Processing and Transportation Before Encapsulation–First Phase

Spacecraft thermal environments are maintained and controlled during ground processing, encapsulation, launch vehicle integration, transportation, and prelaunch preparation phases.

During operations phases in the payload processing facility, before encapsulation by the payload fairing, spacecraft thermal environments will be maintained within temperature and relative humidity ranges indicated in table 5-5.

For each phase, temperature and humidity are continuously monitored and alarmed. During propellant loading periods, temperature can be controlled to a variance of 1.7°C (3°F).

Table 5-5. Payload Processing Facility Thermal Environments

Location/phase	Temperature	Relative humidity
Air lock	18–24°C (65–75°F)	30–60%
Spacecraft processing and fueling cell	20–23°C* (68–73°F)	30–60%
Encapsulation cell	18–24°C* (65–75°F)	30–60%
Propellant storage cells	18–24°C (65–75°F)	30–60%
*Selectable within range		

Ground Processing and Transportation after Encapsulation–Second Phase

Following encapsulation in the payload fairing, the spacecraft environment is maintained with a continuous, conditioned-air supply. Air is ducted to the payload fairing thermal conditioning inlet diffuser (fig. 5-15), and exits to the Block DM-SL cavity through vent valves on the payload structure.

Air-conditioning units on the spacecraft transporter, assembly and command ship, and launch platform are dedicated to maintaining spacecraft environments within the payload fairing during processing and handling at Home Port, in the assembly and command ship, and while in transit to the launch site. The launch platform integrated launch vehicle air-conditioning system satisfies conditioned-air requirements of the payload unit, Block DM-SL, and boost vehicle on the launch pad during prelaunch phases. The flow from the launch platform integrated launch vehicle air-conditioning system is terminated at approximately L-17 min (on retraction of the transporter/erector and separation of the launch vehicle umbilicals). Conditioned airflow to the payload fairing is maintained through the remainder of the countdown (and through an abort recycle operation) by way of the launch platform high-pressure payload fairing purge system.

Table 5-6 summarizes payload unit environmental control system inlet conditions and control capabilities. All air-conditioning systems maintain positive pressure inside the payload fairing to prevent air-transported contaminants from entering the payload fairing. Air quality is maintained by providing purge air that has been high efficiency particulate air–filtered to class 5,000 maximum in accordance with FED-STD-209E.

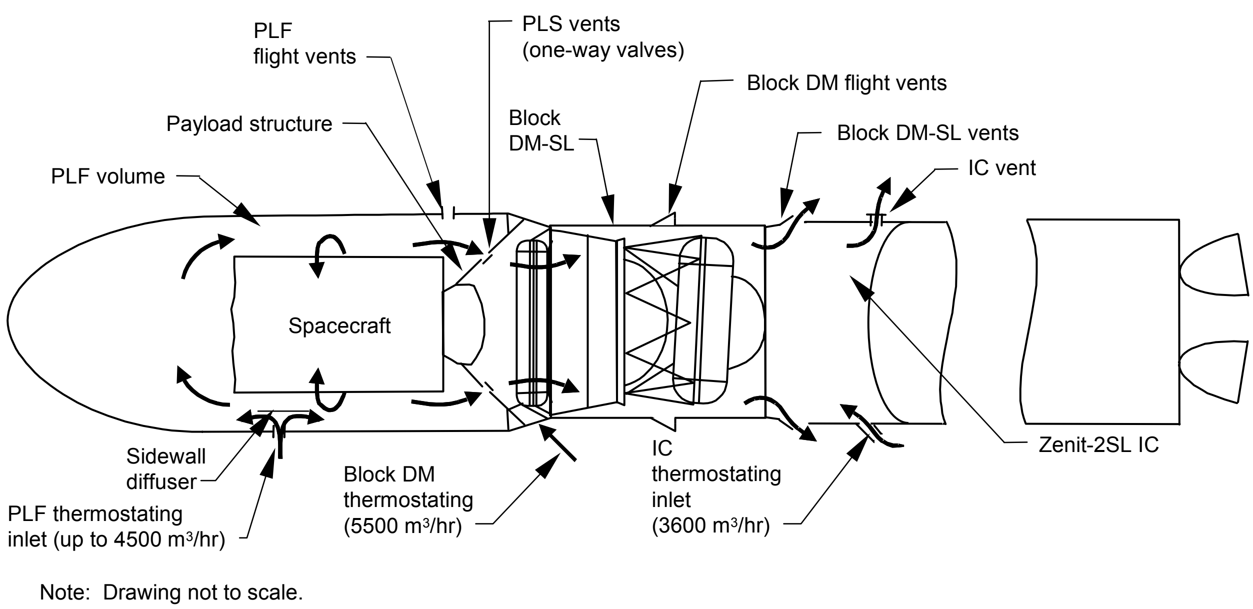

Figure 5-15. Payload Unit Air-Conditioning Venting Scheme

Table 5-6. Payload Unit Environmental Control—Air-Conditioning Inlet Conditions

Operations phase	Inlet temperature range (1)	RH (2)	Flowrate range (3)
Home Port processing/ transportation • After PLF encapsulation in PPF • Transfer from PPF to ACS • ACS processing	12–25°C (4) (54–77°F)	0–60% (4)	9–36.3 kg/min • (19.8–80 lb/min)
Launch platform hangar • Transport from Home Port to launch site • At launch site • Transfer from hangar to launch pad	10–25°C (50–77°F)	0–60%	18.1–90 kg/min • (40–198 lb/min)
Prelaunch operations at launch site • At launch pad erection to vertical • On launch pad to L-17 min Recycle operations • After lowering of ILV, before transfer into hangar	10–25°C (50–77°F)	0–60%	18.1–92 kg/min • (40–200 lb/min)
Prelaunch operations at launch site • After L-17 min to L-0 • In event of abort, through lowering of ILV until primary air reinstated	8–18°C	0–60%	>18 kg/min • (>40 lb/min)

Continuous air-conditioning is maintained throughout all phases by primary and/or backup air-conditioning systems.

Notes: (1) Inlet temperatures are selectable within indicated range and controlled to within ±2°C of setpoint except during critical operations and on launch pad after L-17 min.

(2) Relative humidity controlled to 30–60% if access to spacecraft in payload fairing is required.

(3) Selectable within indicated ranges except during critical operations and on launch pad after L-17 min.

(4) Lower temperatures are available with higher relative humidity (as low as 10°C at 70% RH).

Flight–Third Phase

The Sea Launch payload fairing, described in Section 2, provides protection to the spacecraft from thermal environments during prelaunch, liftoff, and ascent mission phases. Effects of ascent aerodynamic heating on the spacecraft thermal environment inside the fairing are controlled by the insulating characteristics of the fairing. Ablative coatings on external payload fairing surfaces, acoustic damping material on internal surfaces, and the low conductivity of the graphite composite/aluminum honeycomb fairing structure combine to minimize heat transfer to the spacecraft from heated external surfaces during ascent.

Figure 5-16 shows predicted maximum internal payload fairing surface temperatures during the ascent period, which conservatively bound Sea Launch flight measurements. Predicted peak temperatures of acoustic blanket inner surfaces (which comprise 62% of the payload fairing area) remain below 85°C. At the time of fairing jettison, more than 90% of the fairing inner surface area is less than 95°C, 98% is under 120°C, and 2% is in the 120 to 140°C range. Materials comprising payload fairing inner surfaces generally have surface emittances ranging from ε=0.64 for surfaces covered with acoustic damping material to ε=0.83 for noninsulated inner walls.

The Sea Launch system accommodates user-specified limitations on aerodynamic heat loads during periods after payload fairing jettison as constraints on the design of the ascent trajectory and at the time of fairing jettison. Maximum 3σ dispersed free molecular heat loads are calculated for mission-unique launch azimuth, day-of-launch ascent profile, and parking orbit as part of the trajectory design. For the typical spacecraft, fairing separation will occur after the maximum 3σ dispersed free molecular heat rate falls below 1135 W/m^2 (360 BTU/h ft^2), or a value adjusted to meet specific mission requirements. Payload fairing jettison will generally occur at a nominal altitude of approximately 117,000 m (384,000 ft) at times ranging from 190 to 230 sec following liftoff. Delaying time of fairing jettison or raising parking orbit perigee altitude to achieve a reduction in free molecular heating, however, will have a negative effect on launch vehicle performance. Figure 5-17 shows dispersed free molecular heating profiles for typical ascent trajectories.

Spacecraft thermal environments for the period following payload fairing jettison until spacecraft/Block DM-SL separation comprise the combined effects of free molecular heating, incident solar heating, planet-reflected solar heating (albedo), Earth-radiated heating, radiation to space, and heat transfer with the launch vehicle by radiation or conduction.

The Block DM-SL flight, as indicated in Section 3.2, is designed to accommodate preferred attitude pointing, continuous rolls, maneuvers, and orientations during coast and pre-separation phases that satisfy spacecraft thermal control, battery charging, solar exposure, and other customer-specified attitude or exposure requirements.

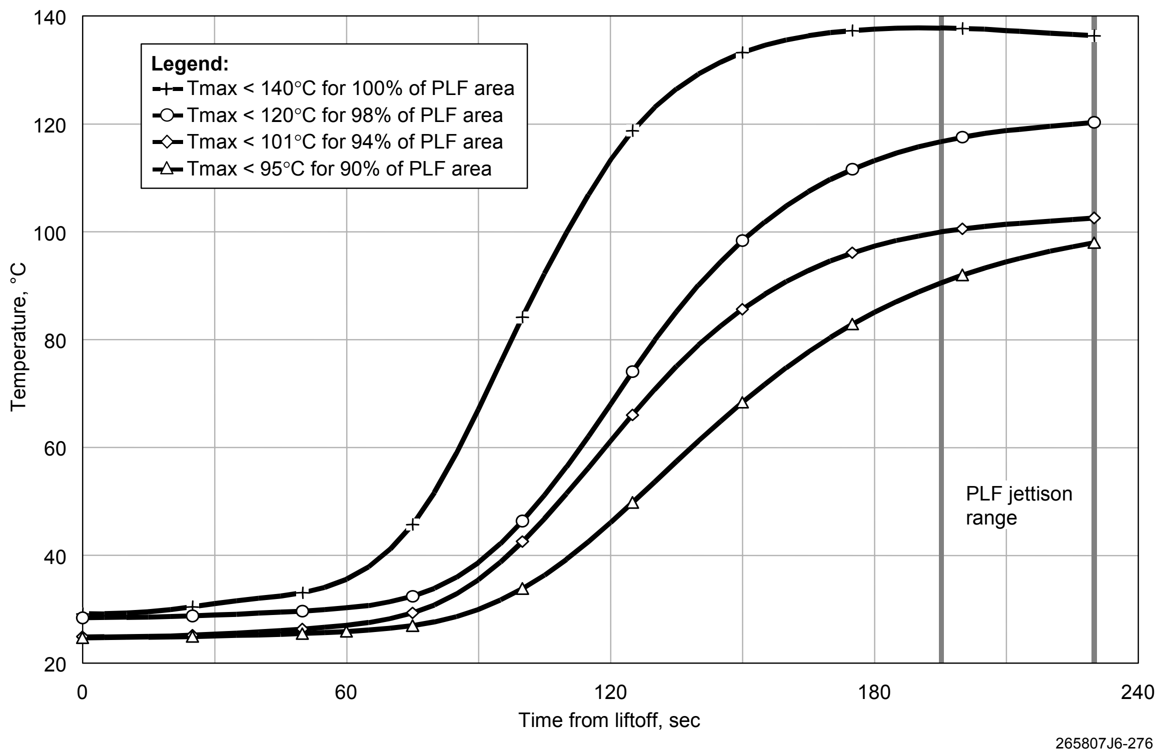

Figure 5-16. Maximum Internal Payload Fairing Surface Temperatures

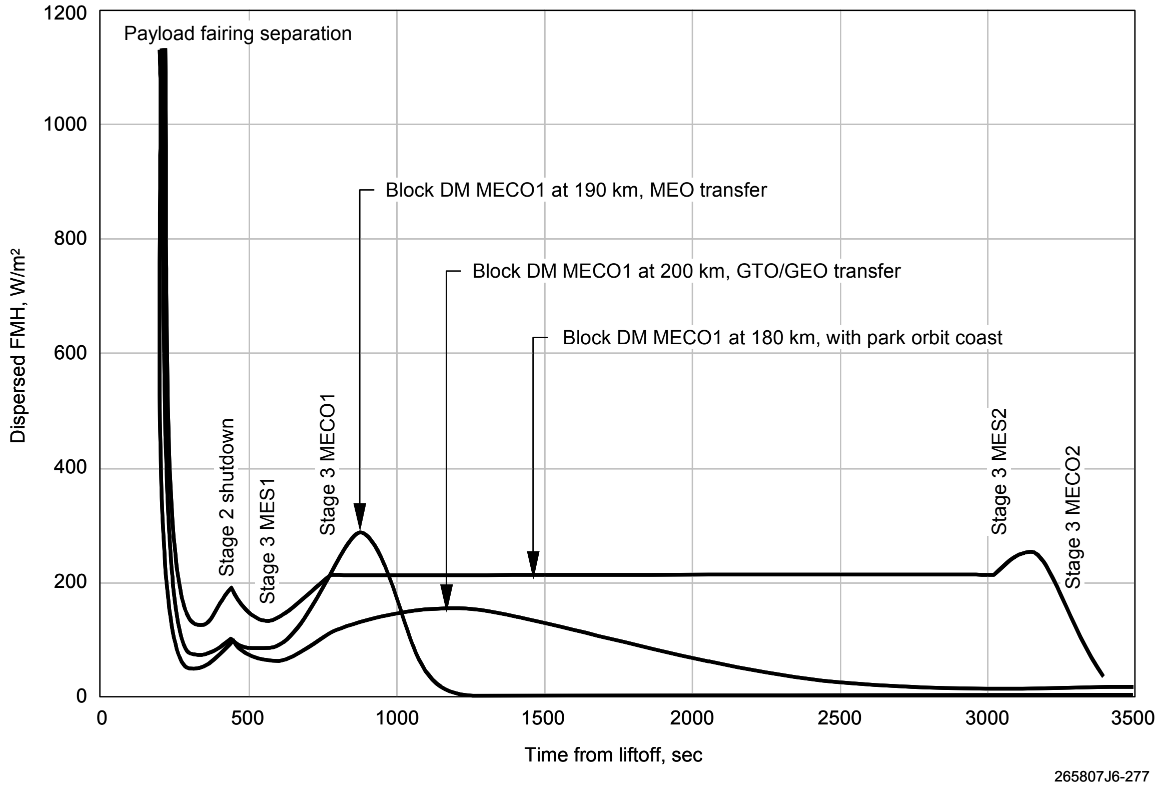

Figure 5-17. Free Molecular Heating Environments

5.8 Payload Unit Ascent Venting

Overview

During ascent, the payload unit is vented through one-way valves in the payload structure and through vents that open approximately 10 sec after liftoff. Figure 5-18 shows the venting scheme. The payload unit cavity pressure is dependent on spacecraft displaced volume and trajectory. Figure 5-19 shows a typical payload fairing cavity pressure band for a generic trajectory. The typical peak ascent depressurization rate (fig. 5-20) is 0.025 Kgf/cm^2-sec (0.36 psi/s). Maximum pressure differential inside the payload fairing at payload fairing jettison will not exceed 345 Pa (0.05 psi).

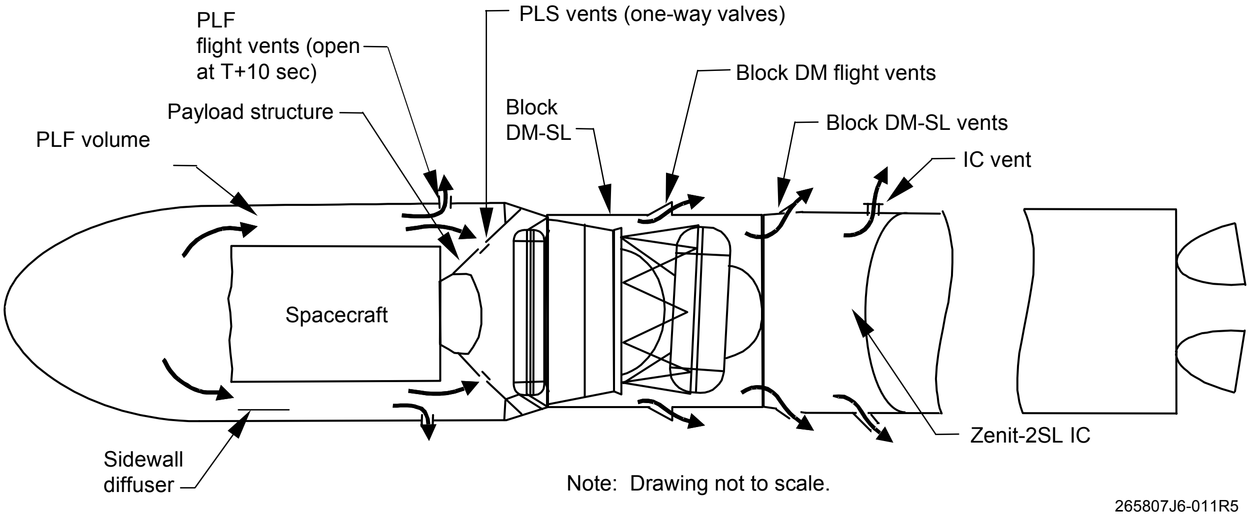

Figure 5-18. Payload Unit Ascent Venting Scheme

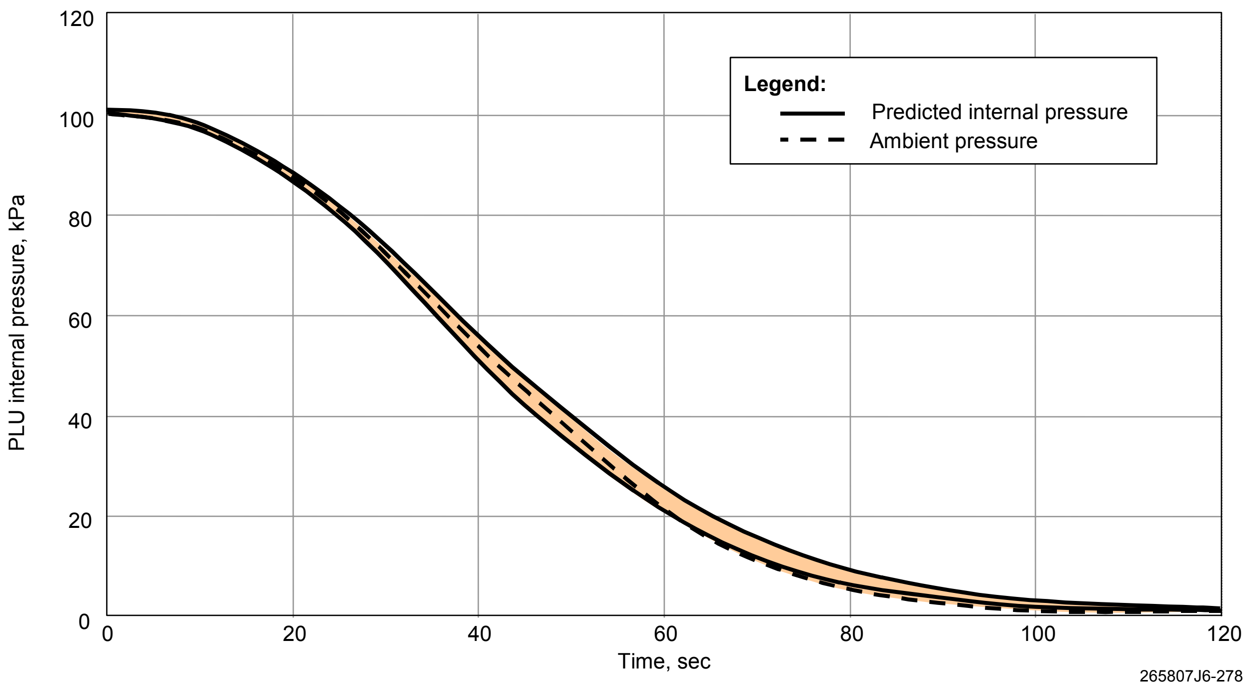

Figure 5-19. Payload Fairing Internal Pressure During Ascent

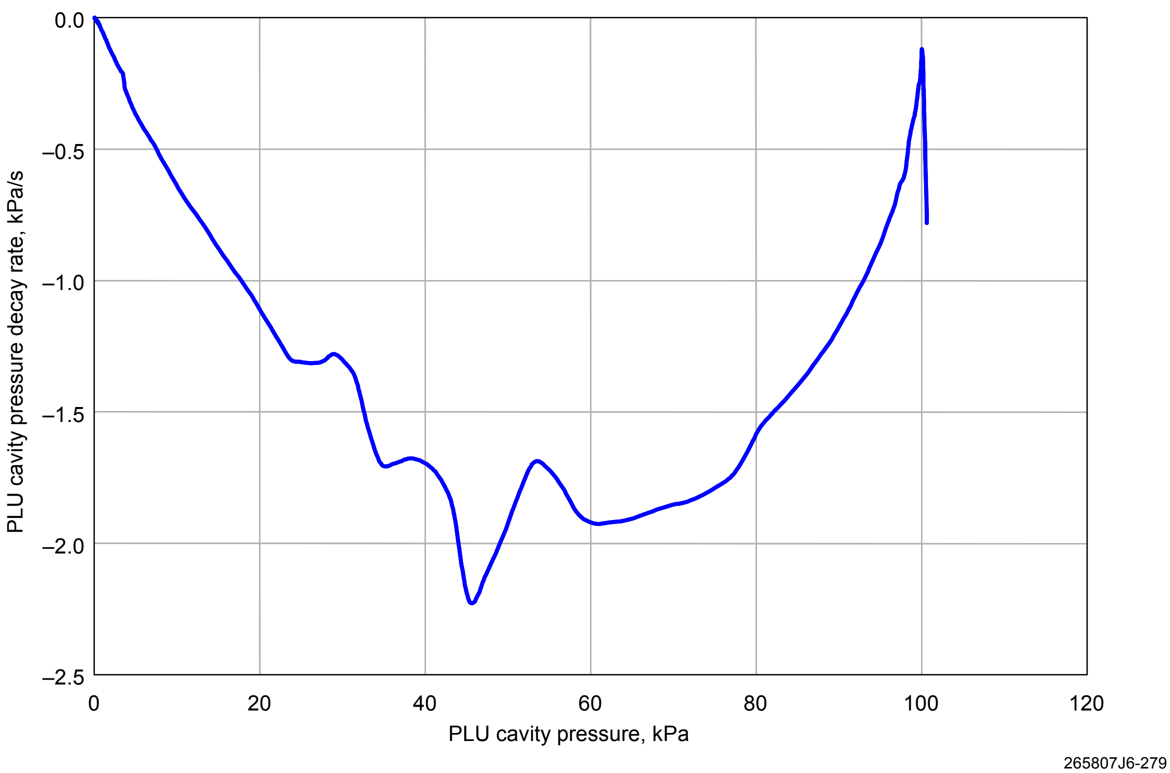

Figure 5-20. Typical Peak Ascent Depressurization

5.9 Contamination

Overview

Contamination of the spacecraft by the launch vehicle is addressed in all phases of the mission. Contamination control includes the following:

- Launch vehicle hardware that comes in contact with the spacecraft environment has been designed, manufactured, and tested to meet strict contamination control guidelines regarding materials outgassing, cleanability, particle generation, corrosion, and wear.
- Integration is performed in controlled (class 100,000) cleanroom environments, including spacecraft stand-alone testing, payload accommodation preparations, and spacecraft encapsulation.
- After encapsulation, the cleanliness of the spacecraft environment is ensured by the maintenance of a continuous clean-air purge to the payload fairing.
- The design of the payload structure isolates the spacecraft from most on-orbit outgassing sources, such as the flight avionics hardware and the Block DM-SL.
- Launch vehicle plume impingement on the spacecraft is minimized by physical barriers and flight design restrictions.

Contamination Control Documents

Contamination control practices at the payload accommodation factory are documented in the *Contamination Control Plan and Specification for Sea Launch Operations at Seattle*, Boeing document D688-10150-1.

Processing of the payload accommodation is conducted in accordance with the environmental controls and operational requirements documented in the *Contamination Control Plan for Sea Launch Home Port Operations Through Launch Operations,* Boeing document D688-10151-1.

The *Generic Payload Contamination Analysis,* Boeing document D688-10131-1, is a comprehensive analysis of contamination deposition on the spacecraft from all ground processing and launch vehicle sources.

Contamination Control During Ground Processing

Ground contamination control begins with manufacture of the payload accommodation and continues through launch. The two halves of the payload fairing undergo final assembly at the factory, and all subsequent processing is performed with the fairing halves mated.

This unique approach dictates that the payload fairing will receive its final cleaning before shipment.

Precision Cleaning Process During Ground Processing

Precision cleaning of the payload fairing inner surface is performed just before installation of the precleaned acoustic blankets. The payload fairing assembly is then double-bagged and placed in a metal container for shipment to Home Port. The interface skirt payload structure is similarly cleaned, double-bagged, and placed in a separate container.

Extensive surface sampling has shown that standard cleaning processes will achieve cleanliness levels well below the generic requirements of 11 mg/m^2 (1.0 mg/ft^2) molecular residue and 0.5% particulate obscuration. Cleanliness verification is performed by close visual inspection. Direct surface sampling is available as a mission option.

Flight Hardware Ground Processing Environment

On arrival at Home Port, the payload accommodation hardware is unbagged in the payload processing facility cleanroom, and a receiving inspection is performed. The payload accommodation is inspected and re-cleaned as required to meet strict visual cleanliness criteria before the spacecraft is encapsulated.

A class 100,000 cleanroom environment is provided for the spacecraft customer during processing in the payload processing facility. Cleanroom garments, materials, and janitorial services are also provided. If necessary, a mission-specific annex to the Home Port control plan is generated to incorporate any unique spacecraft contamination control requirements.

Purge Air Quality During Ground Processing

After encapsulation, the payload fairing air purge defines the spacecraft environment. The purge air is high efficiency particulate air–filtered and delivered at a nominal cleanliness of class 1,000 (in accordance with FED-STD-209E). Purge air is provided continuously from the time the payload unit leaves the payload processing facility through liftoff. In the case of a launch abort, the purge will be maintained during recycle events and subsequent launch attempts.

The purge air quality is monitored with an airborne particle counter near the payload fairing inlet. Monitoring is discontinued only when the integrated launch vehicle is hoisted from the assembly and command ship to the launch platform, and just before the integrated launch vehicle is erected on the launch pad. Purge air quality has averaged well under class 100 for all missions to date.

Helium Exposure

Helium concentration in the spacecraft environment is of concern to some customers. The primary source of helium in the Sea Launch system is venting and leakage during Block DM-SL insulation blanket purging before liquid oxygen tanking. The spacecraft is protected from helium exposure by a positive pressure gradient between the payload fairing and the Block DM-SL cavity, which provides a constant flow of air through the payload structure one-way vent valves.

Spacecraft Access at Sea

If access to the spacecraft is required on the launch platform, a temporary air lock can be installed around the payload fairing access door to provide a clean zone for working and to shield the payload fairing opening from debris. Purge air from the payload fairing will provide a clean air environment within the air lock.

Contamination During Flight

The potential for spacecraft contamination during liftoff, ascent, and transfer orbit is minimized by proper hardware design and flight design. Flight hardware design considerations include surface cleanability, selection of low-outgassing materials, venting design, and containment of separation system pyrotechnics. Flight design considerations include minimization of thruster plume impingement and limiting exposure to materials outgassing during separation maneuvers.

Payload Unit Materials Outgassing

The payload unit is constructed from low-outgassing materials and screened using the ASTM E595 outgassing test method. Small amounts of critical materials may not meet the screening requirement but are accepted based on other factors, such as moderate flight temperature, small surface area, or short-duration use. A full list of payload accommodation nonmetallic materials is provided in the *Generic Payload Contamination Analysis*.

Spacecraft Isolation

The spacecraft is isolated from the Block DM-SL by a closeout membrane and one-way vent valves in the payload structure. These vent valves allow payload fairing purge air to flow aft through the payload structure but are spring-loaded to close during flight. This prevents any particulate or molecular contamination from the Block DM-SL cavity from entering the spacecraft volume.

The wide diameter of the interface skirt also prevents any line-of-sight view to the spacecraft from external Block DM-SL surfaces during flight.

Separation System

Pyrotechnic products of the payload fairing separation system and the spacecraft separation system are contained to prevent contamination of the spacecraft.

The payload fairing separation system design incorporates a pressure-containment tube, which expands to break a structural aluminum flange and separate the two halves of the payload fairing. Aluminum particles generated by breaking the flange have been characterized by extensive testing and represent a minimal contamination risk.

Spacecraft adapter separation systems consist of standard clampband or separation nut designs, which feature O-ring seal containment of pyrotechnic products and debris catchers around frangible bolts.

Plume Impingement

The only Zenit-3SL rocket plumes with the potential for direct impingement on spacecraft surfaces are the Stage 2 separation rockets (see the retrorocket plumes section on the following page) and the Block DM-SL bi-propellant attitude control thrusters (see the contamination and collision avoidance maneuver section on the following page).

Retrorocket Plumes

Zenit-3SL second-stage separation is accomplished by activating four solid propellant retrorockets located at the aft end of the stage. The retrorockets are canted 15 deg outboard. The wide diameter of the interface skirt blocks any direct view from the retrorocket exit plane to the spacecraft and prevents any impingement of high-velocity particles on the spacecraft. A small mass fraction of solid lead (Pb) particles is contained in the solid fuel as a burn stabilizer.

Extensive plume modeling predicts a maximum deposition of 10 angstroms of Pb on any spacecraft surface. Thin film surface effects tests show that this amount of Pb will have minimal effects on spacecraft optical, electrical, and radio frequency properties. This data is provided in the *Generic Contamination Analysis Report*.

Contamination and Collision Avoidance Maneuver

After spacecraft separation, the Block DM-SL performs a contamination and collision avoidance maneuver to avoid contact with the spacecraft and to minimize contamination from outgassing and attitude control thruster plume impingement. Several limiting parameters are specified for the contamination and collision avoidance maneuver flight design, including maximum Block DM-SL tipoff angle, and minimum separation distance from the spacecraft before major contamination and collision avoidance maneuver events.

Major events include long orbit-separation burns and fuel-depletion burns of the attitude control system, and kerosene fuel tank venting. A total plume impingement limit of 1.E-05 g/cm^2 is verified by analysis for each mission-unique separation maneuver.

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6.0 SPACECRAFT DESIGN CONSIDERATIONS

Overview

This Section contains spacecraft design guides to assist the prospective customer with an initial evaluation of spacecraft compatibility with Sea Launch. This includes:

- Mass and center-of-gravity limits
- Modal frequencies
- Electromagnetic compatibility
- Spacecraft design verification requirements
- Horizontal handling
- Pressurized systems
- Ordnance systems
- Multiple manifests and secondary payloads

Contact Sea Launch for Unique Requirements

Contact Sea Launch if a spacecraft exceeds the design guides described in the following sections or requires a unique qualification approach. Sea Launch works with each customer to achieve launch vehicle compatibility.

Figure 6-1 shows the coordinate system used by Sea Launch for the Zenit-3SL and its components.

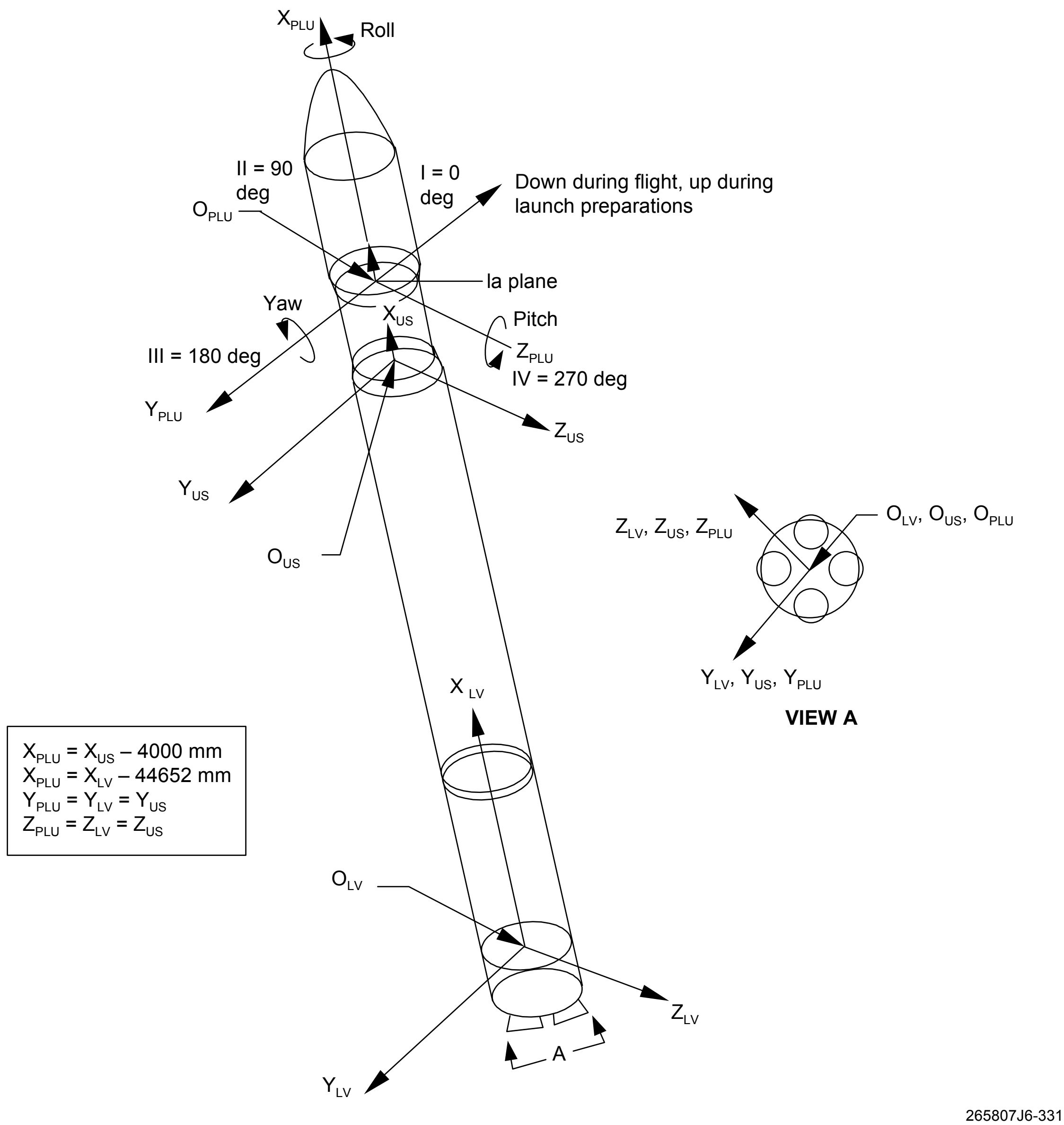

Figure 6-1. Zenit-3SL Coordinate System

6.1 Mass and Center-of-Gravity Limits

Definitive Compatibility Requiring Multiple Verification Activities

Several verification activities must be executed to demonstrate Zenit-3SL compatibility with a specific spacecraft having a given mass and center of gravity. These include:

- Coupled loads analysis
- Strength and controllability analyses
- Critical clearance analyses to assess volumetric constraints
- Performance calculations for the specific mission
- Peaking load calculations for spacecraft having a nonuniform interface stiffness

More information on spacecraft mass is presented in Section 3.3.

Zenit-3SL Structural Capability

The Zenit-3SL launch vehicle can structurally accommodate spacecraft with a wide range of mass and center of gravity for each spacecraft adapter offered by Sea Launch.

Table 6-1 provides the expected spacecraft mass and center-of-gravity limits for the Zenit-3SL when the lateral load factor on the spacecraft is 2.0 g or less (see Sec. 5-2 for a discussion of design quasi-static load factors on spacecraft primary structure). Conservative analyses are used to construct the mass and center-of-gravity limits (table 6-1). Spacecraft with a higher center of gravity for a given mass may be acceptable on further analysis.

Definitive compatibility of a spacecraft with the Zenit-3SL requires all verification activities outlined above. Please contact Sea Launch for a mission-specific Zenit-3SL compatibility assessment when the spacecraft mass exceeds 6100 kg.

Table 6-1. Expected Spacecraft Mass and Center-of-Gravity Limits

SC mass, kg	Spacecraft CG, m		
	SCA1666 with 0% peaking	**SCA702+ (and upgraded SCA1666)**	**SCA1194VS**
≤4600	> 2.5	> 2.5	> 2.5
4700	2.49	2.49	
4800	2.43	2.43	
4900	2.38	2.38	2.49
5000	2.34	2.34	2.44
5100	2.29	2.29	2.39
5200	2.25	2.25	2.35
5300	2.20	2.20	2.30
5400	2.16	2.16	2.26
5500	2.12	2.12	2.22
5600	2.09	2.09	2.18
5700	2.05	2.05	2.14
5800	2.01	2.01	2.10
5900	1.98	1.98	2.07
6000	1.95	1.95	2.03
6100	1.91	1.91	2.00
6200	1.88	1.88	1.97
6300	1.85	1.85	1.94
6400	1.83	1.83	1.91
6500	1.80	1.80	1.88
6600	NA	1.77	1.85
6700	NA	1.74	1.82
6800	NA	1.72	1.79
6900	NA	1.69	1.77
7000	NA	1.67	1.74
7100	NA	1.65	1.72
7200	NA	1.62	1.69
7300	NA	1.60	1.67

Spacecraft Mass and Center-of-Gravity Limits

Figures 6-2 through 6-4 represent the results in table 6-1 for each of the spacecraft adapters offered. These figures show the expected spacecraft mass and center-of-gravity limits for each of the adapters. The center-of-gravity limits for the current SCA1666 clampband adapter depend on the amount of load peaking at the spacecraft interface. Curves are provided for 0% and 30% peaking for this adapter. If the SCA1666 spacecraft adapter is upgraded to realize the full structural capability of the Zenit-3SL, then higher spacecraft mass is permitted, and the penalty imposed on mass and center-of-gravity limits due to load peaking is eliminated.

Definitive compatibility for any given spacecraft requires that all mission integration activities be performed.

Spacecraft with mass and center-of-gravity values outside the designated acceptable region may also be acceptable on further analysis.

The longitudinal center-of-gravity location of the spacecraft in figures 6-2 through 6-4 refers to the spacecraft separation plane. The separation plane for the SCA1666 and SCA702+ spacecraft adapters is at payload unit x-axis station X_{PLU} = 2.10 m (82.7 in). Similarly, the SCA1194VS spacecraft adapter separation plane is at X_{PLU} = 1.97 m (77.6 in).

The maximum radial center-of-gravity offset (nominal plus uncertainty) from the spacecraft longitudinal centerline axis should be less than 5.0 cm (2.0 in). Radial offsets exceeding this require further analysis (e.g., radial offsets of 6.0 cm (2.4 in) have been shown to be acceptable on a case-by-case basis).

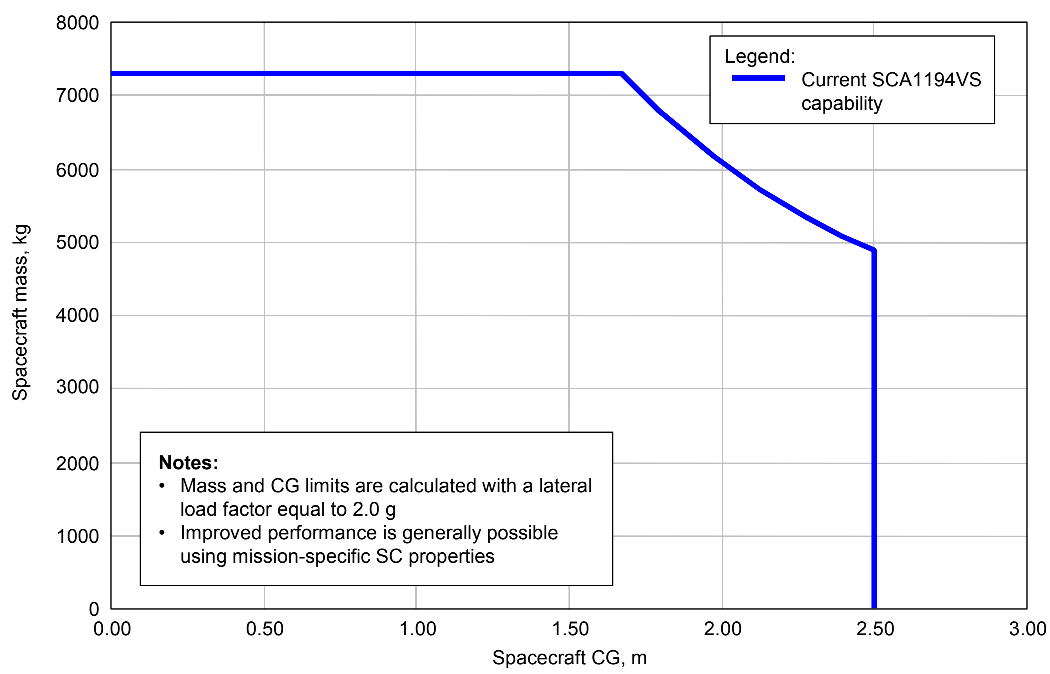

Figure 6-2. Expected Spacecraft Mass and Center-of-Gravity Limits With SCA1194VS

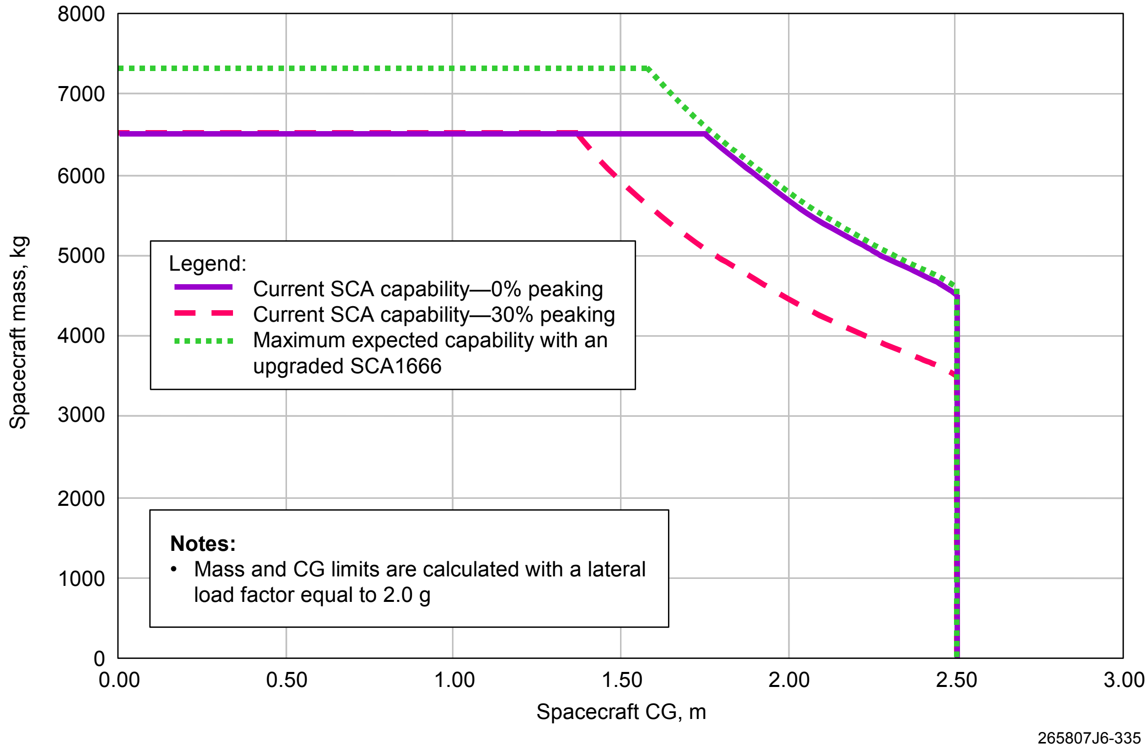

Figure 6-3. Expected Spacecraft Mass and Center-of-Gravity Limits With SCA1666 Spacecraft Adapter

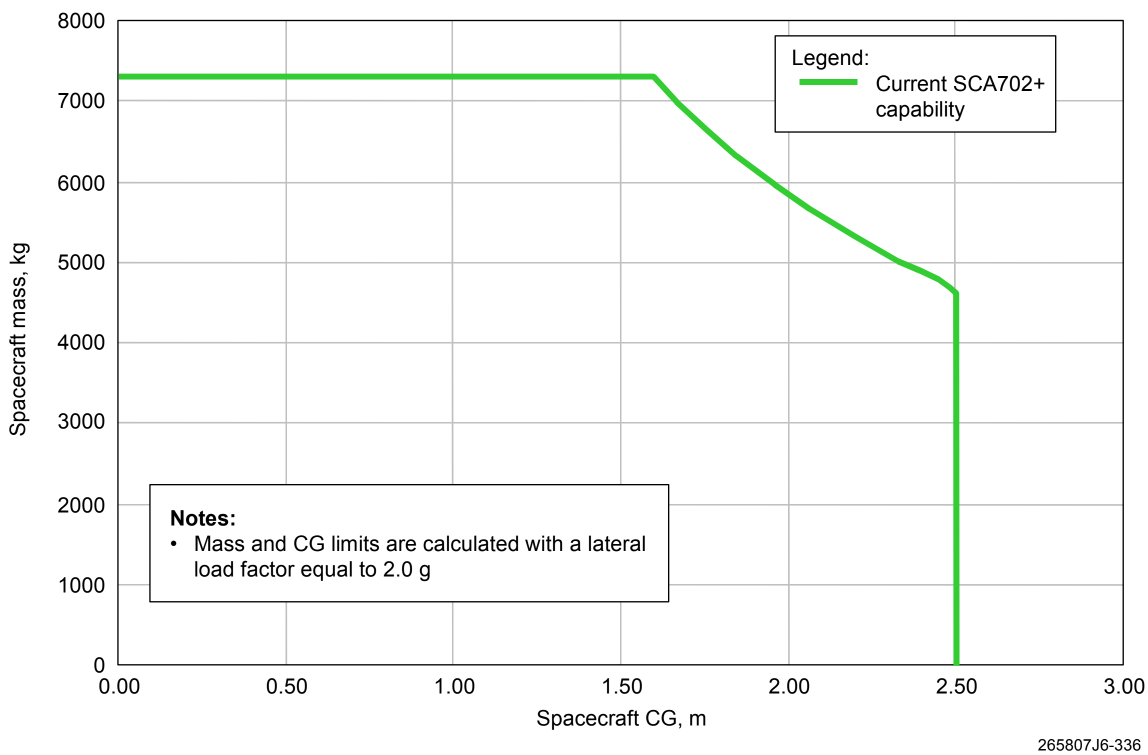

Figure 6-4. Expected Spacecraft Mass and Center-of-Gravity Limits With SCA702+ Spacecraft Adapter

6.2 Modal Frequencies

Frequency Limits

Sea Launch can accommodate spacecraft with longitudinal and lateral fundamental frequencies below those commonly offered in the industry. As a guide, the spacecraft longitudinal fundamental frequency should be ≥20 Hz, and its lateral fundamental frequency should be ≥8 Hz.

6.3 Electromagnetic Compatibility

Radio Frequency Impingement on Launch Vehicle

To avoid electromagnetic interference with launch vehicle systems, spacecraft electrical field radiation impingement on the launch vehicle must not exceed the levels shown in figure 6-5. Spacecraft radio frequency system characteristics will be necessary for integrated analysis and for the required Federal Communications Commission special temporary authority license, which is necessary for Home Port radio frequency testing.

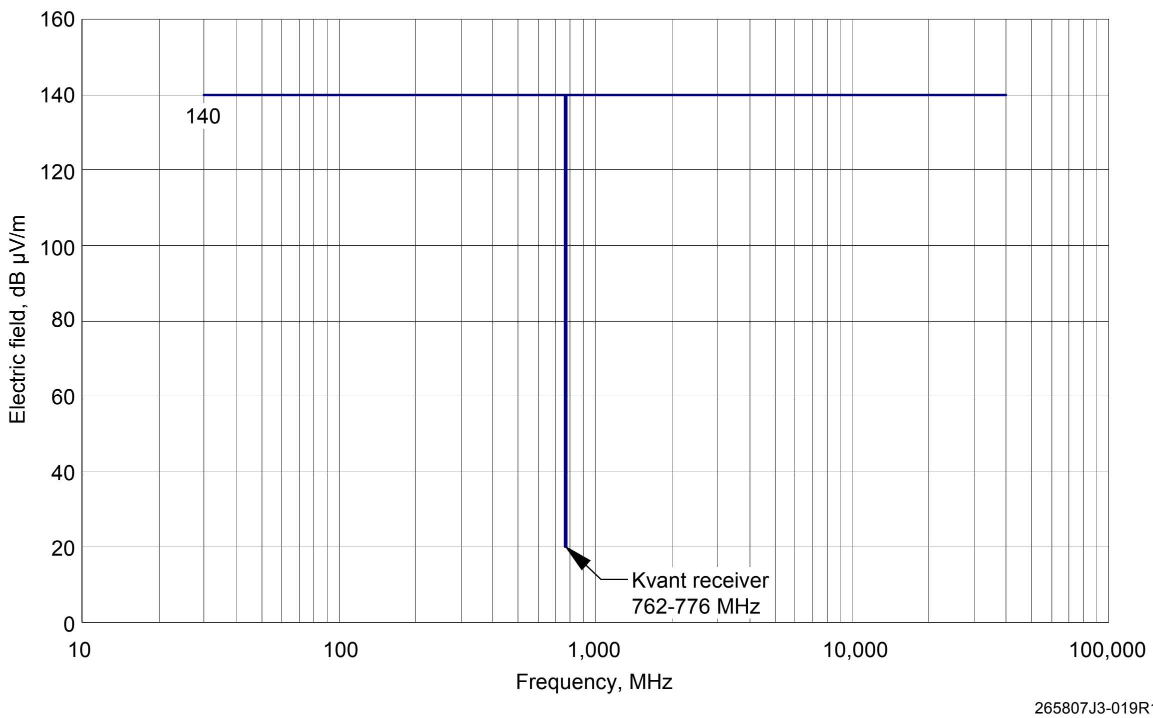

Figure 6-5. Maximum Spacecraft Intentional Electrical Field Radiation Impingement on the Launch Vehicle

Lightning Protection

Sea Launch will use various sensors, satellite imagery, radar, and weather prediction systems (fig. 6-6) (e.g., weather and lightning occurrence predictions) to ensure a lightning-free launch environment. Sea Launch can provide customers with notification of lightning occurrences (e.g., lightning already having occurred within a certain distance) should they wish to decable their spacecraft during spacecraft processing, transit, or checkout.

Lightning/weather service	Spacecraft in PPF	PLU transfer	Spacecraft on ACS	ILV transfer	Spacecraft on LP in HP	Dry rollout and erect	S/C transit to launch site	Launch site	
1 Global atmospheric service	■	■	■	■	■	■			Off-site, real-time warning
2 Boltek lightning monitor (ACS)	■	■	■	■	■	■			On-site, real-time warning
3 ACS-02, PLU transfer to ACS		■							Procedure identifying weather/lightning constraints
4 PLU/ILV transfer RR		■							MD readiness review includes RC-03 WX briefing
5 MP-01, task 15, PLU transfer to ACS		■							MD checklist prior to transfer
6 XFR-01, ILV transfer				■					Procedure identifying weather/lightning constraints
7 MP-01, task 18, ILV transfer to LP				■					MD checklist prior to transfer
8 LP-06, PLU launch countdown						■			Procedure identifying weather/lightning constraints
9 MP-01, task 19, ILV dry rollout and erect						■			MD checklist prior to rollout
10 RC-03 WX briefing		■		■		■	■	■	Procedure performing the weather briefing
11 Boltek lightning monitor (LP)							■	■	On LP, real-time warning
12 Launch Readiness Review								■	MD readiness review includes RC-03 WX briefing
13 Launch Commit Criteria								■	Jointly agreed-to weather/lightning commit criteria

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Figure 6-6. Lightning and Weather Services Used to Determine or Forecast Lightning During Launch Campaign

Radio Frequency Hazards

There are very few areas within the Sea Launch segments that present electromagnetic radiation hazards to personnel, ordnance, or fuels. A few high-power radio frequency transmitters can produce radio frequency hazard levels in areas within the antenna’s main beams. These radio frequency hazard locations have been identified along with the radio frequency hazard conditions. Safety personnel have identified the radio frequency hazard areas as controlled-access areas. Safety training is discussed in Section 11.

Electromagnetic Interference/ Electromagnetic Compatibility Test Report

The spacecraft contractor will be requested to provide Sea Launch with component and subsystem- and equipment-level electromagnetic interference and electromagnetic compatibility qualification test plans and test reports. This data will be used to ensure compatibility with the Sea Launch system.

6.4 Spacecraft Design Verification Requirements

Flexibility to Meet Customer Needs

Design verification requirements for the spacecraft have been engineered and selected by Sea Launch to ensure mission success. These requirements are not rigid and can be modified with Sea Launch approval to meet the verification needs of a spacecraft. In addition, detailed safety design constraints on the spacecraft are contained in the *Sea Launch Safety Manual*.

Customizable Strength Requirements

Strength requirements acceptable to Sea Launch are given in the following section but can be modified to meet customer needs with Sea Launch approval.

Factors of Safety

Minimum yield and ultimate factors of safety for the spacecraft depend on the testing option chosen and the design heritage of the hardware. The minimum factors of safety and test levels for several test options are shown in table 6-2. Note that the minimum ultimate factor of safety shown is 1.3. However, for qualification or proof tests, an ultimate factor of safety equal to 1.25 on limit loads is acceptable for structural components having a flight heritage or when a model uncertainty factor no less than 1.05 is used to determine limit load.

Table 6-2. Factors of Safety and Test Options

	Factors of safety			
Test option	**Yield**	**Ultimate**	**Test level**	**Test success criteria**
Qualification test (test of dedicated article to ultimate loads)	1.0	1. 3	• 1.0 • 1.25	• No detrimental deformation at 1.0 • No failure at 1.25
Proto-qualification test (test of article used subsequently for flight or system test)	1.25	1.4	1.25	No detrimental deformation or misalignment
Qualification by analysis (test of article not required)	1.6	2.0	N/A	N/A
Proof test (performed on each flight vehicle)	1.1	1.3	1.1	No detrimental deformation

Test-Verified Model Required for Final Coupled Loads Analysis

The spacecraft must have positive margins of safety for yield and ultimate loads. These loads are generated from limit loads using factors of safety no less than those displayed in table 6-2. Limit loads for the transient flight events are calculated by Sea Launch in a coupled loads analysis and provided to the spacecraft customer. Limit loads for the quasi-static events are calculated using the Sea Launch quasi-static load factors for ground handling, transportation, and flight. The coupled loads analysis limit loads used for verification must be generated using a test-verified model for the spacecraft. Model verification of the spacecraft can be performed either by modal survey or sine test.

Fatigue Factor of Safety

Compliance to the Sea Launch fatigue environment is demonstrated by showing positive margin to the fatigue spectrum (Sec. 5, table 5-1) after increasing the number of cycles at each load level by a factor of four.

Customizable Test Requirements

Sea Launch requires that the spacecraft structural capability be demonstrated. The Sea Launch qualification requirements on the spacecraft are standard industry practice, but can be modified to meet specific spacecraft needs. Structural testing on the spacecraft generally depends on the design heritage. Unique qualification tests can be developed by the spacecraft customer to account for design heritage. Sea Launch will work with the spacecraft customer by evaluating customer - proposed testing to support the spacecraft integration process.

The following tests are accepted by Sea Launch for demonstrating structural compliance. If the qualification approach that best suits your spacecraft is not discussed here, Sea Launch will evaluate your proposed alternative to ensure spacecraft compatibility.

Model Survey Test

A coupled loads analysis will be performed with a test-verified spacecraft model before flight to verify that the maximum expected limit loads for the spacecraft and the testing performed on the spacecraft structure are in compliance with table 6-2. Model verification of the spacecraft can be performed either by modal survey or sine test. Repeat-mission spacecraft do not require further testing.

Static Loads Test

A spacecraft static loads and/or sine vibration test must be performed for spacecraft structure. The extent of the testing depends on the heritage of the spacecraft structure, but ultimately, spacecraft compliance to table 6-2 must be demonstrated.

Sine Vibration Testing

The sine vibration test levels for qualification, proto-qualification, proof, and acceptance are presented in table 6-3. Qualification testing is for a dedicated test article, and proto-qualification testing is for the first-flight article. Proof testing is for spacecraft that have not been qualification or proto-qualification tested for first flight and must be proof tested for every flight. Once a spacecraft has been qualification or proto-qualification tested, acceptance sine testing on all future repeat spacecraft need not be performed. Acceptance testing is generally performed to demonstrate workmanship and is an option available to the spacecraft customer for minor spacecraft design changes for spacecraft that have not flown previously on Sea Launch. The extent of the testing depends on the heritage of the spacecraft structure and degree of static testing, but ultimately, spacecraft compliance with table 6-2 must be demonstrated.

Notching may be used to prevent excessive loading of the spacecraft structure. However, the resulting sine vibration environment with notching should not be less than a test factor level times the equivalent sine vibration level determined from coupled loads analyses and provided by Sea Launch. The test factor levels depend on the test options chosen and are provided in table 6-2.

Table 6-3. Sine Vibration Test Levels and Duration

Test parameters		Qualification test levels	Proto-qualification levels	Proof test levels	Acceptance levels
SC axis tested	Frequency range				
Longitudinal	5 to 100 Hz	0.75 g	0.75 g	0.66 g	0.6 g
Lateral	5 to 100 Hz	0.75 g	0.75 g	0.66 g	0.6 g
Sweep rate		2 octaves/ min	4 octaves/min		

Acoustic Testing

Qualification of a spacecraft type is required. In place of a qualification test, a proto-qualification test may be run on the first unit. Acoustic testing to proto-qualification or acceptance levels and durations is required for every mission. The acoustic margins and duration for qualification, proto-qualification, and acceptance tests are found in table 6-4.

Table 6-4. Spacecraft Acoustic Margins and Test Duration

Test	Margin	Duration, min
Qualification	+3 dB over acceptance	2
Proto-qualification	+3 dB over acceptance	1
Acceptance	Maximum expected acoustic level	1

Shock Qualification

The spacecraft should be compatible with the shock environment in Section 5.5 with a 3-dB margin. The shock environment in Section 5.5 represents the maximum expected environment with no added margin. Analysis, similarity, and/or test can demonstrate qualification.

Adapter Matchmate and Fit-Check Test

For the first mission of a spacecraft type, a matchmate test is required. The test will be performed between the spacecraft and the adapter flight hardware at the spacecraft manufacturing facility. This test will include firing the spacecraft separation ordnance to define the shock transfer function. Repeat missions will incorporate an adapter fit check at the start of the processing flow at the Sea Launch payload processing facility. These tests include both electrical and mechanical mates (fig. 6-7).

Figure 6-7. Electrical and Mechanical Mates

6.5 Horizontal Handling

Processing While Encapsulated

Spacecraft systems and procedures must be compatible with operations that place the encapsulated spacecraft in a horizontal, cantilevered attitude for transportation and handling. Access to the spacecraft during this period of operations are through the payload fairing access doors. Door location is described in Section 7.

6.6 Pressurized Systems

Design and Safety Requirements

Design and verification of spacecraft flight hardware pressurized vessels, structures, and components must be in accordance with recognized aerospace industry design guidelines. These pressurized systems should also be based on the Sea Launch system payload environment. The design must protect the launch system and personnel before launch and protect the launch system during flight from damage due to pressure system failure. Such criteria as operating pressures, stress levels, fracture control, burst factor, leak-before-burst factor, material selection, quality assurance, proof-pressure testing, and effects of processing and handling in the horizontal orientation should be considered. Design details will be required as a portion of documentation to support regulatory agency requirements on the launch mission.

6.7 Ordnance Systems

Recognized Standards and Regulations

Ordnance systems on board spacecraft for operation of propulsion, separation, and mechanical systems must be designed in accordance with recognized standards and regulations. These systems must preclude inadvertent firing when subjected to Sea Launch–specified shock, vibration, thermal, or electromagnetic environments. Ordnance devices must be classified in accordance with applicable federal and state codes and meet U.S. Government regulations for transportation and handling. Design for initiation of ordnance in the system must incorporate more than one action; no single failure may result in ordnance device activation. Use of a safe-and-arm-device is recommended; however, other techniques may be considered with adequate justification. System design and ordnance classification documentation will be required to support regulatory agency requirements on the launch mission.

6.8 Multiple Manifests and Secondary Payloads

Overview

Sea Launch is currently assessing our ability to offer launch services for multiple manifests and secondary payloads. These types of payloads will be evaluated on a case-by-case basis.

7.0 INTERFACES

7.1 Mechanical Interfaces

Overview

Characteristics of the mechanical interfaces covered in this section include:

- Payload fairing
- Access doors
- Spacecraft adapters

Payload Fairing

Configuration for the payload fairing is shown in Section 2. The Sea Launch payload fairing accommodates the spacecraft static envelope, as shown in figure 7-1. Excursions to the defined spacecraft envelope may be accommodated on a case-by-case basis. Figures 7-2, 7-3, and 7-4 define the spacecraft envelope available below the separation plane for the 1194VS, 1666, and 702+ spacecraft adapters respectively.

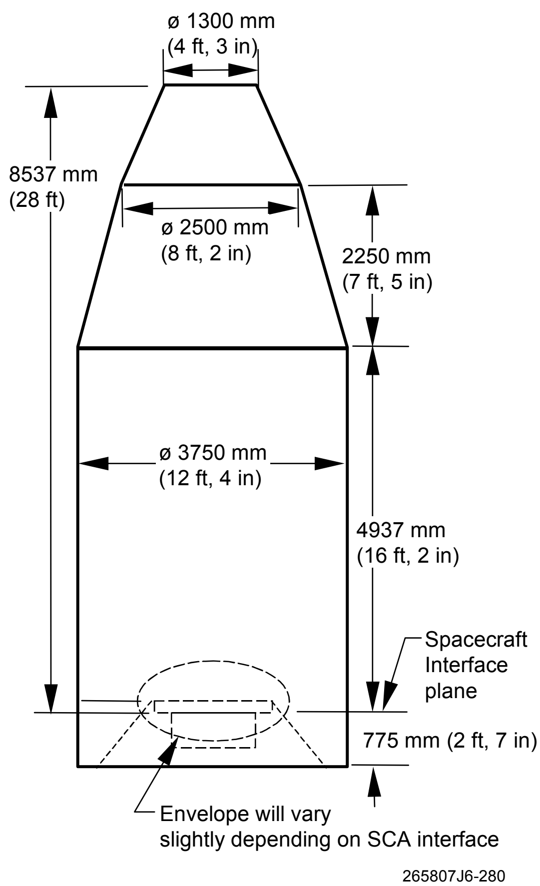

Figure 7-1. Spacecraft Static Envelope

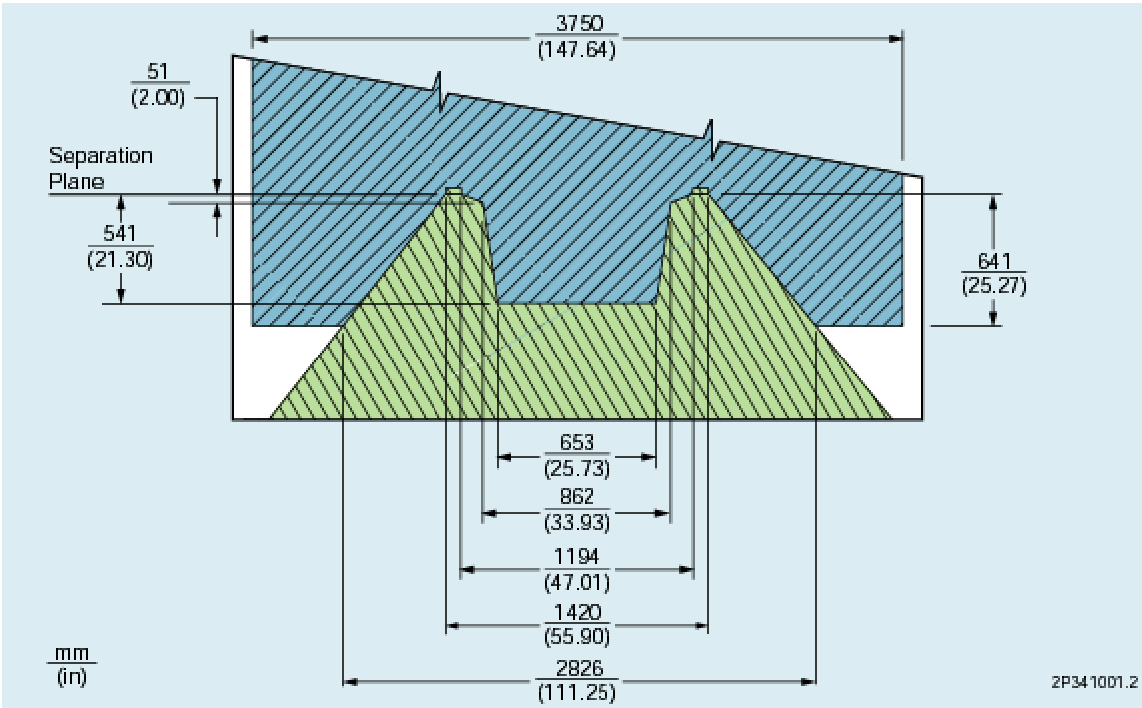

Figure 7-2. Spacecraft Static Envelope SCA1194VS Adapter

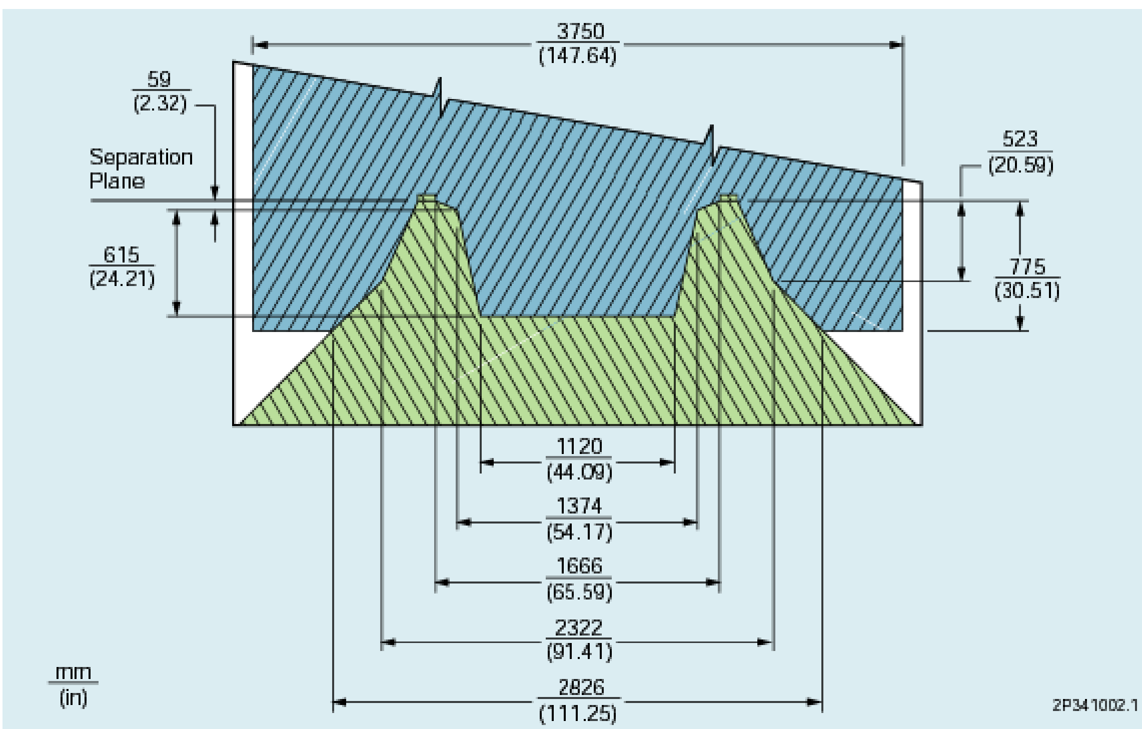

Figure 7-3. Spacecraft Static Envelope SCA1666 Adapter

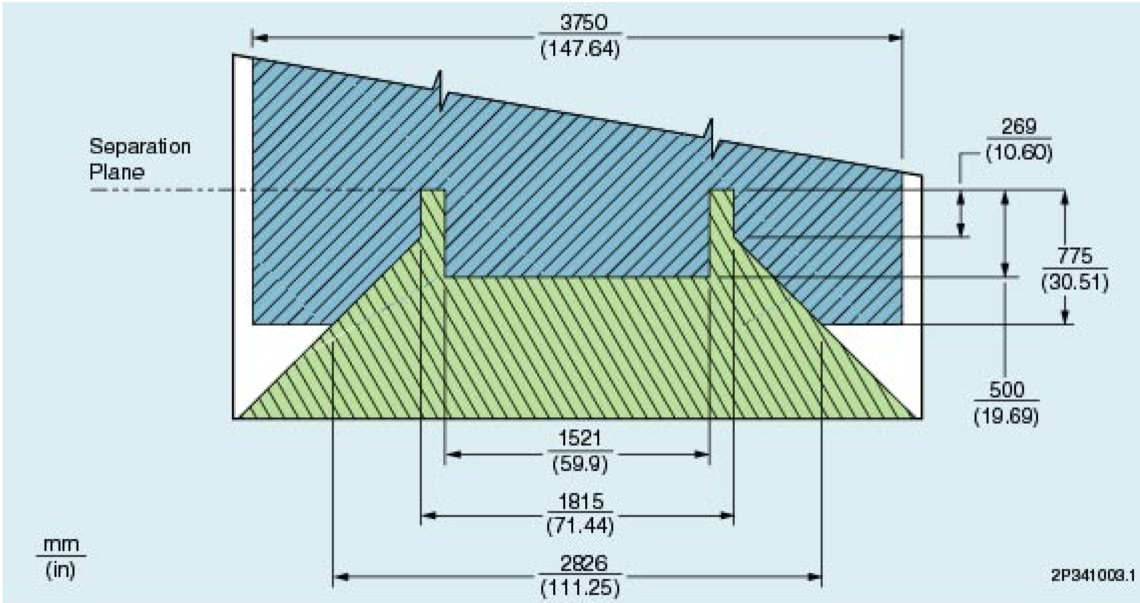

Figure 7-4. Spacecraft Static Envelope SCA702+ Adapter

Access Doors

The standard Sea Launch payload fairing provides up to two access doors, one door per fairing half, with a diameter of 610 mm (24 in). Figure 7-5 shows the zones on the fairing surface where doors may be located, as follows:

- Access doors centered between station 2260.6 mm (89 in) and station 2565.4 mm (101 in) must be defined by L-7.
- Access doors centered at higher stations must be defined by L-12.

As an option, the payload fairing can accommodate additional access door quantities beyond the standard quantity.

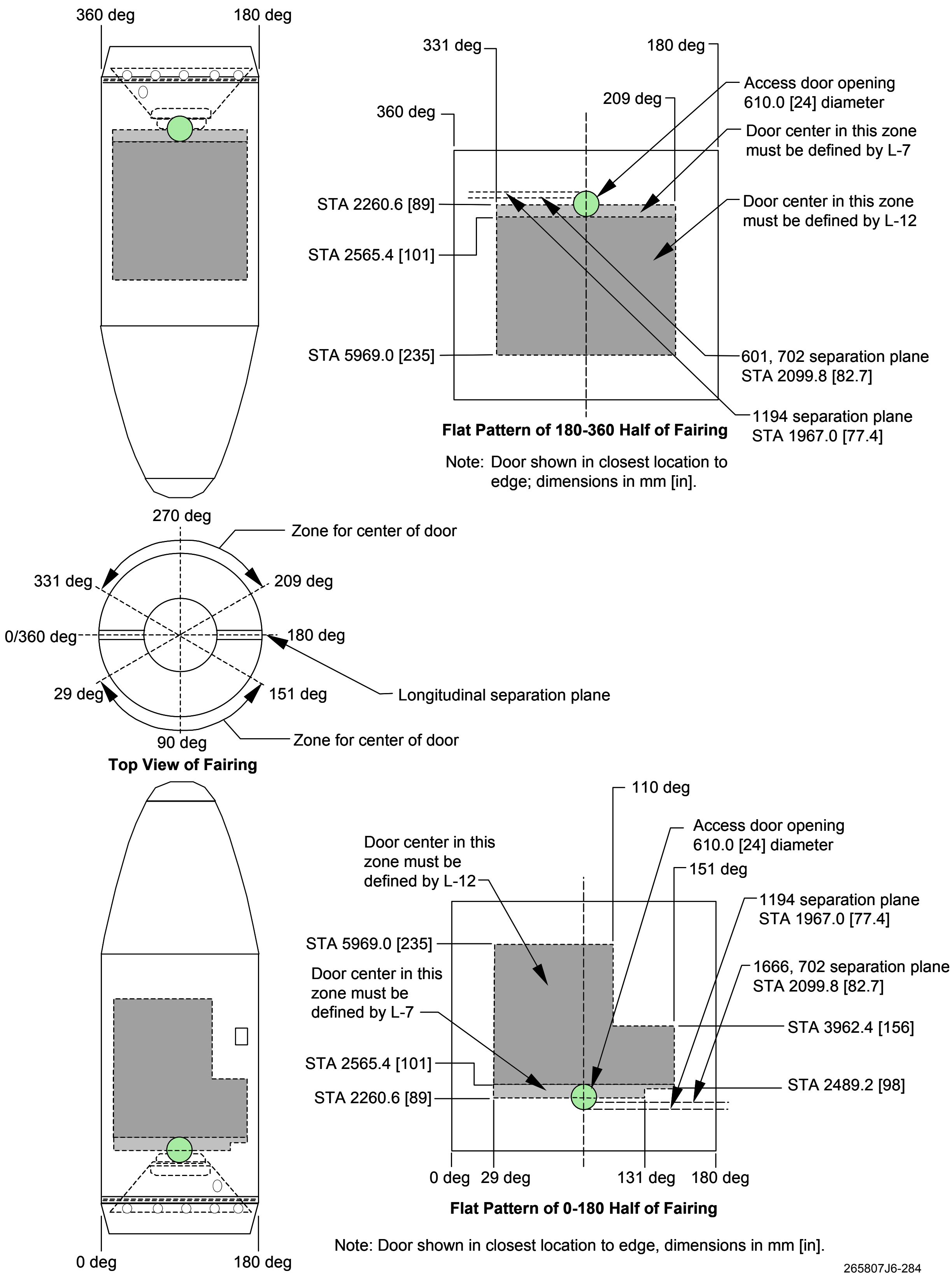

Figure 7-5. Payload Fairing Locations for Access Doors

Spacecraft Adapter and Payload Structure

The 45-deg conic design of the Sea Launch payload structure maximizes the height available to the spacecraft and accommodates the full range of existing and planned spacecraft adapters. The following sections define the standard spacecraft adapters currently offered.

SCA1666

The SCA1666 has a diameter of 1666 mm (65.59 in) at the spacecraft interface and uses a Marmon clamp separation system. This adapter accommodates the Boeing 601-type spacecraft. Six pushoff springs are used during separation to impart an initial delta velocity with respect to the launch vehicle. The spacecraft adapter also has the capability to impart spacecraft spin about an axis transverse to the launch vehicle longitudinal axis. In principle, this is achieved by limiting the stroke of adjacent springs with respect to the stroke of the opposing springs. In addition to the pushoff springs, there are two electrical disconnects and a clampband impulse that participate in the spacecraft separation dynamics. The major elements of this clampband-type adapter are shown in figure 7-6. The SCA1666 is designed to accommodate a 6500-kg (14,33 lb) spacecraft with a center of gravity at 1.8 m (70.9 in) with 0% peaking.

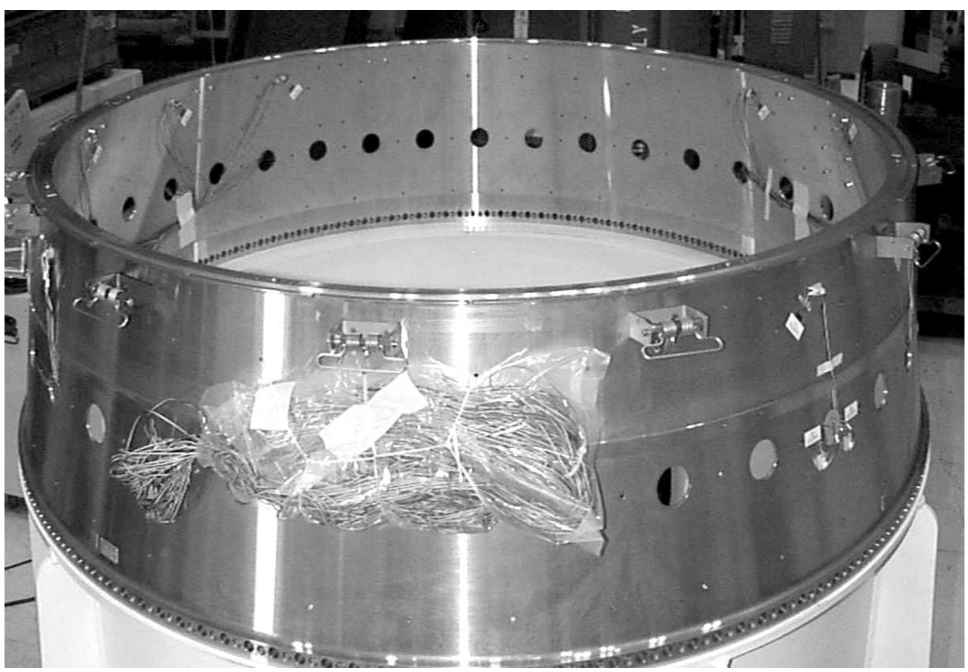

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Figure 7-6. SCA1666 Spacecraft Adapter

SCA702+ and SCA702+GEM

The SCA702+ has a diameter of 1664 mm (65.51 in) at the spacecraft interface and is attached to the spacecraft using four bolts. This adapter accommodates the Boeing 702-type spacecraft. The SCA702+ is designed to accommodate a 7300-kg (16,094 lb) spacecraft with a center of gravity at 1.67 m (5.47 ft) and includes the effects of spacecraft flexibility at the interface. The separation system uses four pushoff springs to impart both an initial delta velocity with respect to the launch vehicle and a spacecraft spin rate about an axis transverse to the launch vehicle longitudinal axis. In principle, this relative motion is achieved by limiting the stroke of two adjacent springs with respect to the stroke of the other two opposing springs. In addition to the pushoff springs, there are two electrical disconnects, which participate in the spacecraft separation dynamics (fig. 7-7).

The SCA702+GEM is an SCA702+ with minor modifications to account for slightly different geometry at the spacecraft interface.

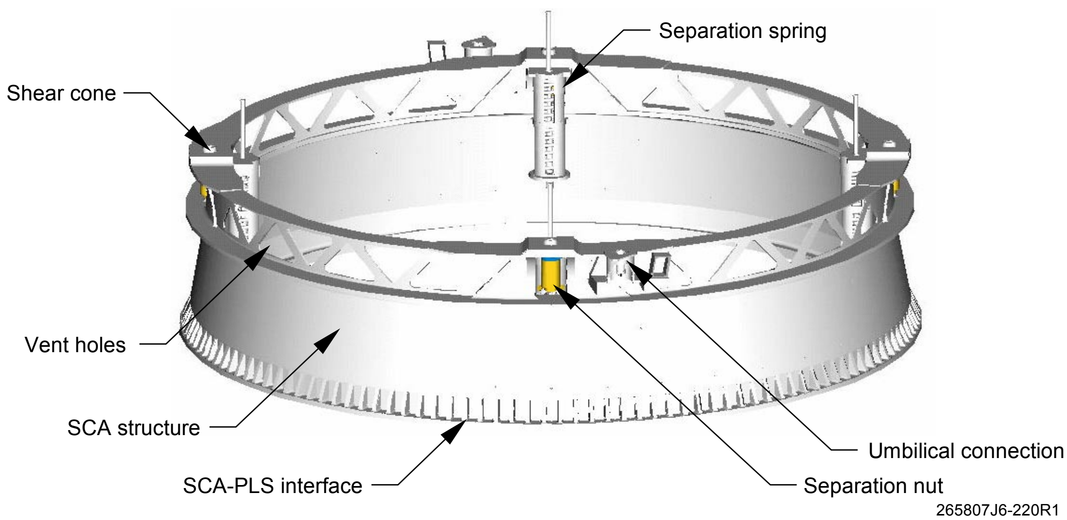

Figure 7-7. SCA702+ Spacecraft Adapter

SCA1194VS

The SCA1194VS has a diameter of 1194 mm (3,917.3 ft) at the spacecraft interface and uses a Marmon clamp separation system. The SCA1194VS is designed to accommodate an 8000-kg (17,637 lb) spacecraft with a center of gravity at 2.0 m (6.6 ft) with 10% peaking. The spacecraft separation system uses from 8 to 14 pushoff springs to impart both an initial delta velocity with respect to the launch vehicle and a spacecraft spin rate about an axis transverse to the launch vehicle longitudinal axis. In principle, this relative motion is achieved by limiting the stroke of adjacent springs with respect to the stroke of the opposing springs. In addition to the pushoff springs, there are two electrical disconnects and a clampband impulse that participate in the spacecraft separation dynamics. The major elements of this clampband-type adapter are shown in figure 7-8.

The SCA1194VS (fig. 7-8) incorporates a clampband soft separation system that uses the proven clampband technology of Saab Ericsson Space. The clampband opening device system was developed by Saab Ericsson Space and uses the principle of the fast-acting shockless separation nut from Starsys Research.

The SCA1194VS consists of a preshaped aluminum band with titanium end fittings. The adapter uses only one band joint with a nominal clampband pre-tension of 60 kN. The clampband opening device is a reusable, and thus testable, system consisting of a flywheel housing and energetically actuated pin puller.

The installation of the SCA1194VS is easier and faster than the previous SCA1194 model. The SCA1194VS requires only one band joint and tensioning operation instead of two, as required with the SCA1194. Additionally, the required access zone is on only one side of the spacecraft.

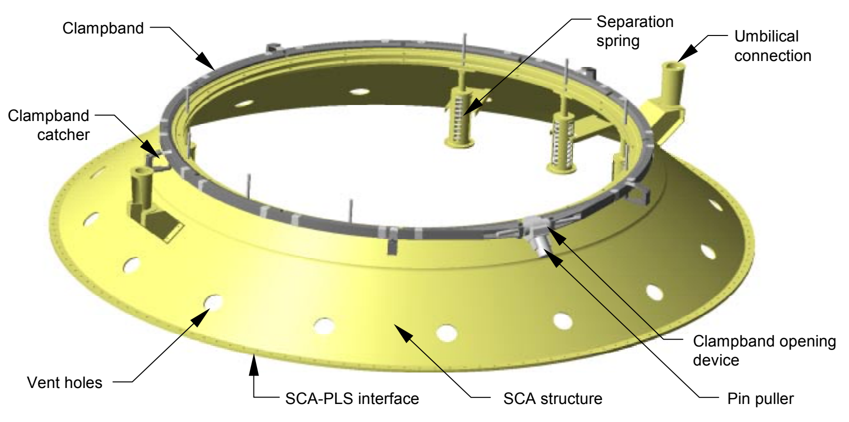

Figure 7-8. SCA1194VS Spacecraft Adapter

7.2 Electrical Interfaces

Overview

Characteristics of the electrical interfaces are covered in the following sections, including:

- Hard-line link (umbilical)
- Radio frequency link
- External communication
- In-flight interfaces
- Electrical power

Spacecraft/ Adapter In-Flight Electrical Disconnects

The launch vehicle adapter standard configuration accommodates two SAE-AS81703–style connectors (37 pins or 61 pins). The spacecraft contractor should procure both halves and provide the mating half to the launch vehicle for installation on the adapter. Additional required connectors can be accommodated and will be negotiated on a case-by-case basis.

Hard-Line Link (Umbilical)

Spacecraft hard-line link electrical interconnections between the spacecraft adapter in-flight disconnects and the spacecraft electrical ground support equipment are provided by two functionally similar but physically separate umbilical cable paths:

- Interface skirt
- T-0

Both umbilical paths are available for testing during integration checkout:

- During transit to the launch site, the interface skirt umbilical is available.
- On the launch pad (from approximately L-24 to L-8), both the T-0 umbilical and the interface skirt umbilical are available.
- At approximately L-8 hr, the interface skirt umbilical is disconnected.
- The T-0 umbilical remains connected until liftoff.

Table 7-1 and figure 7-9 depict umbilical configurations during spacecraft encapsulation, integrated launch vehicle integration, transit phase, and on-pad operations.

Table 7-1. Umbilical Configurations

Available Umbilical Functions

Umbilical cable path	Signal	Power
Interface skirt before L-8 hr	• Up to 20 twisted shielded pairs • Up to 250 mA at 50 V ac or 150 V dc	• Up to 70 A and 105 V dc for battery charging and • Up to 20 A and 105 V dc for external spacecraft power
L-8 to launch	• Up to 20 twisted shielded pairs • Up to 250 mA at 50 V ac or 150 V dc	• Up to 20 A and 105 V dc for battery charging and • Up to 20 A and 105 V dc for external spacecraft power

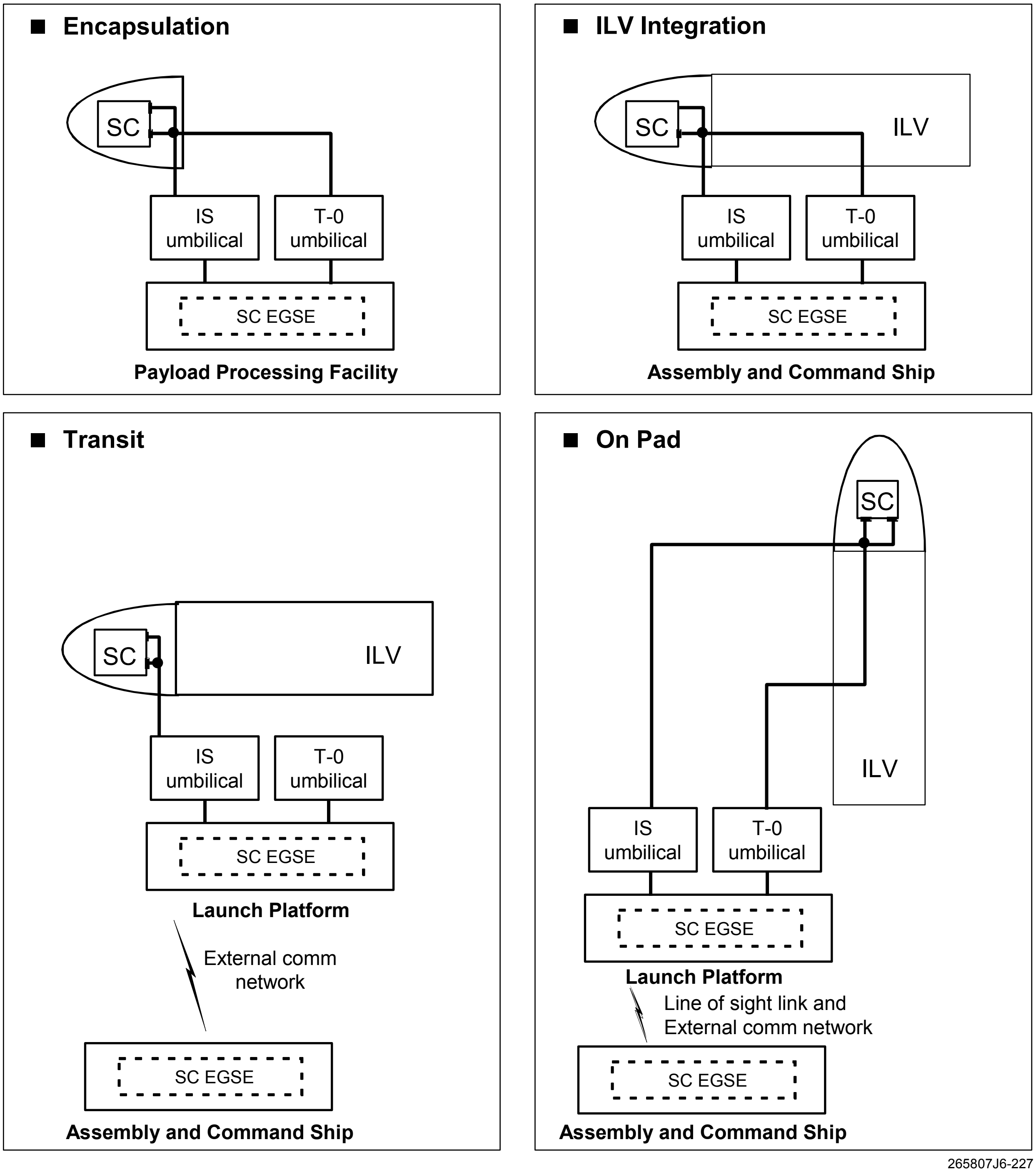

Figure 7-9. Umbilical and Radio Frequency Configurations During Launch Processing Flow

Radio Frequency Link (Rerad)

A direct radio frequency link to the spacecraft is provided by a reradiation system (fig. 7-9). This radio frequency link supports spacecraft telemetry and command communications to spacecraft electrical ground support equipment in the payload processing facility and between the assembly and command ship and the launch platform when the integrated launch vehicle is erected at the launch site.

The reradiation system supports one spacecraft command frequency and one telemetry frequency between 3.0 GHz and 18 GHz. Spacecraft frequencies as low as 1.7 GHz and as high as 40.0 GHz are negotiable on request. This system reradiates the spacecraft radio frequency signals through the fairing, as shown in figure 7-10, and between the spacecraft and the spacecraft electrical ground support equipment as shown in figure 7-11.

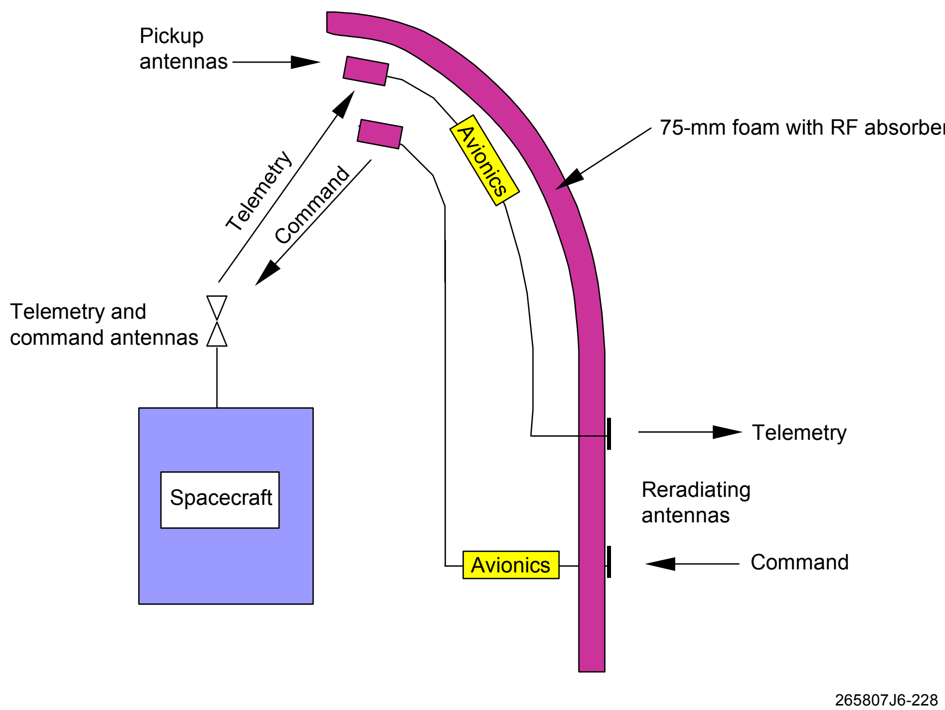

Figure 7-10. Spacecraft Radio Frequency Signal Through Fairing

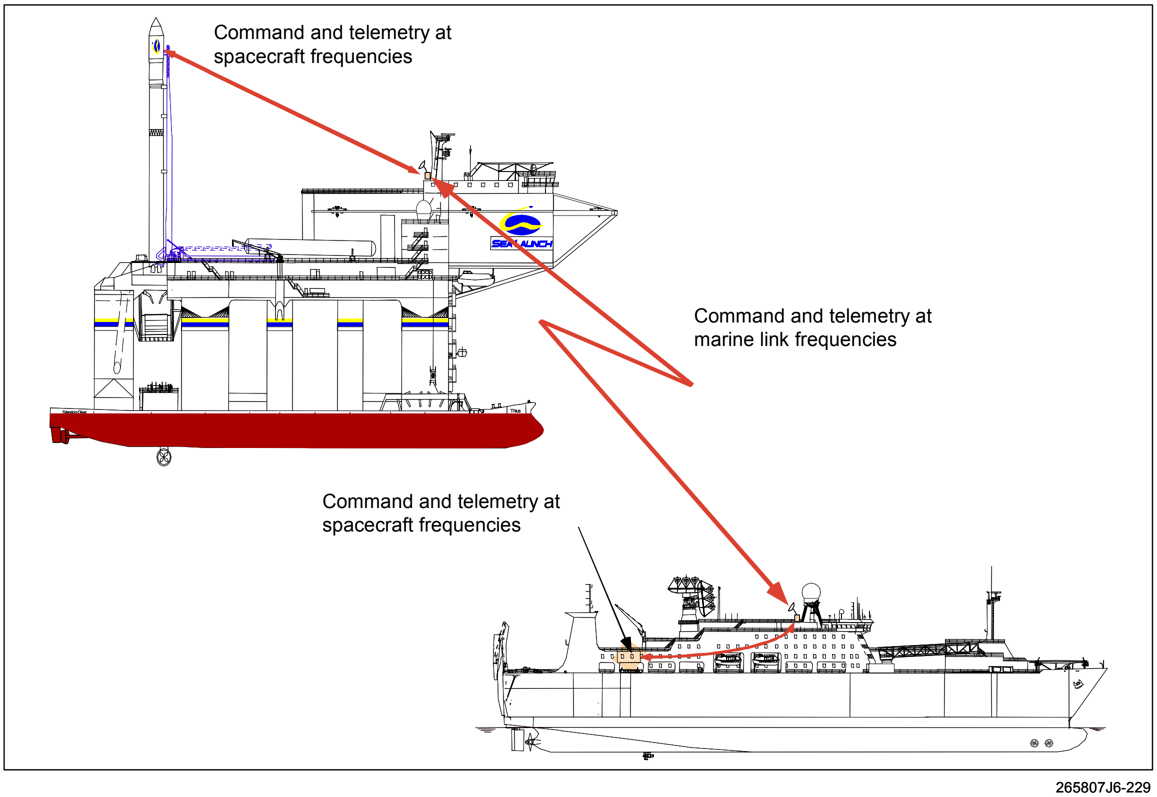

Figure 7-11. Spacecraft Radio Frequency Signal Between Vessels

External Communications Network

The external communications network provides worldwide connectivity in support of Sea Launch operations, including links between the assembly and command ship and the launch platform. This network provides serial digital and/or Ethernet connectivity for spacecraft contractor and customer use. During transit and at the launch site, the link is available by INTELSAT relay. When vessel position permits, the link is available directly by radio frequency line of sight. The capabilities of this network include:

- Spacecraft command and telemetry hard-line links use the external communications network between vessels. This is illustrated in figure 7-12.
- Sea Launch provides communications connectivity using the Brewster, Washington, ground station. This connectivity can be established with a customer-procured data line between the Brewster ground station, the spacecraft mission ground station, and/or the spacecraft factory. Sea Launch also provides an Internet connection, to which the customer has worldwide access.

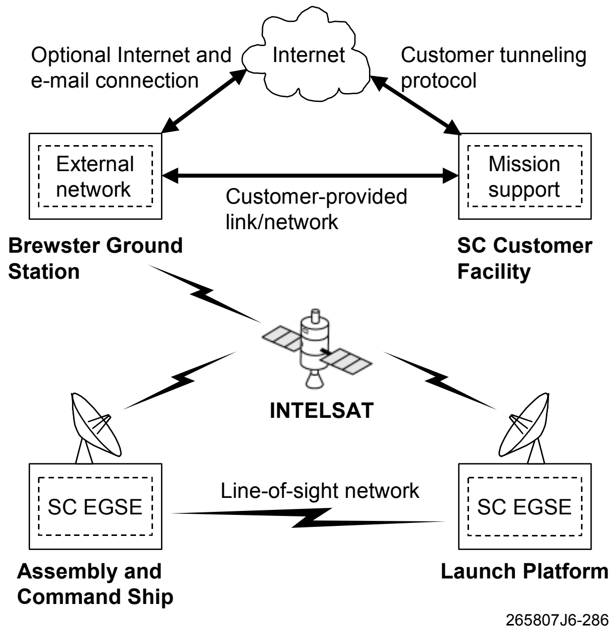

Figure 7-12. Sea Launch External Communications Network

Available In-flight Interfaces

Sea Launch provides several different types of in-flight interfaces to the spacecraft. Table 7-2 provides brief descriptions of the in-flight telemetry, command, and separation breakwire interfaces.

Table 7-2. In-Flight Telemetry, Command, and Separation Breakwire Interfaces

Interface	**Description**	**When provided**
Serial PCM telemetry	The launch vehicle onboard data acquisition system can accommodate two serial data streams from the spacecraft, up to 2 Kbps combined. This spacecraft data is interleaved within the launch vehicle telemetry downlink. It is recovered and provided to the spacecraft or customer as a part of the postflight data processing function. Serial data PCM codes of NRZL (data and clock/RS422) are accommodated. Other PCM coding schemes are optional.	Provided postflight
Analog telemetry	Four launch vehicle analog telemetry channels are available for spacecraft use. These channels accommodate data input at ≥400 samples per sec.	Provided postflight
Digital telemetry	The launch vehicle telemetry system accepts up to eight discrete (bi-level) inputs from the spacecraft.	Provided postflight
In-flight commands	The launch vehicle can provide up to four redundant (primary and backup) pulse-type commands for spacecraft use. The commands can be configured in an application of 28 V or as contact closures. Pulse duration is 50 ms.	Provided in real time
Separation breakwires	The spacecraft is required to provide continuity loops for separation monitoring by the launch vehicle. As a minimum, one loop must be provided for each separation connector, but two loops per connector are preferred. The launch vehicle will provide continuity loops for use by the spacecraft as defined by the spacecraft separation connector pin allocations.	Provided in real time

Electrical Power

Both at Home Port and on the vessels, Sea Launch provides customer electrical ground support equipment with power from uninterruptible power supplies. Either 50 or 60 Hz power is available. This launch-critical power is fault tolerant and isolated from other power sources.

Electrical Grounding

Each Sea Launch facility provides electrically conductive surfaces (copper plates or threaded studs) for connecting the spacecraft electrical ground support equipment to facility ground.

Electrical Bonding

Sea Launch provides a spacecraft adapter-to-launch vehicle interface bond of ≤ 10 mΩ. In addition, the spacecraft-to-spacecraft adapter interface bond should be ≤ 10 mΩ.

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8.0 SPACECRAFT INTEGRATION AND LAUNCH OPERATIONS

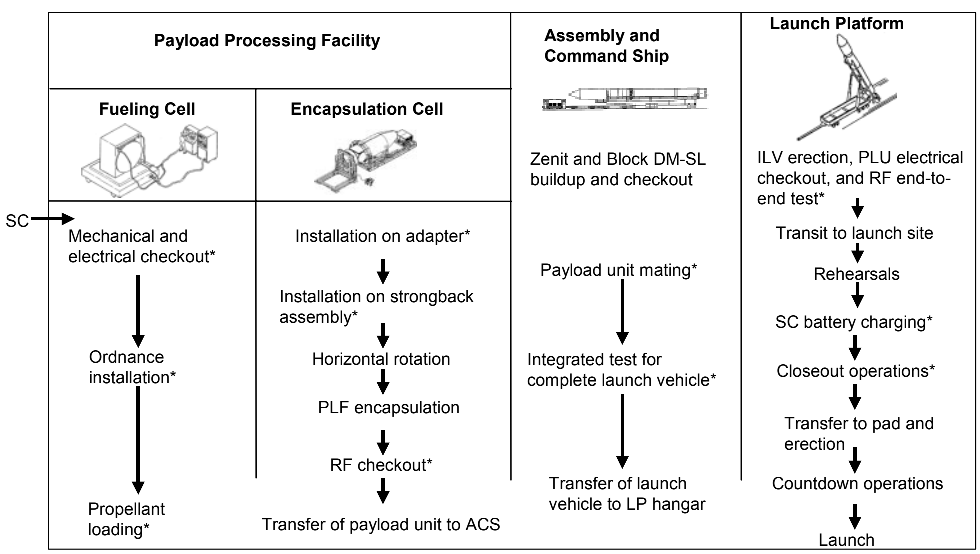
Overview

Sea Launch optimizes the convenience of West Coast spacecraft processing with a true equatorial launch site.

There are three distinct phases of operations:

- Phase I takes place in the payload processing facility. This phase starts with the delivery of the spacecraft to Sea Launch Home Port, in Long Beach, California, and includes final processing of the spacecraft, stand-alone tests, ordnance installation, fueling, and encapsulation with the payload fairing.
- Phase II takes place on the assembly and command ship. This includes mating the encapsulated spacecraft to the Zenit-3SL launch vehicle, and integrated testing.
- Phase III takes place on the launch platform. While still at Home Port, the integrated launch vehicle is erected, and electrical checkout and radio frequency end-to-end tests are conducted. The launch platform then transports the integrated launch vehicle to the equator. Rehearsals are conducted during transit. At the launch site the launch vehicle is rolled out to the launch pad for erection and fueling. The launch is then performed by an automated system.

Figure 8-1 depicts the overall spacecraft processing flow. A typical 50-day processing schedule is shown in figure 8-2. Deviations from the 50-day schedule may be accommodated on a case-by-case basis. Typical 25-day start of combined operations flow through launch is shown in figure 8-3.



*Tasks that directly involve the SC.

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Figure 8-1. Spacecraft Processing Flow

Description	Shift plan	Shifts
Previous launch (at 2400)		–
SC on dock Home Port (notional)		–
SC stand-alone operations (notional)	Variable, SC controlled	10
PLU on dock Home Port		–
PLU stand-alone operations	8 hr/d, 5 d/wk	12
SC required to support combined operations		–
Combined PLU/SC operations	8 hr/d, 5 d/wk	13
Integrated Block DM/Zenit available for PLU mate		–
PLU rollout to ACS. Mate to Block DM, integrated electronic tests, transfer to LP	12 hr/d, 7 d/wk	5
ILV erect, KNSG, preps for transit (no rerad test)	12 hr/d, 7 d/wk	3
ACS/LP transit to launch site	24 hr/d, 7 d/wk	10.1 kn for 12 days
Launch readiness operations, launch	24 hr/d, 7 d/wk	72 hr
Postlaunch securing	24 hr/d, 7 d/wk	24 hr
ACS transit to Home Port	24 hr/d, 7 d/wk	15.6 kn for 8 days
ACS returned from previous launch		–
ILV stand-alone operations	10 hr/d, 6 d/wk	20
Integrated Block DM/Zenit available for PLU mate	10 hr/d, 6 d/wk	3

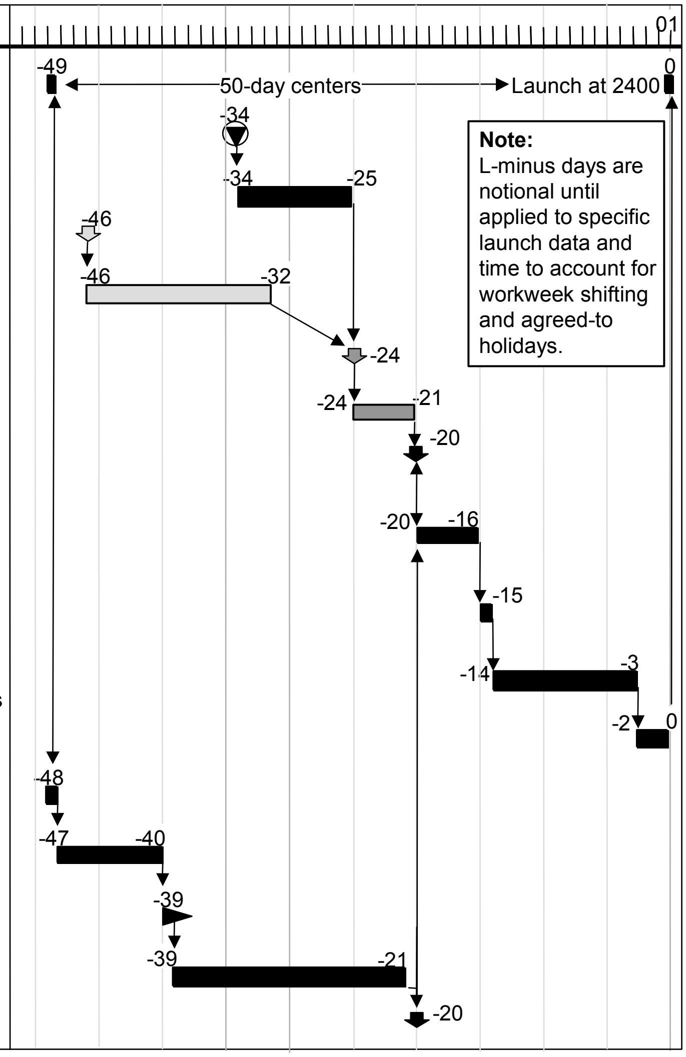

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Figure 8-2. Nominal 50-Day Processing Schedule

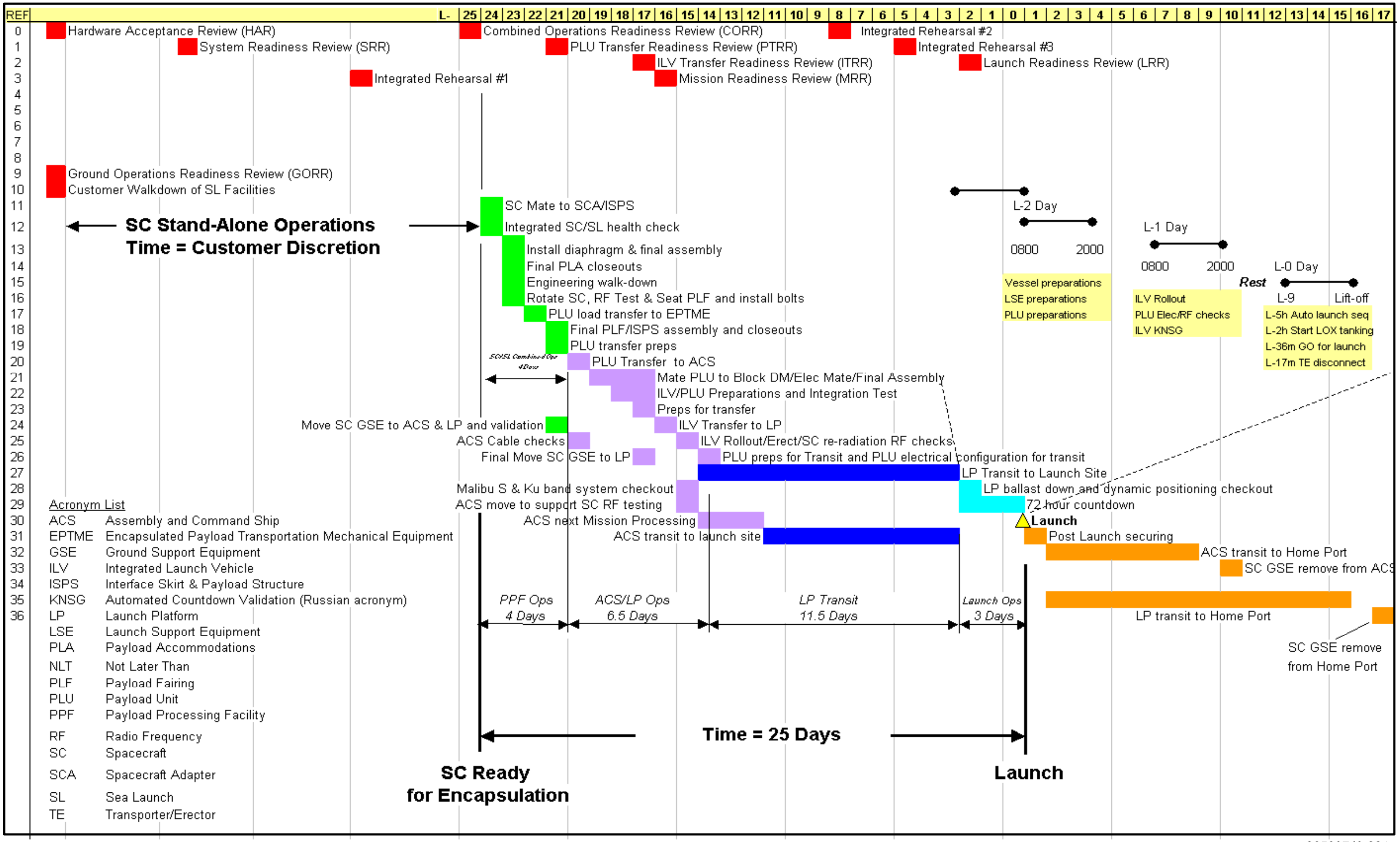

Figure 8-3. Campaign Timeline

8.1 Phase I—Spacecraft Processing in the Payload Processing Facility

Spacecraft Delivery

Payload processing begins with delivery of the spacecraft to Sea Launch Home Port in Long Beach, California. Delivery takes place at the common airlock cell in the payload processing facility (fig. 8-4).

Figure 8-4. Payload Processing Facility at Home Port

Spacecraft Adapter

Before the spacecraft arrives, the spacecraft adapter is mounted on an adapter support stand assembly and moved into one of two high-bay spacecraft processing/fueling cells in anticipation of spacecraft fit check operations.

Spacecraft Processing

Upon arrival, the spacecraft is unloaded into the common air lock and moved into the spacecraft processing/fueling cell. A spacecraft-to-adapter fit check is performed (fig. 8-5).

The spacecraft is then transferred to a customer-provided processing and/or fueling stand. The customer performs electrical and mechanical checkout of the spacecraft, stand-alone tests, ordnance installation, and propellant loading.

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Figure 8-5. Fit Check on Adapter Support Stand

Facilities

Astrotech Space Operations provides facility support services while the spacecraft is in the payload processing facility. Section 10 describes the payload processing facility and services.

- Access lifts are available to support personnel working on the spacecraft.
- An adjacent control room is provided for spacecraft ground support equipment and personnel.
- Garment change rooms, office facilities, remote control facilities, and warehouse or storage facilities are also available.

Payload Fairing Delivery

Before or in conjunction with spacecraft processing, the payload fairing and the interface skirt and payload structure also arrive at the payload processing facility and are unloaded in the common air lock cell.

Strongback Assembly

A strongback assembly is used to rotate the spacecraft from horizontal to vertical for encapsulation (figs. 8-6 and 8-7), as follows:

- Boeing personnel move the interface skirt and payload structure into the encapsulation cell and place it on the strongback assembly.
- When spacecraft stand-alone processing and fueling are complete, the spacecraft is mated to the spacecraft adapter and separation ordnance is installed. The spacecraft is then transported into the encapsulation cell and mated to the interface skirt and payload structure on the strongback assembly (fig. 8-8).
- All systems are fully tested before mating, and all mechanical and electrical interfaces are verified by established procedures.

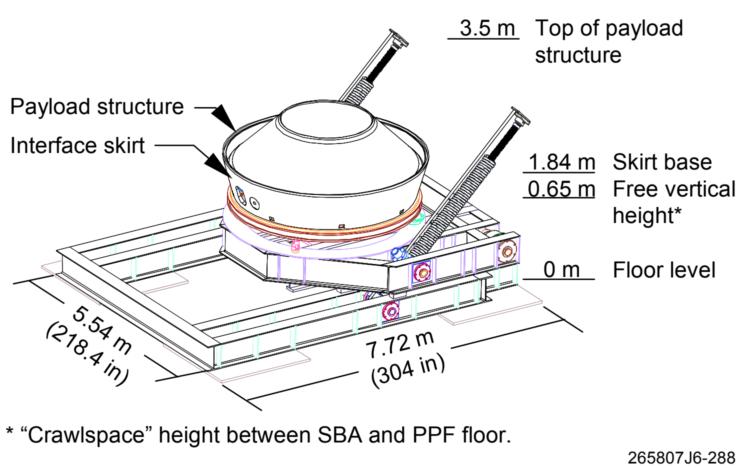

Figure 8-6. Strongback Assembly Vertical Mating Position

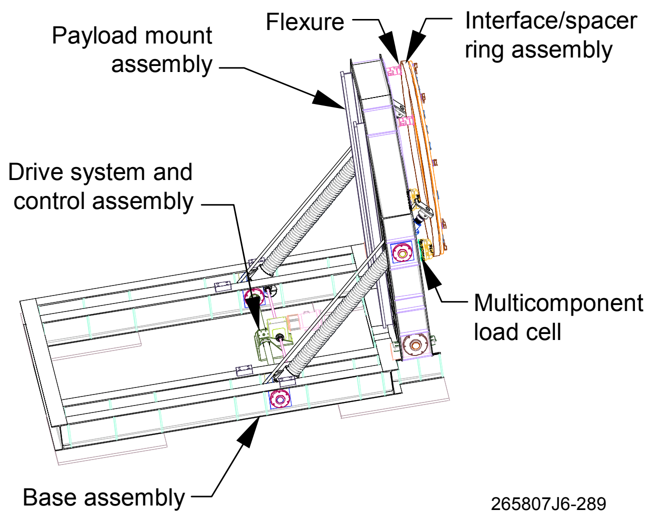

Figure 8-7. Strongback Assembly Horizontal Raised Position

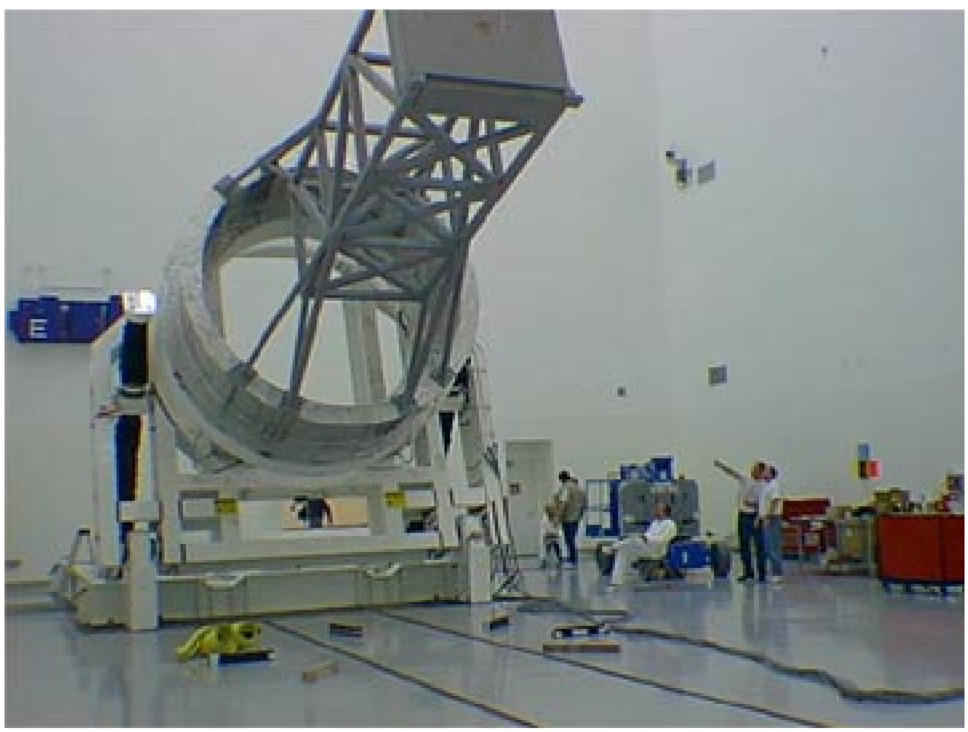

Figure 8-8. Strongback Assembly Rotating to Horizontal With Pathfinder Structure

Encapsulation

Boeing personnel install the payload fairing on the encapsulated payload transportation mechanical equipment. The encapsulated payload transportation mechanical equipment (fig. 8-9) supports the payload fairing in a horizontal position.

Alignments are meticulously inspected and the encapsulated payload transportation mechanical equipment slides the payload fairing over the spacecraft and mates with the interface skirt and payload structure.

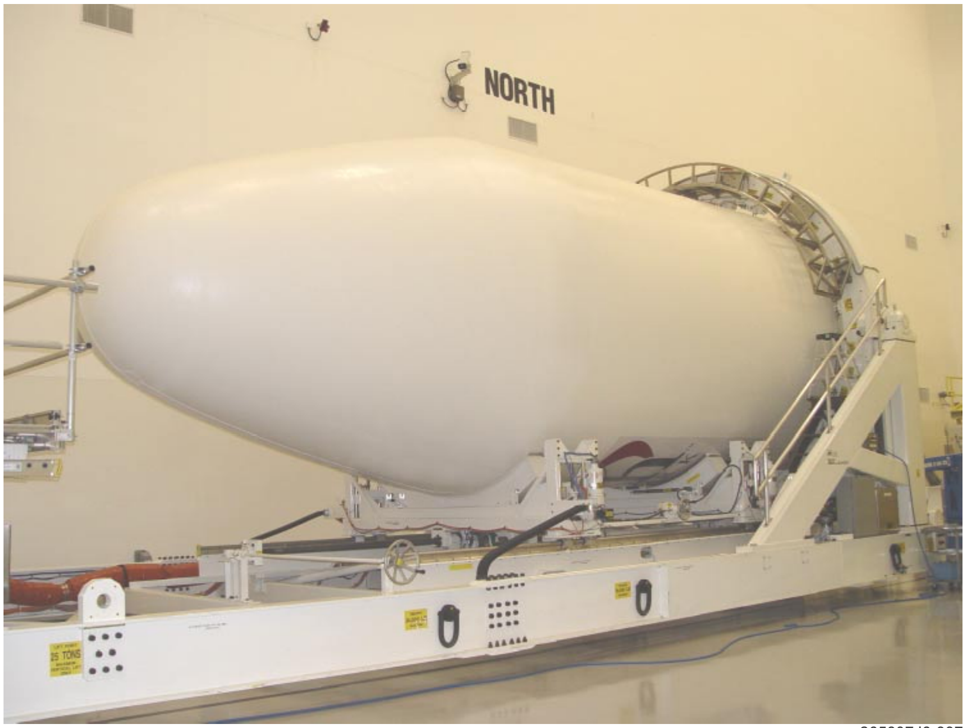

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Figure 8-9. Encapsulated Payload Transportation Mechanical Equipment With Encapsulated Spacecraft

Payload Unit

The encapsulated spacecraft, adapter, interface skirt and payload structure, and payload fairing are called a payload unit.

Communication checks are conducted on the spacecraft, and conditioned airflow is initiated into the payload fairing cavity.

Scaffolding

Scaffolding is available to provide access while the spacecraft is in the horizontal position. Figure 8-10 illustrates this access, and figure 8-11 shows an example in use. Part of this same scaffolding is also available on board the assembly and command ship to provide access for maintenance and to support mating to the Block DM-SL.

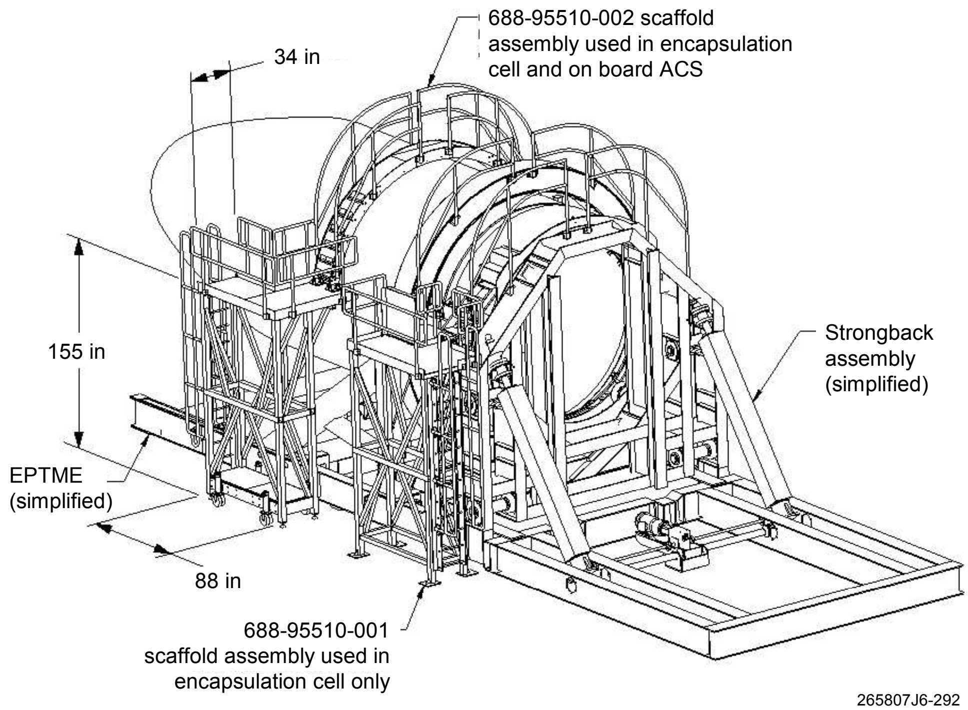

Figure 8-10. Scaffolding Around Encapsulated Spacecraft

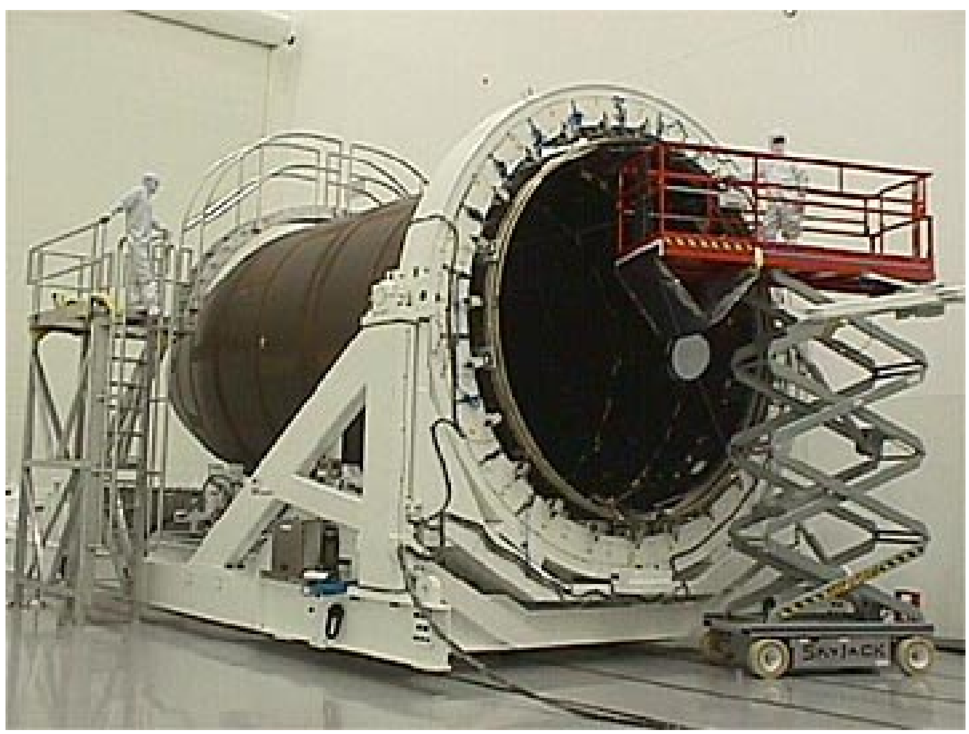

Figure 8-11. Access to Encapsulated Spacecraft

Encapsulated Payload Transport Vehicle

The integrated payload unit is loaded onto an encapsulated payload transport vehicle for transportation to the assembly and command ship.

Spacecraft thermal, contamination, vibration, acoustic, and electromagnetic radiation environments are rigorously maintained throughout transportation to the assembly and command ship.

Transport from Payload Processing Facility to Assembly and Command Ship

Figure 8-12 shows the payload unit, which includes the encapsulated spacecraft, as it exits the payload processing facility.

Figure 8-13 shows the payload unit in transit to the assembly and command ship.

Figure 8-14 shows the payload unit driving onto the stern ramp of the assembly and command ship.

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Figure 8-12. Payload Unit Exiting the Payload Processing Facility

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Figure 8-13. Payload Unit in Transit to the Assembly and Command Ship

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Figure 8-14. Payload Unit on Stern Ramp of the Assembly and Command Ship

Security

Security is a high priority throughout spacecraft processing. In the payload processing facility, access is restricted to authorized personnel only. On the assembly and command ship and launch platform, there are controlled access areas with video camera monitoring. Security guards are stationed at the encapsulated spacecraft 24 hours a day.

8.2 Phase II—Mating to the Launch Vehicle and Integrated Testing on the Assembly and Command Ship

Zenit Processing Before Spacecraft Mating

Zenit-3SL launch vehicle processing is performed on the assembly and command ship while the spacecraft is still in the payload processing facility (fig. 8-15). At the pier, complete systems for loading fuels, compressed gases, and cryogens are provided.

The Zenit first and second stages are fully tested, the Block DM-SL is tested and fueled, and the Block DM-SL upper stage is mated with the Zenit-3SL rocket. After mating and integrated testing, the launch vehicle is now ready to receive the payload unit, which includes the encapsulated spacecraft (fig. 8-16).

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Figure 8-15. Zenit-3SL Launch Vehicles in the Assembly and Command Ship

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Figure 8-16. Payload Unit Mating to the Zenit-3SL

Spacecraft Mating to the Zenit-3SL

After transport to the assembly and command ship, the payload unit is mechanically and electrically mated with the fully assembled Zenit-3SL and Block DM-SL. Integration testing is then performed and the complete integrated launch vehicle is fully checked out.

Transfer to the Launch Platform

The assembly and command ship is repositioned around the pier for transfer of the integrated launch vehicle from the assembly and command ship to the launch platform.

The integrated launch vehicle is rolled out of the assembly and command ship processing bay by a ship rail system. Cranes are used to lift the integrated launch vehicle up into the launch platform for placement in the hangar. Clean conditioned air is provided throughout this operation.

Figure 8-17 shows the integrated launch vehicle ready for lifting from the assembly and command ship.

Figure 8-18 shows the integrated launch vehicle being transferred into the launch platform hangar.

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Figure 8-17. Integrated Launch Vehicle Ready for Lifting

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Figure 8-18. Lifting of Integrated Launch Vehicle

8.3 Phase III—Transit and Launch Operations on the Launch Platform

Transit

Transit for the assembly and command ship (fig. 8-19) and the launch platform (fig. 8-20) from Home Port to the launch site on the equator takes 10 to 12 days (based on 10.1 kn).

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Figure 8-19. Assembly and Command Ship Departing Home Port

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Figure 8-20. Launch Platform Sailing for the Equator

Conditions

During transit to the launch site, the integrated launch vehicle is supported on the transporter/erector in the launch platform hangar. Figure 8-21 shows the transporter/erector rolled out of the launch platform hangar.

Conditioned air is continuously provided to the payload fairing throughout transit to the launch site.

Battery charging is available through the interface skirt connection to spacecraft ground support equipment.

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Figure 8-21. Zenit-3SL Transporter/Erector

Communication Links

Communication links (both direct and satellite) are provided between the spacecraft in the launch platform hangar and the customer's electrical ground support equipment in the spacecraft support room on board the assembly and command ship.

Access

The spacecraft is functionally accessible by redundant radio frequency and hard-line connections and is physically accessible through payload fairing doors. The hangar has access platforms that can be used to access most locations on the outside surface of the payload fairing.

Launch Rehearsals

Two rehearsals, including the mission dress rehearsal, are conducted before the assembly and command ship arrives at the launch site. Participation of customer launch personnel on board the assembly and command ship, spacecraft tracking and communication systems personnel, and the spacecraft control center is encouraged.

The mission dress rehearsal simulates prelaunch and postlaunch operations up through spacecraft separation and completion of the Block DM-SL contamination and collision avoidance maneuvers. During these rehearsals, launch vehicle operations are simulated and the launch vehicle remains safely in the hangar.

Successful completion of the launch rehearsals is a prerequisite to launch.

Launch Platform Stability

At the launch site, the launch platform is ballasted to its semi-submersible launch draft position of 22.5 m (73.8 ft). Platform positioning and orientation are maintained using global positioning system inputs to a dynamic positioning system of thrusters on board the vessel. Stability is maintained by an active trim-and-heel system that compensates for mass movements atop the platform.

Weather Conditions

The launch may be accomplished in significant wave heights up to 2.5 m (8.2 ft); most of the waves in the launch region are of low period and small wave height.

Year-round Launch Capability

The combination of benign weather, inherent platform stability, and active leveling systems makes it possible to launch the rocket year round in most expected weather conditions (fig. 8-22).

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Figure 8-22. Launch Operations at the Launch Site

Link Bridge Operations

The assembly and command ship and launch platform moor alongside each other at the launch site. A connecting bridge is extended from the assembly and command ship to the launch platform to allow prelaunch processing personnel access to the launch platform (fig. 8-23). Final spacecraft “hands-on” operations, such as ordnance arming, are accomplished and payload fairing doors are closed out.

Figure 8-23. Assembly and Command Ship and Launch Platform Connected by Link Bridge

Launch Readiness Review

A launch readiness review is conducted and approval is given to the launch team to commence launch operations.

Launch Vehicle Erection

The hangar doors are opened and the automatic sequence that moves the Zenit-3SL to the launch pad is initiated. As the integrated launch vehicle moves to the pad, electrical, pneumatic, hydraulic, and propellant lines are automatically connected. Before erection, air is switched from the portable conditioned-air supply to the pad conditioned-air supply system, continuously connected to the payload unit.

Erection is automatically accomplished and the integrated launch vehicle is rotated to a vertical position.

Evacuation of Personnel

All personnel, except for critical launch vehicle technicians, are transferred to the assembly and command ship, the connecting bridge is stowed, and the assembly and command ship is repositioned 6.5 km (4.0 mi) away.

After the launch vehicle technicians complete final prelaunch checkouts, the technicians are quickly transferred by helicopter to the assembly and command ship just before rocket fueling.

From this point on, the launch platform is operated under remote control from the assembly and command ship. Radio frequency links provide communications between the ground support equipment rooms and the spacecraft.

Propellant Loading

A poll of launch management and the customer is conducted to give the "go" for launch vehicle propellant loading. The Zenit-3SL is loaded with propellants and compressed gases starting at L-3 hr. Launch holds of up to 4 hr can be accommodated, and if a launch abort is called, a recycle to a second launch attempt can be accomplished within 24 hr.

Second "Go" Poll

The next poll is conducted before disconnecting the launch vehicle umbilical. The transporter/erector returns to the hangar at L-17 min. Up to this point, a hold of 1 hour can be accommodated. Beyond this time, the Zenit-3SL must be reinitialized, which takes up to 5 days.

Reinitialization entails draining oxygen and kerosene from the Zenit-3SL, charging the spacecraft batteries if required, and returning the integrated launch vehicle to the hangar. Conditioned airflow to the spacecraft will be continued through any abort or recycle operations.

Zenit-3SL in Vertical Configuration

The Zenit-3SL is held in place on the launch table by holddown clamps at the base of the first stage. These clamps are not released until computers confirm that the Stage 1 operating thrust has been reached. In order to minimize exhaust effects on the launch platform and acoustic effects on the spacecraft, a water deluge system is used in the flame bucket (fig. 8-24), beneath the launch table.


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Figure 8-24. Liftoff From the Launch Platform

Launch Control Center

The launch control center is located on the shelter deck of the assembly and command ship (fig. 8-25). During all phases of launch processing and flight, the launch control center has the ultimate responsibility and authority for all decisions and commands affecting the integrated launch vehicle. Internal communications on both the assembly and command ship and launch platform include closed-circuit television, telephone, intercom, public address, data communications and computing systems, a line-of-sight system, a countdown clock system, and a mission management display system. Six console positions are available for customer spacecraft personnel in the launch control center.


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Figure 8-25. Launch Control Center on the Assembly and Command Ship

Mission Director Control

If any unplanned event occurs during a mission that affects nominal launch operations, the Mission Director will coordinate all required actions in accordance with instructions contained in the master procedures. These actions may include:

- Overseeing delay-of-launch operations
- Overseeing safety measures
- Identification of the personnel required for assessment and resolution of the event
- Coordination of the personnel team to assess the event and provide recommendations
- Authorization of launch recycle or recovery activities
- Preparation of required notifications and reports

8.4 Flight Operations

Range Tracking and Telemetry

Range tracking and telemetry return is provided by Sea Launch using assets on board the assembly and command ship through NASA's Tracking and Data Relay Satellite System.

Ground monitoring installations include the launch control center on board the assembly and command ship and the Russian ground tracking station in Korolev, outside Moscow.

Line-of-sight telemetry coverage is continued through payload fairing jettison. The Tracking and Data Relay Satellite System telemetry is routed through the central communication node in Brewster, Washington.

Range Coordination

Sea Launch provides all necessary range coordination functions independent of the eastern or western range sites in the United States. These include:

- FAA (air traffic)
- Defense Mapping Agency (notice to mariners)
- NASA (orbital collision avoidance)

There is never a problem with range availability because there are no other launches competing for Sea Launch assets at the same time.

Weather

The assembly and command ship includes:

- Self-contained weather station with C-band Doppler radar
- Upper atmospheric balloon release capability
- Surface wind instruments
- Wave radar
- Ambient condition sensors
- Satellite imagery

A full-time meteorologist is stationed on the assembly and command ship while at sea.

Other

- A helicopter is provided to support mission operations. Both the assembly and command ship and the launch platform are equipped with landing pads.
- A comprehensive photo-optical recording system is used to document launches.
- External communications are handled through INTELSAT satellites and Sea Launch ground stations in Brewster, Washington, and Eik, Norway.

Zenit-3SL Flight Operations

Zenit first- and second-stage flight operations are completely automatic. A mission event timeline is included as table 3-1, Section 3.

All Stage 1 and 2 events occur within the view of the assembly and command ship. The spent stages fall into the Pacific Ocean, far short of the coast of South America and the major coastal shipping lanes. Any deviation of flight trajectory from preprogrammed limits causes onboard systems to automatically terminate propulsion and end the mission. This approach to flight safety has been used successfully for decades by the former Soviet nations and obviates the need for the traditional range safety officer.

At second-stage separation from the Block DM-SL, four solid-propellant rocket motors at the base of Stage 2 fire to back the stage away from the Block DM-SL. The Block DM-SL lower and middle adapters are jettisoned during this period, the lower adapter is jettisoned with Stage 2, and the middle adapter is jettisoned just before Block DM-SL ignition.

Block-DM Flight Operations

Before launch, the Block DM-SL onboard systems are turned on and initialized, its oxidizer tank level is adjusted, and power is transferred from the launch platform umbilical to the Block DM-SL internal power supply. During the Stage 1 and 2 flight, the Block DM-SL remains inactive, except for preparations for autonomous flight. Following Stage 2 separation, the Block DM-SL is inserted into the target orbit with a single main engine burn. For two-burn missions, the Block DM-SL performs a settling burn using the attitude control/ullage propulsion system before the second burn of the main engine. Burn program options include, but are not limited to, one- or two-impulse insertion geosynchronous transfer orbit and multiple burns (up to a maximum of five) to medium Earth orbit or planetary escape.

Following spacecraft insertion into the target orbit, the Block DM-SL separates from the spacecraft and performs a contamination and collision avoidance maneuver. Disposal options include transfer of the Block DM-SL to a higher or lower disposal orbit that mitigates orbital debris generation risk and reduces the spent stage orbital lifetime.

Postlaunch Reports

Sea Launch provides near-real-time confirmation of key ascent events (e.g., payload fairing jettison, engine burns, and spacecraft separation).

An injection report is delivered within 50 min of spacecraft separation. The injection report documents the state vector of the Block DM-SL just before spacecraft separation and is provided to customer personnel in the launch control center.

A postflight report is delivered 60 days after launch. The postflight report documents performance of all Sea Launch systems and interfaces as related to documented requirements.

Data includes operations and launch environments (ground and flight), launch time, separation state vector, injection orbit and accuracy, separation attitude and rates, contamination and collision avoidance maneuver performance, and flight event sequences.

9.0 HOME PORT FACILITIES AND SEA LAUNCH VESSELS

Overview

The Sea Launch Home Port complex provides the facilities, equipment, supplies, personnel, and procedures necessary to receive, transport, process, test, and integrate the spacecraft and its associated support equipment with Sea Launch. Figure 9-1 shows the general layout of the complex. Home Port also serves as the base of operations for both of the Sea Launch vessels. Figure 9-2 shows the assembly and command ship and launch platform at sea. The personnel providing the day-to-day support and service during prelaunch processing and launch conduct to Sea Launch and its customers are located at Home Port.

In addition to the overview provided here, the *Sea Launch Facilities Handbook* for customers provides a complete description of all buildings, support equipment, and services available to Sea Launch customers while at Home Port or on the vessels.

Characteristics of Home Port facilities and Sea Launch vessels are covered in Sections 9.1 through 9.3, including:

- Home Port facilities
- The assembly and command ship
- The launch platform

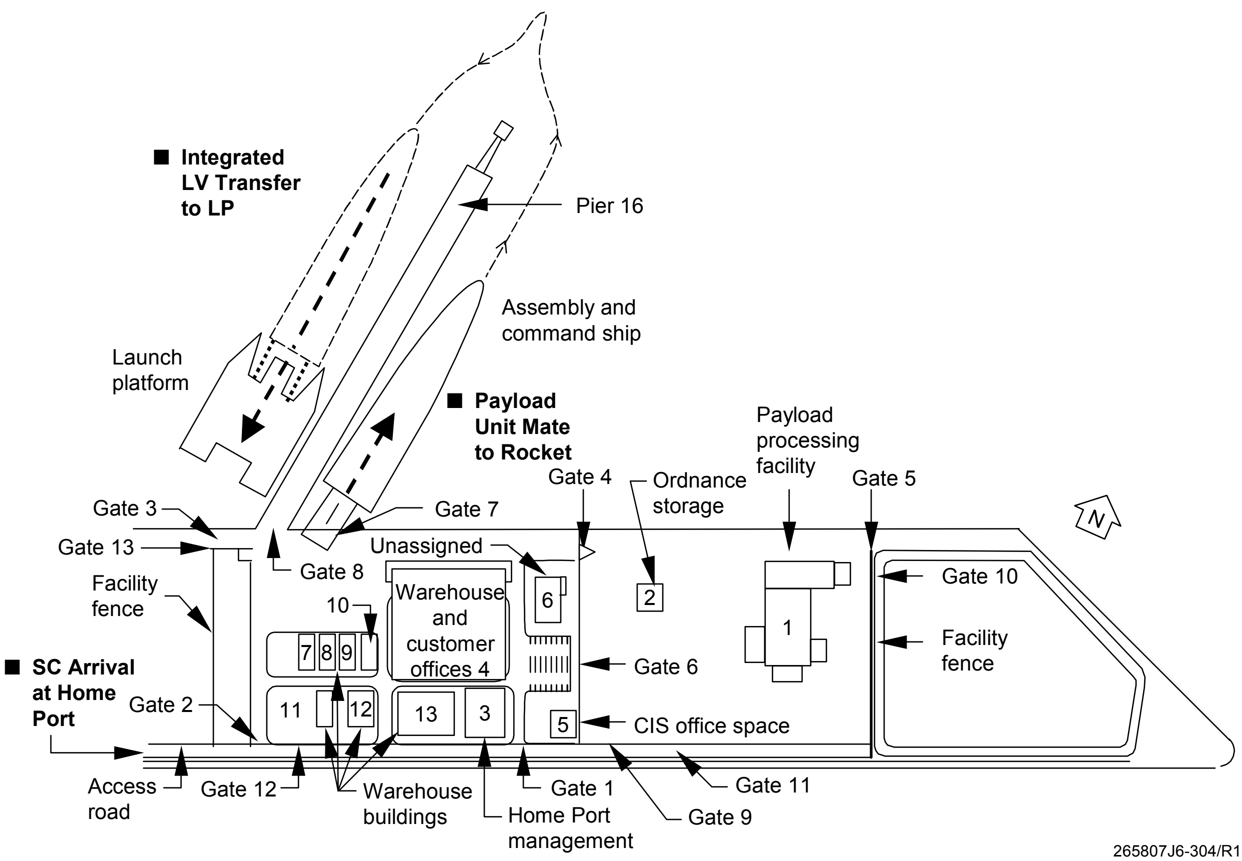

Figure 9-1. Sea Launch Home Port Complex

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Figure 9-2. Sea Launch Vessels

Home Port Location

Home Port is a 17-acre site located in Long Beach, California. Situated just south of Los Angeles, the complex is within the boundaries of the Port of Long Beach and is at the eastern end the former Navy mole that partially forms the Long Beach Harbor. Figure 9-3 depicts the location of Home Port. Access to the site is by the San Diego freeway (I-405) and then either I-110 or I-710 to Long Beach. Long Beach Airport (21 km or 13 mi), Los Angeles International Airport (40 km or 25 mi), and John Wayne Airport (38 km or 24 mi) are all in close proximity.

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Figure 9-3. Home Port Location and Vicinity

9.1 Home Port Facilities

Payload Processing Facility

The payload processing facility (fig. 9-4), also known as Building 1, is located on the east side of the Home Port complex. All spacecraft processing, propellant transfer operations, pressurization, ordnance preparation, and payload fairing encapsulation operations are accomplished in Building 1. Through the use of duplicate and independent processing cells, the payload processing facility can concurrently support the discrete processing campaigns of two customers. The payload processing facility is separated from the rest of the complex by an interior fence with controlled access during hazardous spacecraft operations.

The payload processing facility has an overall area of 2872 m^2 (31,000 ft^2). Major features include:

- Spacecraft processing and fueling cells
- Fuel storage rooms
- Oxidizer storage rooms
- Control rooms
- Garment change rooms
- An air lock
- An encapsulation cell
- A lobby and break room

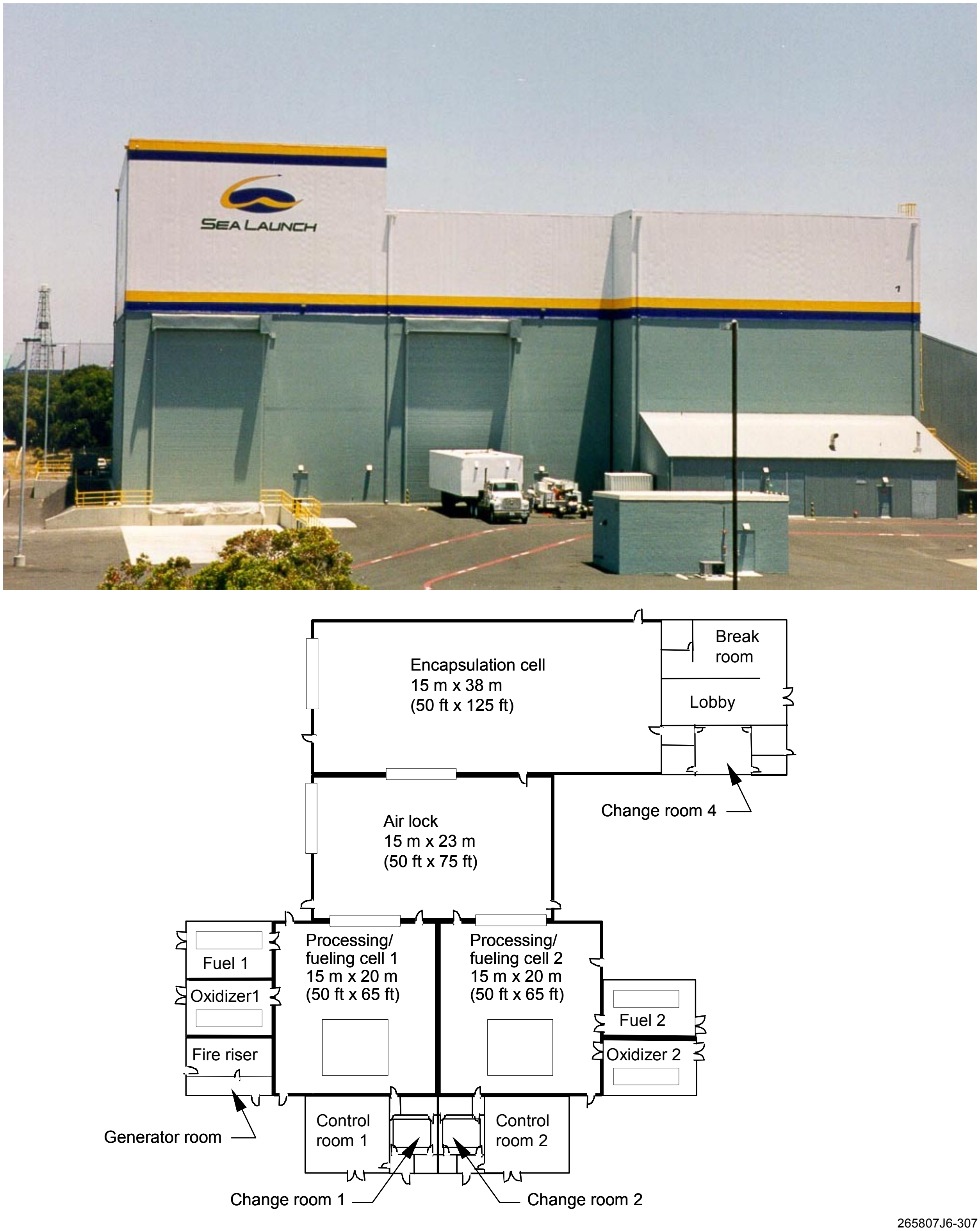

Figure 9-4. Payload Processing Facility—Interior and Exterior Views

Processing and Fueling Cells

The processing and fueling cells are designed to facilitate on-site electrical testing, spacecraft fueling, and final assembly before encapsulation of the spacecraft into the payload fairing. Spacecraft providers are assigned one of the two high-bay processing and fueling cells (fig. 9-4). Both cells have large-capacity overhead cranes, are certified cleanrooms, and have fueling islands that offer fuel spill and contamination control.

Fuel Storage Room and Oxidizer Storage Room

There is a fuel storage room and an oxidizer storage room dedicated to each of the spacecraft processing and fueling cells. Both rooms fully support fuel or oxidizer storage and all fueling operations. Complete personnel protection is provided during hazardous operation, and these rooms offer containment systems in the event of accidental leakage.

Control Rooms

Independent control rooms, from which spacecraft operations are conducted, are located adjacent to each of the processing and fueling cells. Penetrations between the control room and the processing and fueling cells allow direct communication between the spacecraft and its controlling support equipment. A window is installed that allows viewing operations in each processing and fueling cell.

Garment Change Rooms

The garment change rooms are located adjacent to the processing and fueling cells. These rooms provide the supplies and environment appropriate for personnel to don cleanroom garments or other protective suits before entering a processing and fueling cell.

Air Lock

The common air lock provides an environmentally controlled cleanroom that allows access to either the encapsulation cell or one of the two spacecraft processing and fueling cells. Customer equipment is delivered to this cell and distributed throughout the rest of the facility. An overhead crane, forklifts, and other support equipment are available to assist the customer.

Encapsulation Cell The encapsulation cell is an environmentally controlled cleanroom used for the preparation of the payload fairing, the interface skirt, and the payload structure. This cell contains all the equipment necessary to mate the spacecraft to the adapter and encapsulate that assembly within the payload fairing.

Lobby The lobby of the payload processing facility is available for viewing the activities within the encapsulation cell. A break room is connected to the lobby.

Ordnance Facility An ordnance storage Building (Building 2) is located near the payload processing facility at Home Port. This building is used to store the packaged explosive items for use by the launch vehicle and its payload.

Customer Warehouse/ Storage Facilities Building 10 (fig. 9-1) is available to the customer for storing supplies, shipping containers, and other miscellaneous equipment. Storage areas can be secured with access controlled by the customer. With prior coordination, additional customer storage may be arranged.

The Pier The pier (fig. 9-1) provides facilities for mooring, servicing, and supplying the Sea Launch vessels. The pier has all the provisions necessary for providing communications, water, and sewer services to the vessels while in port. It also has equipment for loading fuel, personnel, and equipment on board the vessels.

Building 4 Building 4 provides office and conference space for customer personnel. Also within Building 4, a pair of remote control rooms is provided for customers who wish to remotely control or monitor their operations in the payload processing facility.

Building 3 Building 3 (fig. 9-5) provides the facilities for the resident Home Port administrative and professional staff. This building contains offices, a training area, conference rooms, and a break area.


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Figure 9-5. Building 3, Sea Launch Office Facility

Transportation Services

When customer equipment destined for Home Port arrives by aircraft, Sea Launch provides logistical assistance with customs, transportation, and delivery from local airports. Forklifts, trucks, dollies, and air-bearing pallets are available to the customer to assist with equipment movement within the Home Port complex.

Sea Launch is responsible for transportation of the encapsulated spacecraft between Home Port facilities.

9.2 Assembly and Command Ship

Functions and Characteristics

The assembly and command ship (fig. 9-6) performs four functions for Sea Launch operations:

- Serves as the facility for assembly, processing, and checkout of the launch vehicle
- Houses the launch control center, which monitors and controls all operations at the launch site
- Acts as the base for tracking the initial ascent of the launch vehicle
- Provides accommodations for the marine and launch crews during transit to and from the launch site

The assembly and command ship is designed and constructed specifically to suit the unique requirements of Sea Launch. The ship's overall dimensions are nearly 200 m (660 ft) in length and 32 m (110 ft) in beam. Its overall displacement is approximately 30,830 tonnes (34,000 tons). Major features of the assembly and command ship include:

- A rocket assembly compartment
- The launch control center
- A launch control center viewing room
- Helicopter hangar and pad
- Spacecraft contractor and customer work areas
- Spacecraft contractor and customer accommodations

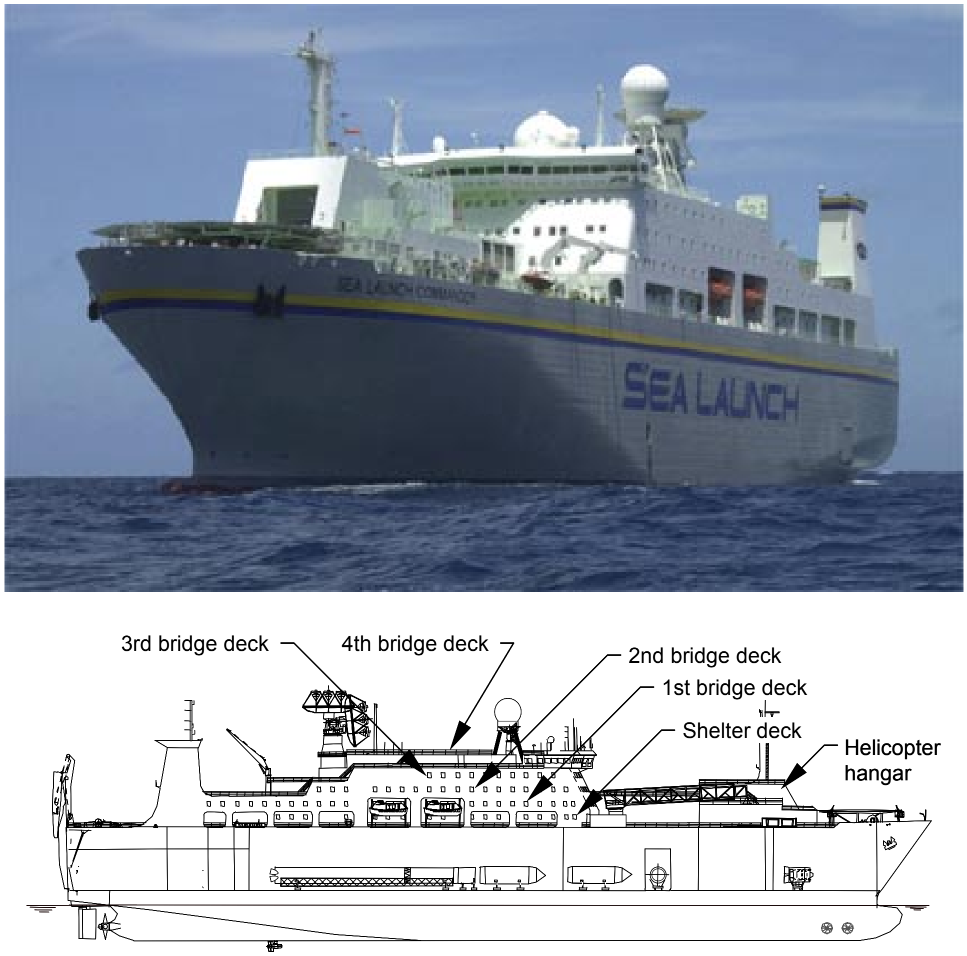

Figure 9-6. Assembly and Command Ship

Rocket Assembly Compartment

The rocket assembly compartment (fig. 9-7), which is located on the main deck of the assembly and command ship, hosts the final assembly and processing of the launch vehicle. This activity is conducted while the vessels are at Home Port and typically in parallel with spacecraft processing.

The bow of the main deck is dedicated to processing and fueling the Block DM-SL.

After the completion of spacecraft processing and encapsulation in the payload processing facility, the encapsulated payload is transferred into the rocket assembly compartment, where it is integrated with the 2-stage Zenit and Block DM-SL.

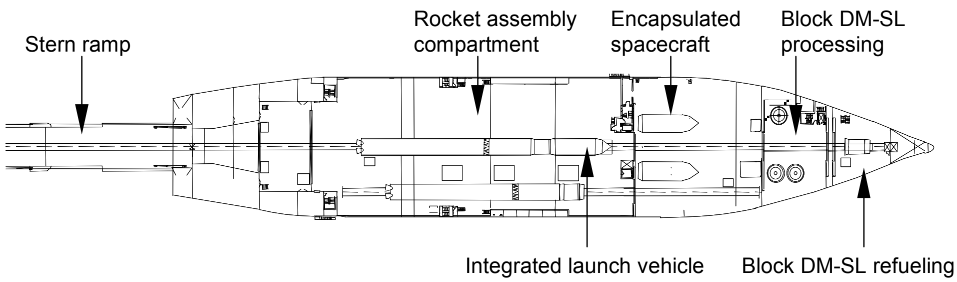

Figure 9-7. Launch Vehicle Processing—Main Deck

Spacecraft Checkout Accommodations

Accommodations are available for spacecraft contractors to check spacecraft health and verify interfaces before and after integration with the launch vehicle. After the payload is integrated with the launch vehicle and all checkouts are complete, the integrated launch vehicle is transferred to the launch platform (fig. 9-8). Environmental conditioning and monitoring of the encapsulated spacecraft is ongoing, from encapsulation through launch.

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Figure 9-8. Launch Vehicle Transfer from Assembly and Command Ship to Launch Platform at Home Port

Launch Control Center

The launch control center is the primary center from which day-to-day and launch operations are conducted. The launch control center is located on the assembly and command ship shelter deck, as shown in figure 9-9. Layout of the console and display features of the room are shown in figure 9-10.

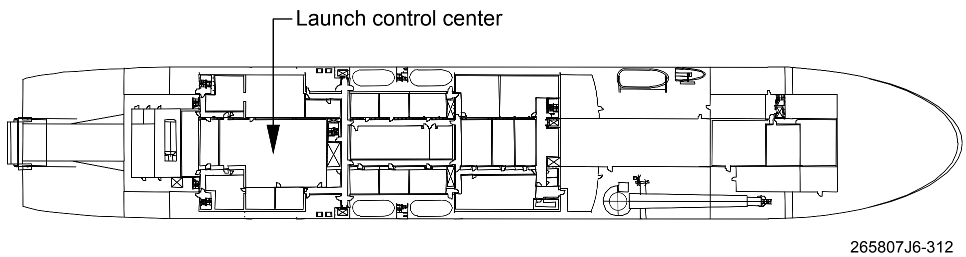

Figure 9-9. Launch Control Center—Shelter Deck

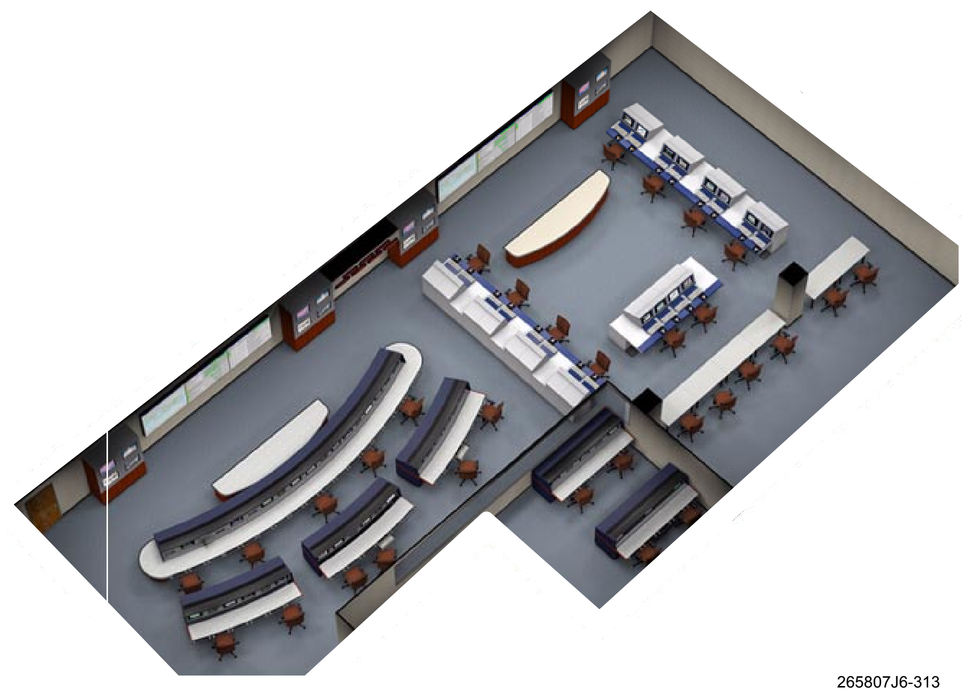

Figure 9-10. Launch Control Center

Mission Management and Display System

The launch control center contains operator consoles and seating, and provides connections with all shipboard communication systems.

The mission management and display system receives and processes information from the shipboard weather equipment, marine systems, closed-circuit television, Energia shipboard launch control system, Energia shipboard flight control system, the global positioning system, and other sources. The system displays information on large projection screens and television monitors at each operator console, and on television monitors at other locations on the assembly and control ship.

The computer system provides standard applications software for the operations and interconnection with other shipboard and on-shore personnel (through the external communications system) for file transfer, e-mail, and Internet capabilities.

Capabilities

Launch control center capabilities available to the customer include:

- Six console stations (fig. 9-11)
- Headset and telephones to connect each console station to the mission control communications network
- Countdown clocks, mission control information, and closed-circuit television camera views on the front wall

Data management network connection is provided by a local area network that allows Internet access through a local firewall server.

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Figure 9-11. View of Launch Control Center Consoles and Front Wall (Boeing/Customer Side of Room)

Viewing Room

Adjoining the launch control center is a viewing room for observing launch activities. This room contains seating for as many as 10 customers or prominent guests, allows observation of the launch control center, and provides access to the communications networks and telephone system.

Customer Work Areas

The spacecraft contractor and customer work areas are located on the first bridge deck directly above the launch control center (fig. 9-12). The area has ground support equipment rooms, office areas, conference rooms, individual offices, and storage rooms.

The ground support equipment rooms provide space for the equipment necessary to control and monitor the spacecraft during mission operations. The ship's overhead cranes load the ground support equipment onto the deck area just behind each room.

The ground support equipment rooms contain:

- Patch panels for hard-line links to the launch control center
- Countdown and countup clocks
- Public address, intercom, and telephone services
- Overhead monitor displays connected to closed-circuit television networks
- 120/208-V, 60-Hz and 220/380-V, 50-Hz power
- Uninterruptible power supplies for 60-Hz and 50-Hz power

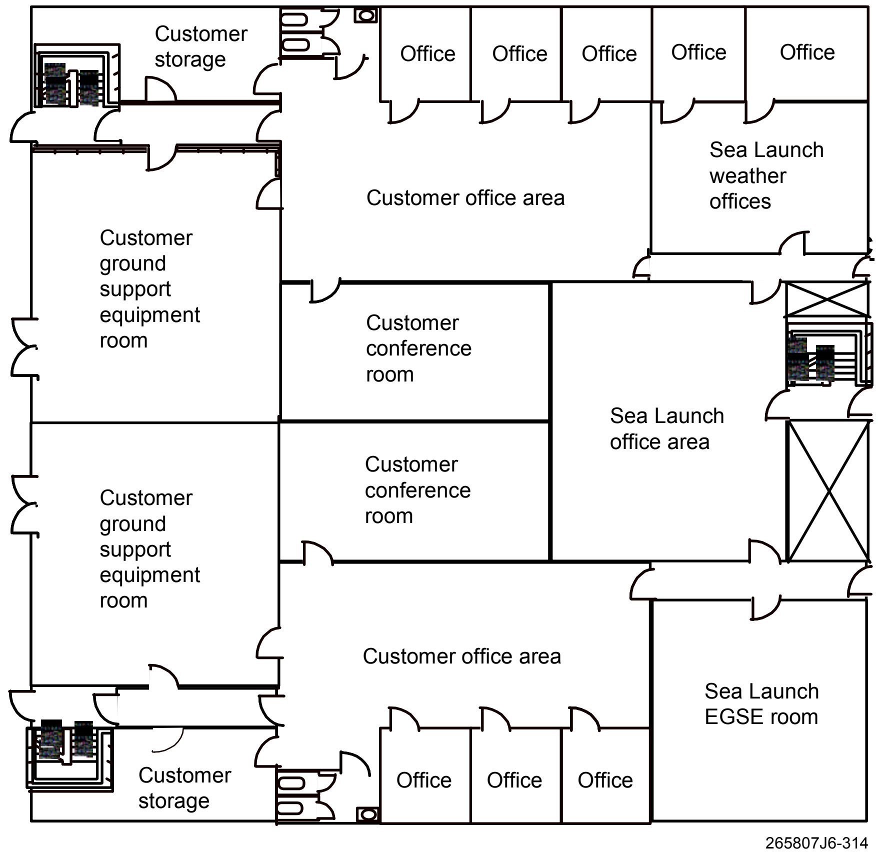

Figure 9-12. Spacecraft Contractor Work Area on First Bridge Deck

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Customer Office Areas

The two office areas for spacecraft customers consist of an open bay and three individual offices. A conference room and a storage room dedicated to customer use are also provided adjacent to the office area. Additional conference space is provided directly behind the launch control center.

Each conference room has seating, overhead projectors, and teleconferencing equipment.

Communication Satellite Services

Telephones, fax machines, teleconferencing, and data links are provided from the assembly and command ship to customer home locations through commercial communication satellite services (fig. 9-13). Radio frequency links between the assembly and command ship and the launch platform allow communications with the spacecraft in the hangar and on the launch pad, and between spacecraft ground support equipment rooms on the assembly and command ship and the launch platform.

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Figure 9-13. Assembly and Command Ship INMARSAT B

Cabin Accommodations

Customer and spacecraft contractor accommodations are located on the first bridge deck and the second bridge deck (fig. 9-14). The assembly and command ship has accommodations for a total of 15 customer and spacecraft contractor personnel (fig. 9-15). Crewmembers assigned to the assembly and command ship are allocated either individual or shared cabins.

As many individual cabins as possible are assigned. Some cabins are equipped with a separate fold-down bunk, which serves as a temporary berth for launch platform crewmembers who have transferred to the assembly and command ship during final launch preparations.

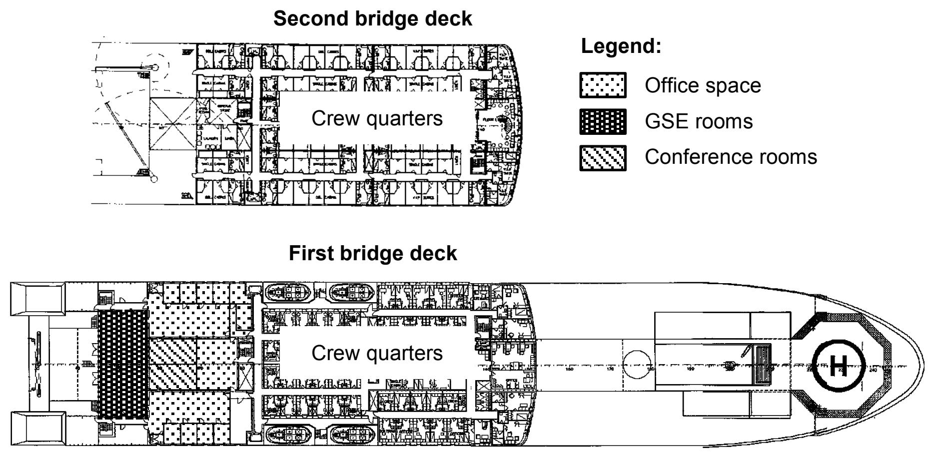

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Figure 9-14. Spacecraft Customer Accommodations

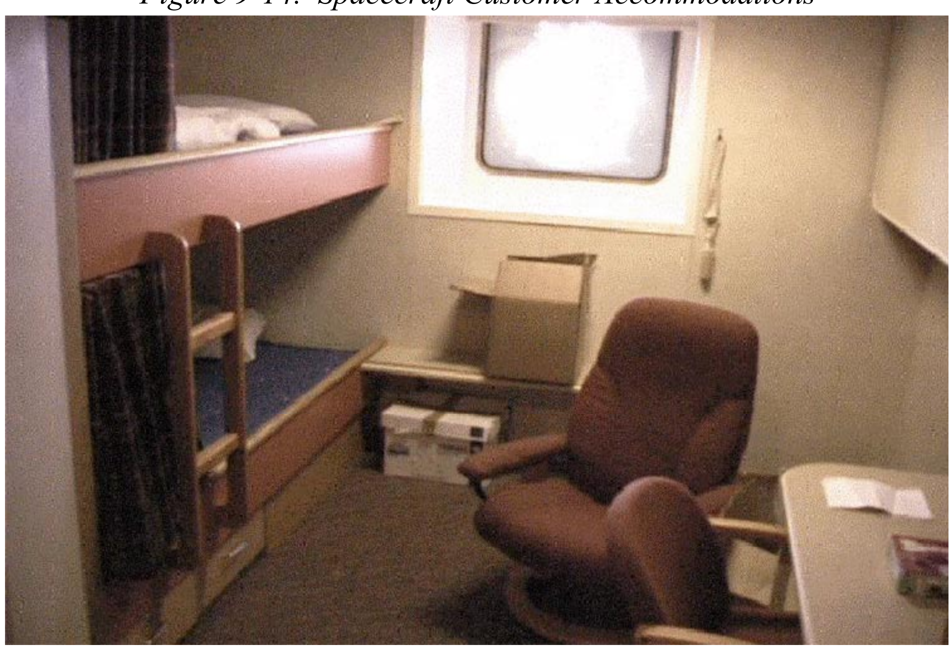

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Figure 9-15. Assembly and Command Ship Cabin Accommodations

Dining, Recreation, and Medical

The assembly and command ship provides many off-hours entertainment opportunities for the crews during the transit to and from the launch site. Regular meals are served by the Sea Launch catering staff in the dining hall (fig. 9-16).

Mealtimes are rearranged as necessary to support continuous operations at the launch site during final preparations. Other features of the assembly and command ship include a cafeteria, lounge, coffee lounge, theater, recreation room, exercise room, and sauna (fig. 9-17).

A hospital is also provided, and the assembly and command ship marine crew includes a doctor.

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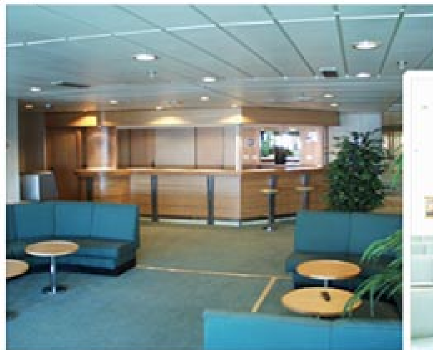
Figure 9-16. Main Cafeteria

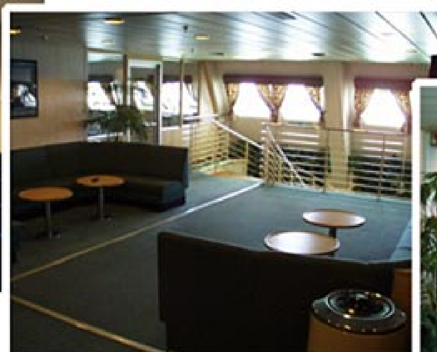
■ Cafeteria



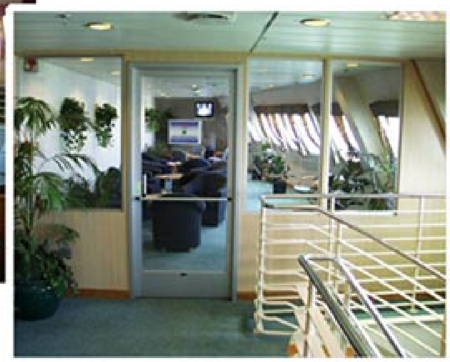
■ Coffee Bar

■ Lounge

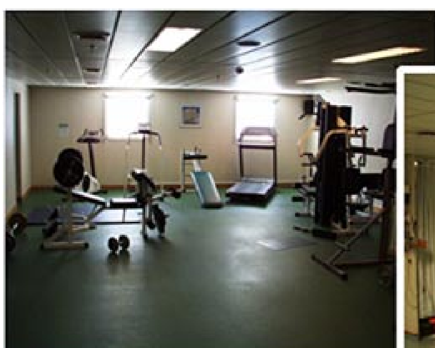
■ Theater



■ Forward Lounge



■ Smoking Lounge



■ Weight Room

■ Hospital

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Figure 9-17. Assembly and Command Ship Facilities

9.3 Launch Platform

Characteristics

The launch platform has all the necessary systems for erecting the integrated launch vehicle into the launch position, fueling the launch vehicle, and conducting launch operations (fig. 9-18). The launch platform transports the integrated launch vehicle to the launch site in the enclosed hangar on the launch deck. It also provides accommodations for the marine crew and the launch crew staffing the launch platform during transit to and from the launch site.

After the launch vehicle has been erected and all launch system checks are complete, the crewmembers are evacuated from the launch platform to the assembly and command ship using a link bridge between the vessels or by helicopter. Launch platform stationkeeping and launch operations are conducted remotely from the assembly and command ship through redundant radio frequency links between the vessels.

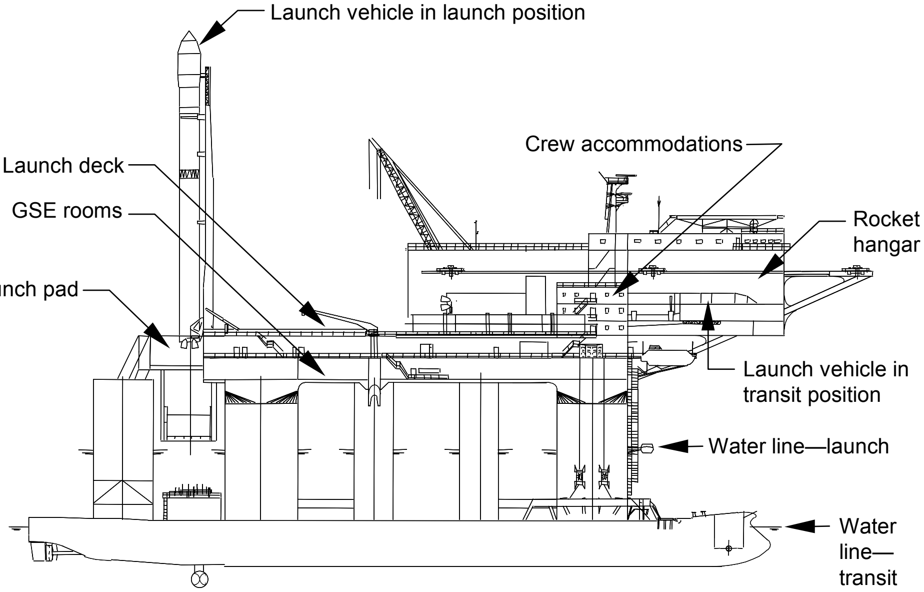

Figure 9-18. Launch Platform During Final Countdown

Specifications

The launch platform is an extremely stable platform from which to conduct launch operations. The launch platform rides catamaran style on a pair of large pontoons. It is self-propelled by a four-screw propulsion system (two in each aft lower hull), which is powered by four direct-current double armature-type motors, each of which are rated at 3,000 hp. Once at the launch location, the pontoons are submerged to a depth of 22.5 m (70.5 ft) to achieve a very stable launch position, level to within approximately 1 deg.

The ballast tanks are located in the pontoons and in the lower part of the columns. Six ballast pumps, three in each pontoon, serve them. The launch platform has an overall length of approximately 133 m (436 ft) at the pontoons, and the launch deck is 78 by 66.8 m (256 by 219 ft). Its overall transit displacement is approximately 27,400 tonnes (30,100 tons).

Accommodations

The spacecraft contractor work area (fig. 9-19) is located on the starboard side of the launch platform on the 38500 deck. This area has rooms for customer ground support equipment, offices, and storage.

Crew accommodations are located on decks 38500, 42500, and 45500, on either side of the launch vehicle hangar. The launch platform has accommodations for six spacecraft contractor personnel. Crewmembers assigned to the launch platform are allocated either individual or shared cabins.

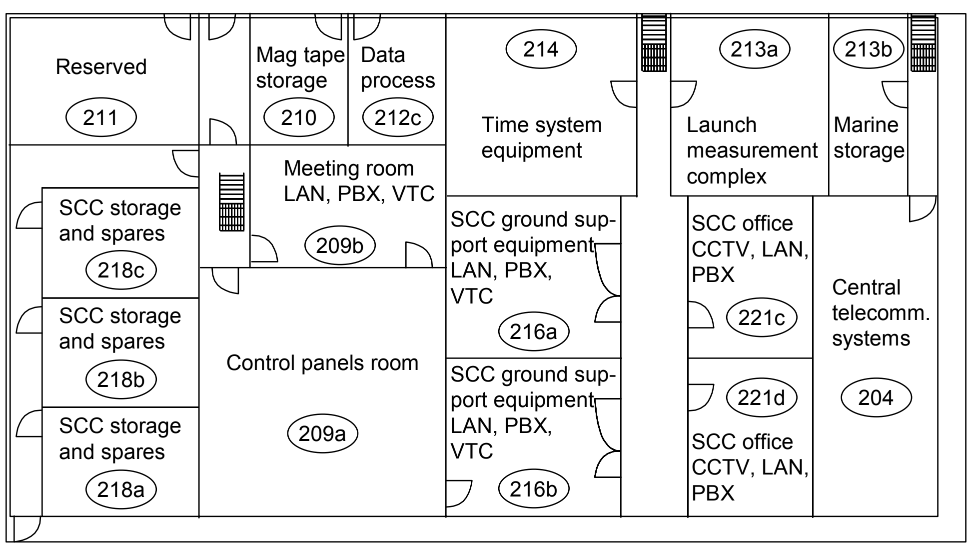

Figure 9-19. Spacecraft Contractor Work Areas on Launch Platform, 38500 Deck Level

Communications and Access

Telephones, fax machines, teleconferencing, and data links are provided on the launch platform. Radio frequency links allow communication between the assembly and control ship and the spacecraft, in the hangar and on the launch pad. Radio frequency links are also provided between spacecraft contractor ground support equipment rooms on the assembly and control ship and the launch platform.

In addition to radio frequency and hard-line connections to the spacecraft, physical access through doors in the payload fairing is available during the transit to the launch site. No physical access to the spacecraft is available once the launch vehicle is erected on the pad.

Dining, Recreation, and Medical

The launch platform has a recreation and video room for off-hours entertainment for the crew during transit to and from the launch site. Regular meals are served by the Sea Launch catering staff in the cafeteria. In addition, there is a small self-serve dining area to provide food and beverage service.

A hospital is also provided and the launch platform marine crew includes a doctor.

10.0 OPERATIONS SUPPORT SYSTEMS

10.1 Mission Support Systems

Overview

Sea Launch provides a number of support systems that are available for the customer's use in support of the launch, including:

- Communications
- Weather systems
- Helicopter support

The systems are described in further detail in this section.

Communications

Internal communication systems (fig. 10-1) are distributed between the assembly and command ship and the launch platform. This system includes closed-circuit televisions, telephones, intercom, public address, video teleconferencing, and vessel-to-vessel communications (also known as the line-of-sight system).

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Figure 10-1. INTELSAT Earth Terminal

Weather Systems

The assembly and command ship has a self-contained weather station with the central office located on the first bridge deck (fig. 10-2). Components of the weather system include a motion-stabilized C-band Doppler radar, upper-atmospheric balloon release station, surface wind instruments, wave radar, and ambient condition sensors. The onboard meteorologist has access to satellite imagery and information from an onsite buoy (fig. 10-3). Forecasts are provided periodically throughout the processing flow to verify operational weather constraints. Weather data is continuously updated for display on the mission management display system.

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Figure 10-2. Weather Office

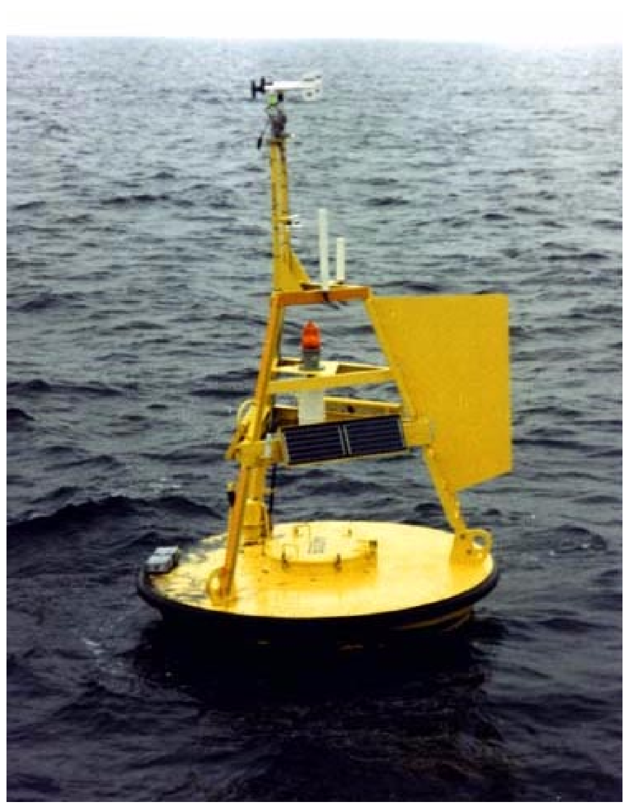

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Figure 10-3. On-Site Meteorological Buoy

Helicopter Operations

Sea Launch operates a Bell 230 helicopter (fig. 10-4) to support mission operations such as prelaunch and postlaunch platform inspections, downrange clearing of the launch corridor, perimeter security patrol, and additional functions. The aircraft can carry as many as eight passengers. The assembly and command ship and the launch platform are equipped with helicopter landing pads rated at 12,000 lb. The assembly and command ship is also equipped with a helicopter hangar and a 4,000-gal fuel storage tank. The helicopter has an operational range of 300 nmi and can be used for medical emergencies, if required.

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Figure 10-4. Sea Launch Bell 230 Helicopter

Photographic Services

The Sea Launch photo-optical measurement system has several components on the assembly and command ship and launch platform. On the launch platform, a high-speed film system and several sound-initiated still cameras are installed to document liftoff of the launch vehicle. On the assembly and command ship, an optical tracking system is provided (fig. 10-5). This tracking mount is equipped with a combination of high-speed film and video cameras outfitted with telescopic and zoom lenses to document the flight phase through fairing separation.

Digital cameras also are available on both vessels and at Home Port to support flight hardware closeouts, configuration documentation, or other photographic requirements.

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Figure 10-5. Optical Tracker

External Agency Coordination

Sea Launch also handles all coordination with external agencies that are required for launch notifications and to ensure compliance with the launch license.

These agencies issue the necessary advisories:

- FAA (air traffic)
- National Imaging and Mapping Agency (notice to mariners)
- NASA (orbital collision avoidance)

Sea Launch also sends out additional notices to mariners to all fisheries that may have vessels in the area and any local air traffic coordinators that may be affected.

10.2 Telemetry Assets

Overview

Sea Launch uses line-of-sight telemetry systems for the initial flight phase, as well as the Tracking and Data Relay Satellite System for later phases. The line-of-sight system, which includes the Proton antenna and the S-band system, is located on the assembly and command ship (figs. 10-6 and 10-7). Other telemetry assets include Russian ground tracking stations and the Energia Moscow control center. The following sections apply to launch vehicle and payload unit telemetry reception and routing.

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Figure 10-6. Proton Tracking Antenna

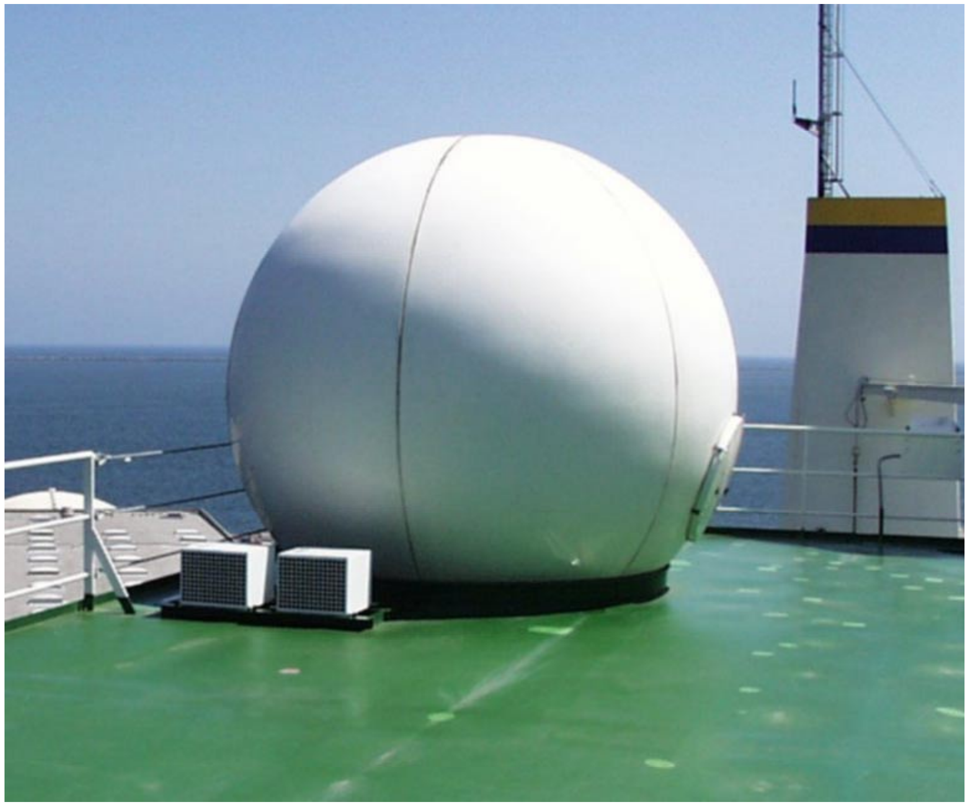

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Figure 10-7. S-Band System Radome

Flight Vehicle Line of Sight Coverage

Zenit and Block DM-SL data is received by the Proton antenna complex on board the assembly and command ship from shortly before liftoff until approximately 7 or 8 min into the flight. This data is sent first to assembly and command ship room 8, the Yuzhnoye telemetry area, and then to room 15, the Energia telemetry area.

Simultaneously, payload unit data is being received in room 94, the Boeing telemetry room, from the S-band system (fig. 10-7). The S-band system is capable of relaying very large amounts of data. Its duration is from shortly after liftoff until payload fairing separation, which occurs approximately 3 min into the flight. Following fairing separation, the payload unit telemetry system begins to deliver telemetry data through the Tracking and Data Relay Satellite System.

Tracking and Data Relay Satellite System

Sea Launch uses a unique dual telemetry stream with the Tracking and Data Relay Satellite System. Telemetry is simultaneously received from the Zenit stages, the Block DM-SL upper stage, and the payload unit during certain portions of the flight. The Block DM-SL upper stage and payload unit data are combined, but the Zenit data is sent to a separate Tracking and Data Relay Satellite System receiver. Zenit data is received shortly after liftoff at approximately 9 sec and continues until Zenit Stage 2/Block DM-SL separation, at around 9 min. This data is routed from the NASA White Sands Ground Station to the Sea Launch Brewster Ground Station and to the assembly and command ship. The data is also recorded at White Sands and at Brewster for later playback to the SDO Yuzhnoye design center in Dnepropetrovsk, Ukraine.

When the payload fairing separates, the payload unit transmitter shifts from sending high-rate payload accommodation data by line-of-sight to sending combined data from payload unit/Block DM-SL by Tracking and Data Relay Satellite System. The combined data is again routed from White Sands to Brewster, where it is separated into Block DM-SL and payload unit data and then sent on to the assembly and command ship. The data is received on board the ship through the INTELSAT communications terminal and routed to room 15 for upper-stage data and room 94 for payload unit data. Simultaneously, Brewster routes Block DM-SL data to the Energia Moscow Control Center. Tracking and Data Relay Satellite System coverage continues until after playback of the recorded Block DM-SL data. Data is also recorded at White Sands and Brewster for later playback.

Russian Tracking Facilities and Moscow Control Center

For missions where there may not be adequate Tracking and Data Relay Satellite System coverage, Russian tracking facilities may be brought on line. For low-inclination trajectories, the Block DM-SL will not be within line-of-sight of the Russian tracking facilities until it obtains sufficient altitude. When the Block DM-SL is within line of sight of a Russian tracking facility, telemetry is transmitted to the tracking facility and passed on to the Moscow Control Center and to the launch control center on the assembly and command ship by way of communication satellites. Telemetry recorded on board the Block DM-SL is also relayed to the ground station.

The Zenit's first and second stages are totally autonomous. A system called Kvant is also used during the countdown to load the flight data on board the Block DM-SL. When in view of ground stations, Kvant allows for an independent orbit determination by comparing uplink and downlink radio frequency carrier phase shifts. This orbit determination is separate from the onboard guidance telemetry.

During all phases of launch processing and flight, the launch control center on the assembly and command ship has ultimate responsibility and authority for all decisions and commands affecting the launch vehicle, Block DM-SL, and the spacecraft.

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11.0 SAFETY

Overview

This section describes the Sea Launch spacecraft customer safety integration and licensing process and details the requirements for safety approval. These include:

- The safety integration approach
- Safety assessment phases
- Launch licensing
- The safety of operations

All launches conducted by Sea Launch require safety evaluation and approval by the Sea Launch Safety and Mission Assurance Directors and licensing by the U.S. Department of Transportation Office of the Associate Administrator for Commercial Space Transportation.

To obtain safety approval, the customer will demonstrate that its equipment and operations comply with established Sea Launch safety requirements. Sea Launch requires the customer to provide necessary data to assess all potential hazards introduced by the spacecraft processing and launch activities and effectiveness of control measures used by both the customer and Sea Launch.

Authority

Sea Launch is responsible for safety of operations and compliance with federal, state, and local codes and regulations. The Sea Launch President and General Manager delegates responsibility and authority for management of the safety program to the Sea Launch Safety and Mission Assurance Directors.

The Sea Launch Safety Director has prime responsibility for implementation and maintenance of the Sea Launch system safety program, as documented in the *Sea Launch System Safety Plan*, Boeing document D688-10014-1.

11.1 Safety Integration Approach

Overview

Sea Launch uses a three-phase approach to define data required and to conduct reviews for new launch customers or the first launch in a series of launch missions. Follow-on missions with similar spacecraft and operations use an abbreviated version of this approach, in which changes to the previously approved mission are identified and discretely approved. This process and the required safety data are identified in chapter 3 of the *Sea Launch Safety Regulations Manual*, Boeing document D688-10024-1.

Customer Responsibilities

The customer must demonstrate to Sea Launch that the spacecraft payload, support equipment, and operations comply with established Sea Launch safety regulations. For this approval, the customer submits documentation describing the hazardous elements of the spacecraft, support equipment, and operations, and participates in periodic mission reviews.

Sea Launch Responsibilities

Sea Launch incorporates customer safety data into a spacecraft interface hazard analysis to assess impacts to the Sea Launch system. A safety review schedule and data submittal agreement is established during initial customer interface discussion and documented in the customer/Sea Launch mission integration schedule and customer/Sea Launch safety agreement.

Safety and Readiness Reviews

Sea Launch conducts safety review phases concurrent with mission preliminary design review and critical design review phases where applicable. A ground operations readiness review is conducted before beginning spacecraft and payload unit operations at Home Port. This completes the safety review and approval process.

A mission readiness review is conducted before vessels leave Home Port for the launch site. A launch readiness review is conducted before launch countdown operations begin. These reviews ensure that preparations for launch have been completed and all conditions of the launch license have been met.

Any open safety issues following the mission readiness review and launch readiness review will be recorded and final disposition completed and agreed to by the mission director before beginning operations.

Figure 11-1 shows the Sea Launch phased safety integration process and data development and reviews.

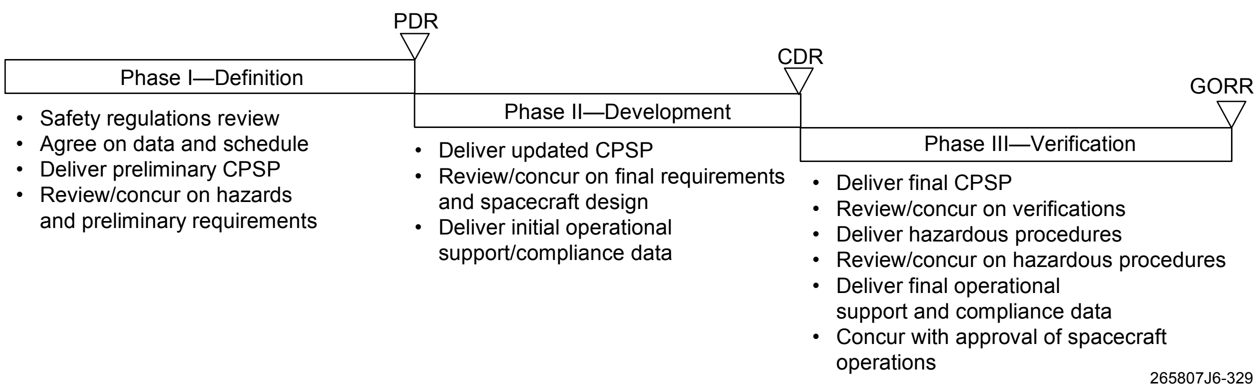

Figure 11-1. Sea Launch Safety Integration Process

11.2 Safety Assessment Phases

The three safety assessment phases required by Sea Launch are:

- Definition phase
- Development phase
- Verification phase

This section defines responsibilities and completion criteria for the customer and Sea Launch.

Phase I — Definition

The responsibilities of the customer during the definition phase are to:

- Review the Sea Launch safety regulations and identify applicability and tailoring necessary
- Coordinate with Sea Launch to define requirements unique to the customer, agree on final definition of safety data deliverables, and review and approve schedules
- Prepare and submit documentation addressing all hazards associated with the spacecraft and spacecraft processing and the requirements to control the identified hazards in the preliminary spacecraft design

The responsibilities of Sea Launch during this phase are to:

- Coordinate tailored customer safety requirements and safety data deliverables, and review and approve schedules
- Review the customer prelaunch safety package and coordinate questions and issues with the customer for resolution
- Compare the customer equipment designs and hazard control requirements with Sea Launch safety regulations to ensure that minimum system interface requirements are met

This definition phase will be completed when all hazards and hazard causes have been identified and means for eliminating, reducing, or controlling the hazards have been defined.

This phase is anticipated to conclude at the mission preliminary design review.

Phase II — Development

The customer responsibilities during the development phase are to:

- Submit updated customer prelaunch safety package documentation describing final hazard definition, final hazard control requirements, and final spacecraft system design
- Define planned hazardous systems manufacturing, qualification, and acceptance verification methodology (e.g., hazard analyses, test reports, and inspection records) that satisfy the hazard control requirements and system design identified during Phase I
- Define safety-critical operational methodology and systems to be used for spacecraft processing and for hazard mitigation. Include preliminary identification of procedures to be used at Home Port and on board vessels to control hazardous spacecraft processing operations

This development phase will be completed when final hazard identification, final spacecraft system design, preliminary procedures, and specific safety verification methods have been identified and agreed on.

This phase is anticipated to conclude at the mission critical design review.

Phase III — Verification

Customer responsibilities for the verification phase are to:

- Submit verification and acceptance documentation showing compliance to established safety requirements as defined in Phase II
- Submit hazardous operations procedures for Sea Launch review and approval for any operations defined as hazardous
- Provide specific operations supporting information on hazardous materials, personnel qualifications and training, and critical support equipment certification. Individual customer personnel training on use and maintenance of equipment and appropriate medical evaluations are to be identified in the qualifications and training certification records

Sea Launch will review and compare verification data to safety requirements and verification identified in Phases I and II. Spacecraft customer procedures will be incorporated within existing Sea Launch procedures to form a coordinated, mission-specific document set for processing and launch operations. After implementation of all changes considered necessary and approval of operating procedures and supporting data, Sea Launch Safety will approve the planned customer operations.

During this verification phase, the spacecraft interface hazard analysis will be completed and closed.

This phase is anticipated to conclude at the ground operations readiness review and must be completed before the start of spacecraft processing at Sea Launch facilities.

Following completion of Phase III and the readiness review, customer-processing operations at Home Port may begin.

11.3 Launch Licensing and Flight Safety

Authority and Licensing

Sea Launch supports safety evaluation and obtains licensing by the U.S. Department of Transportation Office of the Associate Administrator for Commercial Space Transportation (FAA/AST).

After successfully demonstrating the repeatability and reliability of the Sea Launch operations concept, FAA/AST granted Sea Launch a launch operator's license in 2002, which authorizes the conduct of missions with launch azimuths ranging between 7° N and 7° S, without the need to apply for launch-specific licenses each time. The Sea Launch operator's license is valid for 5 years. For missions outside the licensed range of launch azimuths, launch-specific license applications will still be required.

Licensing Requirements

Information supplied by the customer is incorporated into the application package submitted to the FAA/AST by Sea Launch for licensing. This information includes:

- Data on the breakup characteristics of the spacecraft to verify that casualty probabilities remain within program FAA guidelines should a flight failure occur
- Spacecraft ownership and operator, final orbit, and licensing for radio frequency transmissions
- List of hazardous materials on board the spacecraft to support review of the potential environmental impacts should a launch failure occur

FAA/AST Compliance

All launch licenses issued by the FAA/AST require review of the potential environmental impacts of the Sea Launch system and launch operations. Spacecraft hazardous materials are considered impacts on the environment should a launch failure occur. The FAA/AST conducted an environmental assessment to cover the entire scope of Sea Launch operations, and a finding of no significant impact was issued. Spacecraft environmental characteristics must not compromise the terms of the finding of no significant impact.

Sea Launch complies with FAA/AST requirements to minimize orbital debris by a contamination and collision avoidance maneuver of the orbiting upper stage (Block DM-SL). The contamination and collision avoidance maneuver moves the stage away from the spacecraft a safe distance to a disposal orbit. At the completion of the contamination and collision avoidance maneuver, all Block DM-SL main engine propellants and gases are vented, all valves are latched open, and all power is depleted.

Launch Operation Coordination

Before and during launch operations, Sea Launch coordinates with appropriate U.S. Government agencies to issue warnings in the interest of public safety. Coordination includes identification of four points along the trajectory:

- Immediate launch area
- Stage 1 impact area
- Fairing impact area
- Stage 2 impact area

Sea Launch coordinates launches with the following agencies:

- FAA/Central Altitude Reservation Function
- United States Space Command (through NASA)
- National Imagery and Mapping Agency

After the vessels sail for launch operations, FAA/AST representatives accompany the launch team on board the vessels to fulfill their responsibilities for oversight of the launch and flight. Sea Launch assists onboard FAA/AST representatives in compliance monitoring of the terms and conditions of the license.

11.4 Safety of Operations

Operational Safety Requirements

Operational safety requirements governing customer operations in Sea Launch facilities are defined in chapter 4 of the *Sea Launch Safety Regulations Manual*, Boeing document D688-10024-1. These requirements ensure safety of personnel and equipment in preparing and launching the spacecraft.

The customer responsibilities for activities that occur in Sea Launch facilities and on Sea Launch vessels are to:

- Coordinate all customer activities with Sea Launch operations and safety functions
- Identify all hazardous spacecraft processing operations anticipated in Sea Launch facilities and vessels
- Develop customer- and spacecraft-unique procedures
- Train personnel
- Provide and maintain all unique personnel protection equipment required to support spacecraft operations independent of or in addition to normal facility and vessel operations
- Ensure that requested Sea Launch provided personnel protective equipment and services are identified in the applicable interface requirements document and spacecraft campaign document
- Provide a safety contact within the processing team who will be part of the safety organization at Home Port and on board the vessels

Sea Launch will monitor safety during customer highly hazardous operations at Home Port.

Safety Training

Customer personnel will be skilled in spacecraft processing operations conducted in Sea Launch facilities and vessels.

Customer personnel working with Sea Launch equipment in Sea Launch facilities are required to complete orientations in equipment familiarity, emergency procedures, and facility-unique constraints.

Customer personnel needed for operations on board Sea Launch vessels will be provided specialized safety training for operations and emergency procedures unique to the ship and maritime environment.

12.0 SYSTEM RELIABILITY

Overview

Sea Launch understands the need for a reliability program to support insurance, licensing, and customer-related inquiries. Sea Launch has a reliability program that has proved to provide a highly reliable product and launch capability. The program consists of:

- Predictions; tracking Zenit-3SL
- Critical item identification
- Anomaly resolution
- Status and meeting support

This section describes reliability enhancements and continued reliability growth.

Reliability

The predicted reliability of the Zenit-3SL compares favorably with that of other existing launch vehicles. The average flight success ratio of comparable launch vehicles is predicted to be 95.6%.

The predicted reliability of the Zenit-3SL is 96.9% and encompasses the implementation of fixes for previous failures in the Block DM and Zenit stages. The Block DM-SL and Zenit first and second stages all have minor modifications to adapt them for use within the Sea Launch system.

Based on planned validation involvement and shared reliability improvements from each of the Sea Launch partners, we are confident we can maintain and improve the stated reliability capability of 96.9% for the Zenit-3SL.

Reliability Subsystems and Components

Zenit-3SL reliability is enhanced by the use of mature subsystems and components, the extensive use of redundancy for fault tolerance in mission-critical areas, ample design parameter margins (e.g., strength, stability, and propulsion), manufacturing quality monitoring, and extensive testing of flight hardware.

Anomaly Resolution System

The Sea Launch anomaly resolution system, based on the existing Boeing failure review, analysis, and corrective action system used on several integrated air vehicles and avionics platforms, has been established along with a system database. The anomaly resolution system is in place to acquire and assess failure history, criticality, and effectiveness of changes, and to be used as a database from which recommendations can be validated. The anomaly resolution system is also used to gather data on test and flight failures, design changes, test results, and repair decisions.

Ensuring Reliability Growth

Sea Launch has processes and plans in place to ensure continued reliability growth (fig. 12-1).

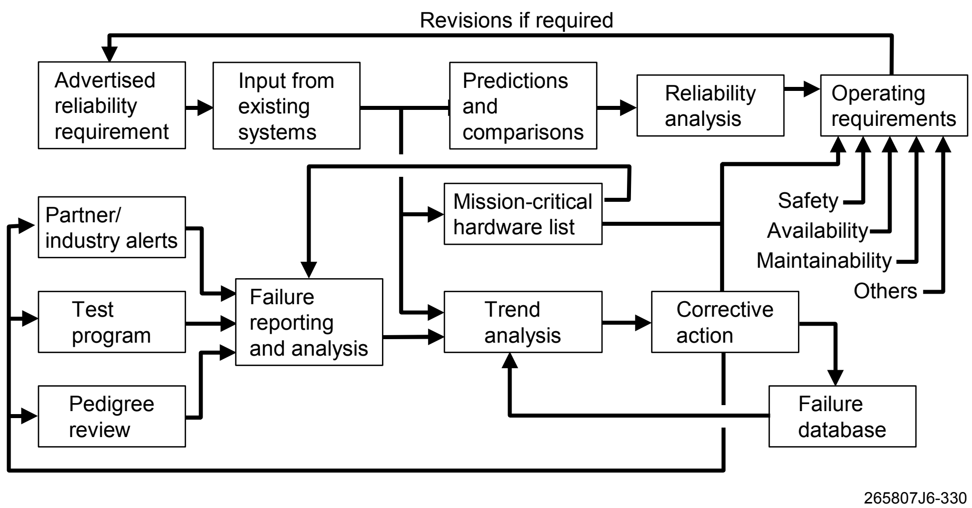

Figure 12-1. Anomaly Resolution System

APPENDIX A

User Questionnaire

When completed, this questionnaire provides BLS and BCSC, acting on behalf of the Sea Launch Company, LLC, with the preliminary data necessary to begin evaluation of the compatibility of the Sea Launch system with a new spacecraft type and to start the integration process. Companies considering the Sea Launch system should complete this questionnaire and return it to:

Boeing Launch Services

5301 Bolsa Avenue

Huntington Beach, CA

92647-2099, USA

(Attention: Customer Engineering)

BLS and BCSC will treat this data as customer proprietary information and will not disclose any part of the information contained herein to any entity outside the Sea Launch Company, LLC, without expressed written permission.

For further information contact:

Fred Schriener

Phone: 714-896-4554 (X-5195)

Fax: 714-896-4554

User Questionnaire

Spacecraft Physical Characteristics	SI Units		English Units	
Maximum height above interface plane	_______	mm	_______	in
Spacecraft protrusions below interface plane (drawing)				
Maximum cross-sectional area	_______	mm	_______	in
Static envelope drawing				
Adapter interface drawing				
Spacecraft volumetric displacement	_______	m^3	_______	ft^3
Spacecraft free-air volume	_______	m^3	_______	ft^3
Spacecraft coordinate system (drawing)				
Mass properties* at launch (and separation, if different)	Dry/wet		Dry/wet	
Mass	_______	kg	_______	lb
Center of gravity (origin on centerline, at I/F plane)				
X axis (X assumed to be longitudinal axis)	_______	mm	_______	in
Y axis	_______	mm	_______	in
Z axis	_______	mm	_______	in
Moments and products of inertia about the CG				
Ixx	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
Iyy	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
Izz	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
Ixy	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
Ixz	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
Iyz	_______	$kg\text{-}m^2$	_______	$slg\text{-}ft^2$
PLF access hatches (drawing)	_______			
Size	_______			
Location	_______			
Purpose	_______			
When are they used?	_______			

* Identify values as maximum, minimum, or nominal and list tolerances as appropriate.

Spacecraft Orbit Parameters	SI Units	English Units
Final orbit apogee	______ km	______ mi
Final orbit perigee	______ km	______ mi
Final orbit inclination	______ deg	
RAAN	______ deg	
Argument of perigee	______ deg	
Launch date	____________	
Launch window	______ min	

Guidance Parameters

Maximum angular rate at separation		
Roll/spin	______ deg/sec	
Tolerance	± ______ deg/sec	
Pitch and yaw	______ deg/sec	
Tolerance	± ______ deg/sec	
Separation attitude	____________________	
Separation velocity	______ m/sec	____ ft/sec
Maximum pointing error (cone angle)	______ deg	
Maximum tipoff rate	______ deg/sec	
Minimum tipoff rate (if applicable)	______ deg/sec	
Maximum angular acceleration	______ deg/sec^2	

Electrical Interface

In-flight separation connectors		
MS part number (flight)	________________	
MS part number (EGSE)	________________	
Electrical power requirements		
External power for spacecraft bus		
Voltage	________________	V
Current	________________	A
Battery charging		
Battery voltage	________________	V
Maximum current	________________	A
Hard-line link		
Link required	Y / N	
Remote bus voltage sense	Y / N	
Baseband command rate	________________	bps
Command baseband modulation	________________	
Baseband telemetry PCM code	________________	
Baseband telemetry rate	________________	bps
RF link (re-rad)		
RF telemetry link required?	Y / N	
If Yes, complete the following table.		

Effective isotropic radiated power	**(dBW)**
Maximum	-
Nominal	
Minimum	
Antenna gain (referenced to boresight)	(dB)
0	
±10 deg	
±20 deg	
±30 deg	
±40 deg	
±60 deg	
±80 deg	
Antenna location	(mm)
Xsc	
Ysc	
Zsc	
Antenna location	(mm)
Xsc	
Ysc	
Zsc	
Antenna boresight	
Polarization	
Bandwidth	
Transmit frequency	
Subcarrier frequency	
Data rate	
Subcarrier modulation	
Carrier modulation	
Carrier modulation index	
Required link error rate (BER)	

RF command link required? Y / N

If Yes, complete the following table.

Required Flux Density at Spacecraft Antenna	(dBW/m^2)
Maximum	
Nominal	
Minimum	
Antenna gain (refers to boresight)	
0 deg	
±10 deg	
±20 deg	
±30 deg	
±40 deg	
±60 deg	
±80 deg	
Antenna location	(mm)
Xsc	
Ysc	
Zsc	
Antenna boresight	
Polarization	
Frequency (only one at a time)	
Carrier modulation	
Data rate	
Required carrier-to-noise density at spacecraft antenna	

External communications ____________________

Ethernet ____________________

RS422 ____________________

Brewster link ____________________

In-flight interfaces ____________________

Serial PCM? Y / N

Number of channels ____________________

PCM code ____________________

Data rate ____________________

Analog telemetry? Y / N

Number of channels ____________________

Samples per second ____________________

Digital telemetry (discrete) ____________________

Number of channels ________________________

In-flight discrete commands ________________________

Number of commands ________________________

Contact closure or voltage pulse ________________________

Times of occurrence ________________________

Duration ________________________

Status requirements ________________________

Separation break wires ________________________

Numbers required ________________________

Electromagnetic radiation curve ________________________

Spacecraft missions

Spacecraft requirements

Does the spacecraft have any special EMC concerns (e.g., lightning or RF protection)?

What frequencies of intentional emitters (ACS, LP, and LV) are of special interest to the spacecraft?

What are the spacecraft sensitivities to magnetic fields?

When in launch configuration, which antennas will be radiating?

Thermal Environment	**SI Units**	**English Units**
Spacecraft allowable air temperature range		
Ground processing (pre-PLF encapsulation)	____ to ____ °C	____ to ____ °F
After encapsulation	____ to ____ °C	____ to ____ °F
Prelaunch	____ to ____ °C	____ to ____ °F
EGSE allowable air temperature range		
Ground processing	____ to ____ °C	____ to ____ °F
On ACS	____ to ____ °C	____ to ____ °F
On LP	____ to ____ °C	____ to ____ °F
Allowable humidity range		
Spacecraft processing	________ % to	________ % RH
After encapsulation in PLF	________ % to	________ % RH
Prelaunch	________ % to	________ % RH
EGSE	________ % to	________ % RH
Maximum ascent heat flux (pre-PLF jettison)		
	________	________
	________	________
Maximum free molecular heat flux		
At PLF jettison	________ W/m²	________ W/ft²
Following PLF jettison	________ W/m²	________ W/ft²
Maximum ascent depressurization rate	________ Pa/s	________ psi/s
Maximum ascent differential pressure	________ Pa	________ psi
Maximum differential at PLF jettison	________ Pa	________ psi
Thermal maneuver requirements in flight	________________	
Orientation requirements in flight	________________	
Heat dissipation	________	
Spacecraft processing	________ W	
After encapsulation	________ W	
Prelaunch	________ W	
What thermal analyses are required of Sea Launch?	________________	

Dynamic Environment

	Vertical		Cantilevered	
Allowable acceleration loads				
Lateral	________	g	________	g
Axial	________	g	________	g
Allowable vibration curve at interface				
Sinusoidal				
Random				
Allowable acoustics environment				
Allowable shock curve				
Fundamental natural frequencies				
Axial	________	Hz		
Lateral	________	Hz		
Maximum allowable air impingement	________	ft^3/min		

Ground Processing Requirements

		SI Units	English Units
Match mate test?	Y / N		
Test location			
Payload separation system (PSS) firing required?	Y / N		
SCA separation distance		______ mm	______ in
Transportation to Home Port			
Spacecraft			
Transport method			
Location delivered to (e.g., airport, seaport, or Home Port)			
Spacecraft container dimensions	Height	______ m	______ ft
	Width	______ m	______ ft
	Length	______ m	______ ft
Container weight (with spacecraft)		______ kg	______ lb
CG of shipping container			
Environmental control and monitoring equipment			
Special handling considerations			
GSE			
Number of GSE shipping containers	______		
Maximum container dimensions		___ m x ___ m x ___ m	___ ft x ___ ft x ___ ft
Maximum container weight (loaded)		______ kg	______ lb
Delivered with spacecraft?	Y / N		
Transport method			
Location delivered to			
Environmental control and monitoring equipment			
Special handling considerations			
Home Port			
Spacecraft dimensions with handling fixture		___ m x ___ m x ___ m	___ ft x ___ ft x ___ ft
Spacecraft weight with handling fixture		______ kg	______ lb
Time required in processing facility	______ days		

Ground Processing Requirements (continued)

Standard facility services provided at Home Port are outlined in Section 8 of the User's Guide. Any special services required by the user should be described below.

Spacecraft
- Handling ____________________
- Electrical power ____________________
- Temperature/humidity ____________________
- Grounding, ESD control ____________________
- RF ____________________
- Cleanroom ____________________
- Consumables or commodities ____________________
- Environmental monitoring ____________________
- Hazardous materials storage ____________________
- Ordnance storage ____________________
- Other ____________________

EGSE
- Handling ____________________
- Electrical power ____________________
- Temperature/humidity ____________________
- Other ____________________

Operations
- Communication requirements ____________________
- Storage ____________________
- Security ____________________
- Office space ____________________
- Access (disabilities, equipment) ____________________
- Other ____________________

____

Ground Processing Requirements (continued)

ACS (PLU/LV integration)

How long can the spacecraft remain encapsulated and in horizontal orientation? ____________________

Describe spacecraft access requirements on the ACS. ____________________

Standard facility services provided on the assembly and command ship are outlined in Section 10 of the User's Guide. Any special services required by the user should be described below.

- Spacecraft ____________________
  - Electrical power ____________________
  - PLF temperature, humidity, and cleanliness ____________________
  - RF control ____________________
  - PLF access (frequent environmental controls) ____________________
  - Purges ____________________
  - Consumables ____________________
  - Environmental monitoring ____________________
  - Other ____________________
- EGSE (size and weight) ____________________
  - Electrical power ____________________
  - Temperature/humidity ____________________
  - Other ____________________
- Operations
  - Communications ____________________
  - Storage ____________________
  - Security ____________________
  - Personnel accommodations ____________________
  - Office space ____________________
  - Other ____________________

Ground Processing Requirements (continued)

LP (transit, prelaunch, launch operations)

Describe spacecraft access requirements on the LP. ______________________

Standard facility services provided on the launch platform are outlined in Section 10 of the User's Guide. Any special services required by the user should be described below.

Spacecraft

- Electrical power ______________________
- PLF temperature, humidity, and cleanliness ______________________
- RF control ______________________
- PLF access (frequent environmental controls) ______________________
- Purges ______________________
- Consumables ______________________
- Environmental monitoring ______________________
- Access ______________________
- Other ______________________

EGSE (size and weight) ______________________

- Electrical power ______________________
- Temperature/humidity ______________________
- Other ______________________

Operations

- Communications ______________________
- Storage ______________________
- Security ______________________
- Personnel accommodations ______________________
- Office space ______________________
- Other ______________________

Contamination Control Requirements

Facility environments (indicate any applicable environmental limits for your payload):

Airborne particulates	________	(per FED-STD-209)
Airborne hydrocarbons	________	ppm
Nonvolatile residue rate	________	mg/m^2 - month _____ mg/ft^2 - month
Particle fallout rate	________	% obscuration/day

What are your prelaunch spacecraft cleanliness requirements and verification methods (e.g., visibly clean, percentage of obscuration, NVR wipe)?

Do you have launch phase allocations for contamination from the booster?

If yes, indicate allocations:

	Molecular ($\mu g/cm^2$)	Particulate (percentage of obscuration)
Thermal control surfaces	________	________
Solar array	________	________
Optical surfaces	________	________
Star tracker or sensors	________	________
Other	________	________

Do you require a gaseous spacecraft purge? ____________

Type and quality of gas ________________________________

Continuous or intermittent ________________________________

What are your specific cleanroom garment requirements (e.g., smocks, coveralls, caps, hoods, gloves, or booties)?

Do you have any specific cleanroom process restrictions (e.g., use of air tools, air pallets, welding, or drilling)?

Other special contamination control requirements:

APPENDIX B. SEA LAUNCH STANDARD OFFERINGS AND OPTIONS

This appendix lists Sea Launch standard offerings and options for:

- Standard-offering hardware
- Standard-offering launch services
- Standard-offering facilities and support services
- Optional services

STANDARD-OFFERING HARDWARE

The following sections list the basic hardware items and associated services that will be provided for a Sea Launch mission.

Payload Accommodations

Standard accommodations include:

- Payload fairing with up to two access doors and a customer logo
- Spacecraft adapter with compatible mechanical interfaces and separation system—current standard-offering spacecraft adapters are SCA1194VS, SCA1666, SCA702+, and SCA702+GEM (contact Sea Launch for adapters not listed)

Launch Vehicle

Sea Launch vehicle configuration includes:

- Zenit two-stage booster with tailored flight software
- Block DM-SL upper stage with tailored flight software

Electrical Interfaces

Radio frequency interfaces

Radio frequency (command and telemetry) links between spacecraft and spacecraft electrical ground support equipment in the payload processing facility and when the integrated launch vehicle is erect at the launch site by means of a rerad system.

Hard-line interfaces include:

- Two in-flight disconnect connectors for telemetry, command, and power interfaces to the spacecraft
- Hard-line (command and telemetry) umbilical links
- Up to two serial data telemetry streams
- Up to four analog telemetry channels
- Up to eight discrete telemetry inputs
- Up to four redundant (primary and backup) commands
- In-flight disconnect break wires as needed

Environmental Controls

Sea Launch will maintain spacecraft environments within the limits specified in the spacecraft/Sea Launch interface control document while the spacecraft is in the payload processing facility and encapsulated in the payload unit.

Interface Test

For each first-of-type spacecraft, Sea Launch will perform a matchmate test at the spacecraft factory that includes the spacecraft adapter and a flight-equivalent separation system. Matchmate tests consist of mechanical and electrical interface testing between the spacecraft and the spacecraft adapter.

STANDARD-OFFERING LAUNCH SERVICES

The following sections list the basic launch services that are provided for a Sea Launch mission.

Mission Management

- Sea Launch management—includes program-level services, such as contracts, cost, scheduling, and program management.
- Mission management—includes mission-specific activities, such as integration, analysis, and operations.

Meetings and Reviews

Meeting and milestone reviews include:

- Customer kickoff meeting
- Preliminary interface control document review
- Mission integration review (including final interface control document review)
- Safety review board
- System readiness review
- Ground operations working group and technical interchange meetings (as required to ensure regular contacts with the customer)
- Ground operations readiness review (ready to receive spacecraft)
- Combined operations readiness review (ready to mate spacecraft to payload accommodations)
- Payload/integrated launch vehicle transfer readiness review (ready to integrate payload unit to launch vehicle)
- Mission readiness review (ready to leave Home Port)
- Launch readiness review (ready to launch)
- Postlaunch customer review

Documentation

Generic

The following documents will be provided to each customer according to the agreed-to mission integration schedule:

- *Generic Analysis Plan*
- *Sea Launch Operations Plan*
- *Sea Launch Facilities Handbook* for customers
- *Electromagnetic Interference and Electromagnetic Compatibility Plan*
- *Contamination Control Plan for Sea Launch Operations*
- *Sea Launch Safety Regulations Manual*
- *Sea Launch System Safety Plan*
- *Sea Launch Security Plan*

Mission specific

The following documents will be provided to each customer according to the mission integration schedule (developed by Sea Launch with customer concurrence after mission identification):

- Mission integration schedule
- Spacecraft/Sea Launch system interface control document
- Spacecraft campaign document
- Launch schedule
- Launch description document
- Launch commit criteria
- Countdown and master procedures
- Matchmate plan (if required)

Mission Integration

Analyses

The following analyses will be conducted and documented as described in the generic analysis plan. Unless noted otherwise, each analysis will involve two cycles (preliminary and final) for first-time integration and one cycle for repeat integration.

- Mission design
- Spacecraft shock analysis (one cycle for both first-time and repeat integration)
- Spacecraft acoustic analysis
- Spacecraft separation analysis
- Critical clearance analysis (dynamic)
- Coupled loads analysis
- Integrated launch vehicle structural assessment (one cycle for both first-time and repeat integration)
- Prelaunch environmental control system analysis (normal and abort scenarios)
- Flight thermal analysis
- Venting analysis
- Contamination assessment
- Electromagnetic compatibility assessment
- Avionics and electrical interface assessment (one only for first-time and repeat integration)
- Spacecraft on-pad link analysis (one cycle for both first-time and repeat integration)
- Spacecraft/payload accommodations clearance analysis (static)
- Postflight analysis (one cycle for both first-time and repeat integration)

Verification

Sea Launch will perform verification of spacecraft requirements as defined in the spacecraft/Sea Launch system interface control document.

Separation state vector

A spacecraft separation state vector is provided to the customer within 50 min of separation.

Transportation

Sea Launch provides:

- Assistance to the customer for obtaining ground transportation for the spacecraft and support equipment from any Los Angeles–area airport or seaport to Home Port, and return of support equipment after the flight
- Assistance in customs procedures for the spacecraft and its associated support equipment

Home Port Activities

Primary prelaunch events include:

- Fit check—a spacecraft-to-spacecraft adapter fit check conducted at Home Port
- Spacecraft checkout and fueling
- Encapsulation
- Payload unit checkout
- Payload unit/launch vehicle integration
- Integrated launch vehicle integrated test
- Transfer of the integrated launch vehicle to the launch platform
- Payload unit and spacecraft radio frequency end-to-end test

Transit Activities

At-sea operations include:

- Transportation of the integrated launch vehicle, ground support equipment, and customer launch support personnel to and from the launch site (on board the assembly and command ship and launch platform)
- Operational rehearsals
- Monitoring of spacecraft environments and support spacecraft operations

STANDARD-OFFERING FACILITIES AND SUPPORT SERVICES

The following sections list the facilities and support services available to each Sea Launch customer.

Home Port (HP)

Home Port facilities are described in detail in the Sea Launch Facilities Handbook for customers. Facilities at Home Port are available to the customer for approximately 60 days during the launch campaign. All customer equipment must be removed from Sea Launch facilities within 3 workdays after the vessels return to Home Port following launch.

Customer operations may be scheduled on a 24-hr basis with access to the customer office building and the payload processing facility.

HP Facilities

- Processing and fueling cell
- Control room
- Remote control room
- Offices
- Conference room
- Storage

HP Communications

- Intercom
- Spacecraft command and telemetry cabling
- Closed-circuit television monitors and cameras
- Telephone
- Launch video
- Countdown net
- Handheld radios

HP Security

- The facilities have 24-hr perimeter security.
- Security devices are installed on all internal and external doors leading to the payload processing areas.
- The facilities have 24-hr electronic monitoring for ingress and egress, and smoke and fire detection.

HP Support Services

- Separate technical and facility electrical power
- Use of Home Port mechanical support equipment (e.g., manlifts and forklifts)
- Access to video and still photography equipment
- Photographic services
- Protective garments for cleanrooms and hazardous operations
- Negotiated quantities of gaseous nitrogen, liquid nitrogen, gaseous helium, isopropyl alcohol, and other general-purpose cleaning agents and solvents
- Analysis of up to 10 samples of gases, propellants, or cleaning materials
- Monitoring system for detection of hazardous vapors
- Receipt and staging of spacecraft propellants (30-day limit for propellants on site)
- Receipt and storage of ordnance components
- Use of calibrated weights
- Photocopier and facsimile machine

Assembly and Command Ship (ACS)

Assembly and command ship capabilities are described in detail in the Sea Launch Facilities Handbook for customers.

ACS Facilities

- Customer ground support equipment room
- Launch vehicle assembly compartments; shared with Sea Launch personnel
- Customer conference room
- Customer offices
- Cabins to accommodate up to 15 spacecraft personnel; 21 during launch platform evacuation
- Six seats in the launch control center (each console can accommodate two people)
- Two seats in the prominent guest viewing area
- Storage

ACS Shared Areas

- Launch control center conference room
- Lounge
- Observation areas
- Dining facility
- Recreational facilities

ACS Internal Communications

The following communication links are available within the assembly and command ship and between the assembly and command ship and the launch platform when they are in proximity:

- Intercom (including countdown net)
- Closed-circuit television monitors and cameras (including launch video)
- Telephone

ACS External Communications

The following external links are available to the customer during the deployment phase, by way of a satellite link to Brewster, Washington:

- One countdown audio net link
- One live launch video link
- 128-Kbps local area network (configurable to 64-Kbps RS422 serial digital data link)
- 64-Kbps RS422 serial digital data link
- Five dedicated telephone lines with access to long-distance circuits
- Internet connectivity

ACS Security

- Card readers control access to various secure areas of the ship
- 24-hr electronic monitoring for smoke and fire detection

ACS Support Services

- Negotiated number of copies of Sea Launch's video camera footage and still photography
- Meal service
- Hospital (staffed by a medical doctor)
- Photocopier and facsimile machine

Launch Platform (LP)

Launch platform capabilities are described in detail in the *Sea Launch Facilities Handbook* for customers.

LP Facilities

- Customer ground support equipment room
- Customer office
- Cabins to accommodate up to six spacecraft personnel
- Storage

LP Shared Areas

- Recreation and video room
- Dining facility
- Conference room

LP Internal Communications

The following communication links are available within the launch platform and between the assembly and command ship and the launch platform when they are in proximity:

- Intercom (including countdown net)
- Closed-circuit television monitors and cameras (including launch video)
- Telephone

LP External Communications

The following external links are available to the customer during the deployment phase, by way of the satellite link to Brewster, Washington:

- One countdown audio net link
- One live launch video link
- 128-Kbps local area network (configurable to 64-Kbps RS422 serial digital data link)
- One dedicated telephone line with access to long-distance circuits
- Internet connectivity

LP Security

- Card readers control access to various secure areas of the vessel
- 24-hr electronic monitoring for smoke and fire detection

LP Support Services

- Monitoring system for detection of hazardous vapors
- Negotiated number of copies of Sea Launch’s video camera footage and still photography
- Meal service
- Hospital (staffed by a medical doctor)
- Photocopier and facsimile machine

OPTIONAL SERVICES

The following services can be provided by Sea Launch on customer request. These services are considered optional and are subject to negotiation. Requests for other services, not described in this document, will be considered by Sea Launch on a case-by-case basis.

Mission Analysis

Repeating any analysis listed or any additional analysis or design work due to changes made by customer special request.

Interface Tests

- Matchmate testing at the spacecraft factory for repeat of spacecraft type
- Separation shock test

Electrical Interface

- Spacecraft serial PCM telemetry codes other than NRZL with accompanying clock (RS422)
- Radio frequency link (rerad) capability to the assembly and command ship launch vehicle assembly room and the launch platform hangar.

Support Services

Arrangements for the following services will be made by Sea Launch on customer request. Charges for requested services will be billed to the customer.

- Long-distance telephone calls (from telephones, facsimile machines, and teleconferencing facilities)
- Access to Internet service provider
- Bandwidth that exceeds standard offering
- Office supplies
- Office equipment (computers)
- Secretarial services—bilingual for non-English-speaking customers
- Translation and interpretation services
- Telecommunications charges associated with forwarding data from the communications node in Brewster, Washington, to the destination
- Standard equipment calibration services
- Support of Home Port personnel during off-shifts (e.g., second or third shift on weekdays and any weekend shifts)
- Analysis of particulate and nonvolatile residue in the cleanrooms
- Customer-requested evacuation of personnel during marine operations
- Specialized handling equipment

Materials

- Gaseous nitrogen
- Oxygen
- Helium
- Liquid nitrogen
- Isopropyl alcohol
- Deionized water
- Solvents and gases in addition to negotiated quantities

Facilities

- Use of additional office space may be negotiated as available
- Use of any facilities beyond the time frame allocated to the customer may be negotiated as available